HIGH ALTITUDE ADAPTATION IN A PERUVIAN COMMUNITY

Number 1. December, 1968

OCCASIONAL PAPERS IN ANTHROPOLOGY
DEPARTMENT OF ANTHROPOLOGY
The Pennsylvania State University
University Park, Pennsylvania

PEABODY MUSEUM OF ANTHROPOLOGY

HIGH ALTITUDE ADAPTATION IN A PERUVIAN COMMUNITY

A summary paper with detailed appendices covering various aspects of a long-term project, entitled "Andean Biocultural Studies"

Reports prepared by

Paul T. Baker
Gabriel Escobar
Gordon De Jong
Charles J. Hoff
Richard B. Mazess
Joel M. Hanna
Michael A. Little
Emilio Picon R.

Occasional Papers in Anthropology No. 1

Department of Anthropology
Pennsylvania State University
University Park, Pennsylvania

December, 1968

The Pennsylvania State University

Occasional Papers in Anthropology

Anthropological research produces a considerable body of factual data, which is useful to a limited audience. The use of standard publication media also results in a considerable delay between the completion of research projects and their publication. For these reasons, we have initiated this series, which will be devoted to preliminary reports and the presentation of detailed data. The reports will be limited for the present to the results of research activities in the Department of Anthropology of the Pennsylvania State University. These reports will not be professionally edited and will appear only as appropriate material is generated. Copies may be obtained by writing to the Department of Anthropology.

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Human Adaptation to High Altitude:

A Biological Case Study of a Quechua Population Native to the High Andean Region with Special Reference to Hypoxia and Cold.

Paul T. Baker

Stretching along western South America from Columbia to Chile lies a large section of the Andean plateau or Altiplano, which rises above 2,500 meters (about 8,250 feet). This area is suitable for human habitation up to the permanent snowline, which is generally above 5,300 meters (17,590 feet). There are now in excess of ten million people living in this zone, and the historical and archaeological records indicate that it has been densely populated for a long time. Indeed, before Europeans arrived, the Inca empire, which centered in this zone, formed one of the two major civilizations of the Western Hemisphere and probably contained about 40 percent of the total population in the Hemisphere as of 1500 A. D.

With such a history, one would assume this to be an ideal environment for biological man and the development of his culture. Yet, in point of fact, modern sea level man finds this one of the more uncomfortable and difficult environments in the world. The historical records show that such was the case even in the 1500's when the Spanish complained of the "thinness of the air," moved their capital from the highlands to the coast, and reported that in the high mining areas the production of a live child by Spanish parents was a rare and almost unique phenomenon (1). Today, this environmental zone remains the last major cultural and biological center of the American Indian. The population has an extremely low level of European gene admixture and virtually no African admixture. The few cities are Hispanicized, but the rural areas retain a culture form, which in most aspects antedates the Spanish arrival on the continent.

It would be far too simplistic to suggest that this unique history is explicable entirely on the basis of altitude effects on sea level man. Yet, there is sound scientific evidence to show that, depending on altitude, all sea level men will suffer symptomatic discomfort at high altitudes. They will also have a long-term or permanent reduction in maximal work capacity and undergo a number of physiological changes, such as rises in hemoglobin levels and pulmonary arterial pressure. Initial altitude symptoms for some few individuals develop into acute pulmonary endema, which can be fatal if untreated. On the basis of less complete scientific evidence, it appears that sea level man will also suffer from temporary reductions in fertility, reduced ability of the female to carry a fetus to term, and a high neonatal mortality (2, 3, 4).

With these problems in mind, a group of scientists from the Pennsylvania State University, in collaboration with members of the Instituto Biologiá Andina of Peru, decided to investigate the biological and cultural characteristics of an ecologically stable high altitude Peruvian population living in traditional fashion. It was hoped that, in this manner, some insight could be gained into the nature of this quite obviously successful and unique example of human adaptation. In the present article, I will review some of the results available from this continuing study (5).

The general problem may be subdivided into three questions: (1) What are the unique environmental stresses to which the population has adapted; (2) How has the population adapted culturally and biologically to these stresses; and (3) How did the adaptive structures become established in the population?

To answer these questions we chose as high and as stable a population as was reasonably accessible. Our basic method was one of combining ecological comparisons and experimental analysis.

The Study Population

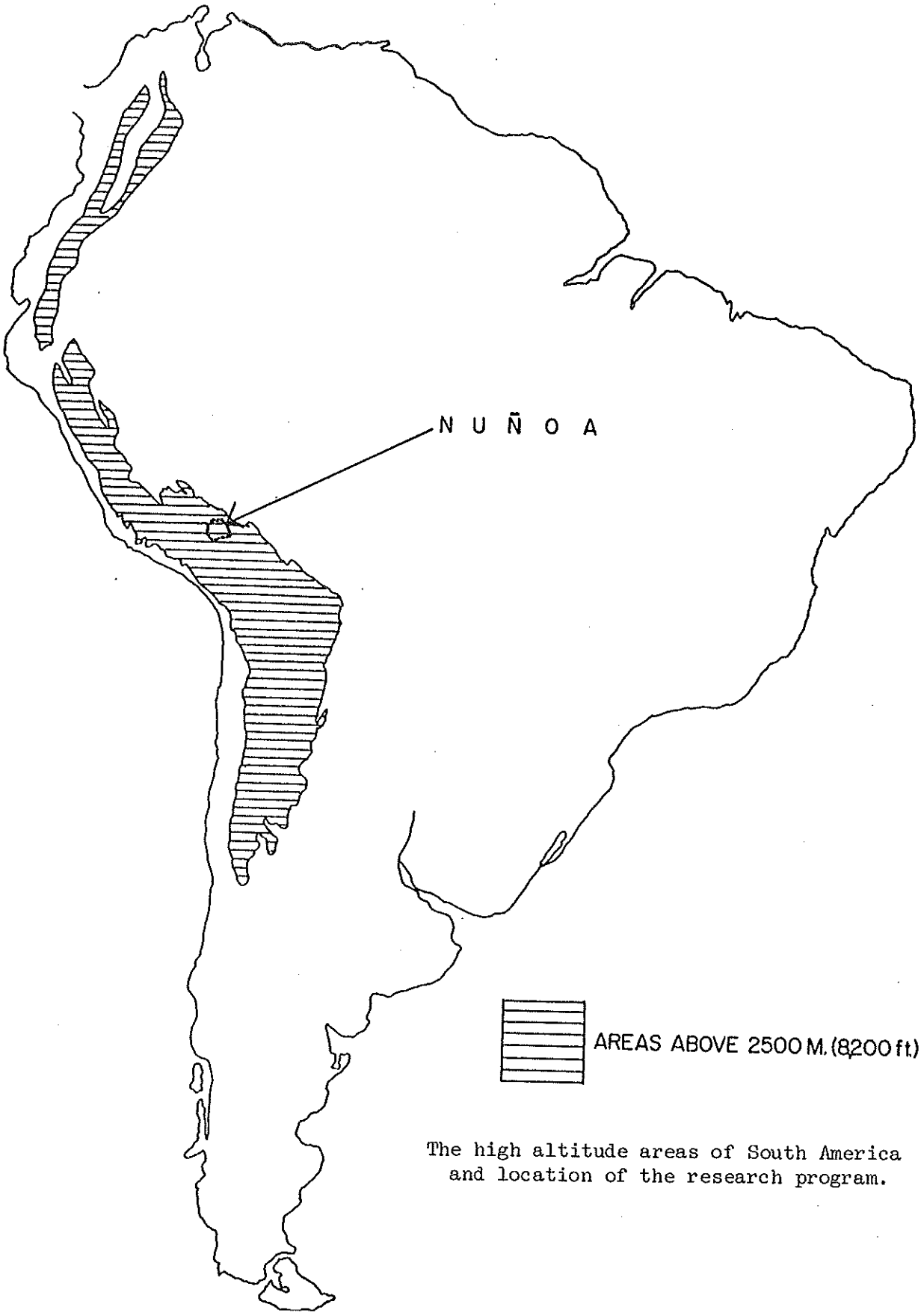
The population chosen for study lives in the political district of Nunoa, department of Puno in southern Peru. The district had a population of 7,750 in 1961 and an area of about 1600 square kilometers. Geographically, the district consists of two major diverging river valleys, which are several kilometers broad and flat in the lower part, but branching and narrow above. Surrounding these valleys are steep-sided mountains. In the lower reaches of the valleys, the minimum altitude is 4,000 meters (13,000 feet), while the higher parts of some valleys reach above 4,800 meters (14,850 feet). The intervening mountains rise slightly above 5,500 meters in parts.

The climatic conditions of the district are being studied through a series of weather stations on the valley floors and mountain sides at different altitudes. On the basis of present records, the pattern is fairly clear. The lower valley floor shows an annual temperature averaging about 8°C with a variation of only about 2°C from January, the

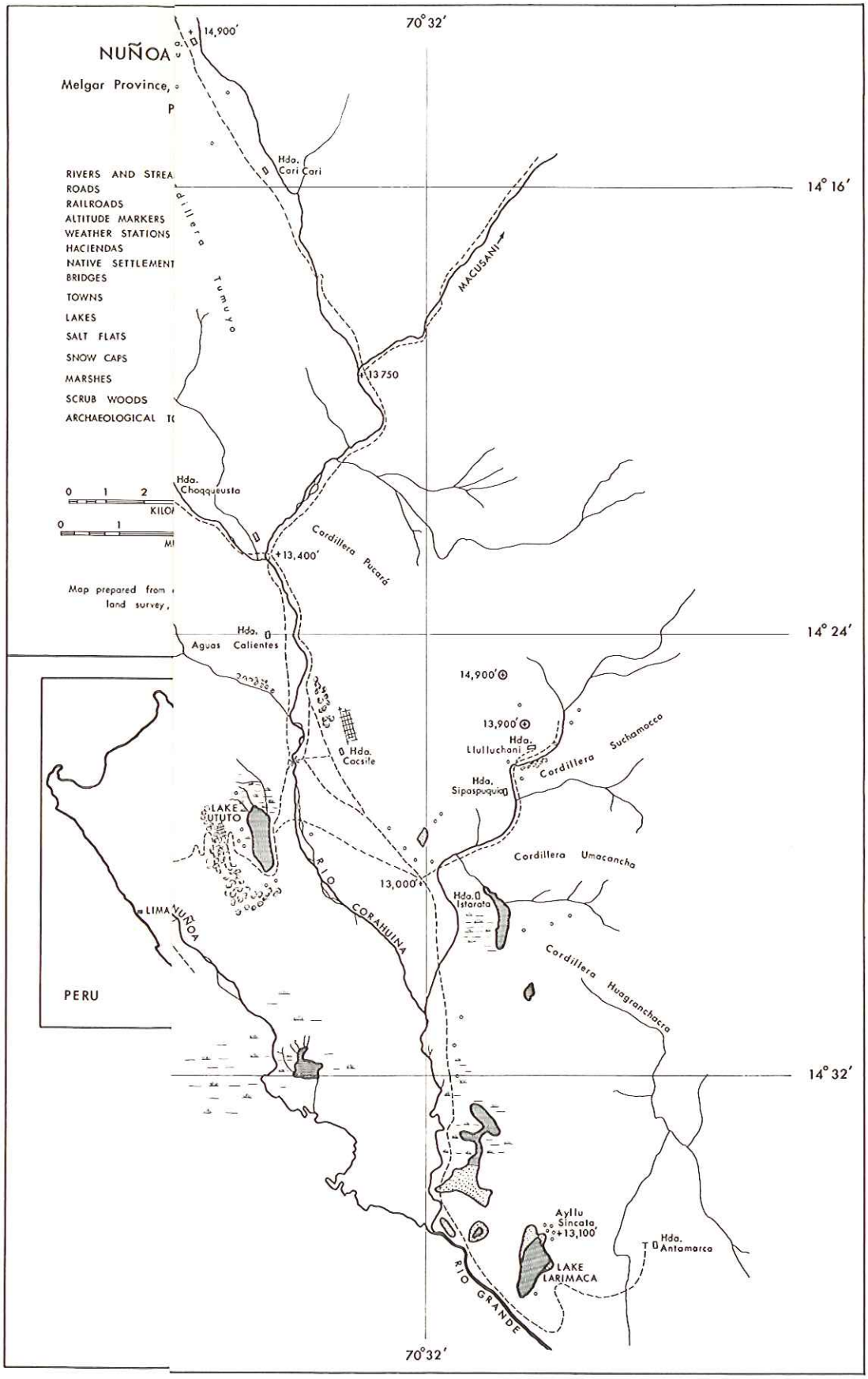
the warmest month, to June, the coldest. This is much less than the diurnal variation which averages about 17°C. The seasonal variation is due almost entirely to cloud cover associated with the wet season. Some snow and rain fall in all 12 months, but significant precipitation begins about October, reaches its peak in January, and finishes in April. Since diurnal variation is high, some frost occurs even in the wet months. Mean temperatures fall proportional to altitude (about 1.00°C per 100 meters); but, because of the sink effect in the valleys, minimum temperatures are usually somewhat lower on the valley floors than the low mountain sides.

The district is almost entirely grassland, with two small areas of slow-growing conifers. Under these climatic and floral conditions, herding has become the dominant economic activity. Alpaca, llama, sheep, and cattle, in that order, are the major domestic animals. Cultivation is limited to frost resistant subsistence crops, such as "bitter" potatoes, quinoa, and canihua. Even these crops can be grown only on the lower mountain sides and limited sections of lower valley floors. In recent years, crop yields have been very low because of drought, but are low even in good years.

A single town, also called Nuñoa, lies within the district and contains about one-fourth of the district population, while the rest of the population lives in a few native-owned settlements called allyus, or on large ranches called haciendas, which are frequently held by absentee landlords. The social structure may be loosely described as containing three social classes. These are a small upper class of



The high altitude areas of South America and location of the research program.


NUÑOA
Melgar Province,
RIVERS AND STREA
ROADS
RAILROADS
ALTITUDE MARKERS
WEATHER STATIONS
HACIENDAS
NATIVE SETTLEMENT
BRIDGES
TOWNS
LAKES
SALT FLATS
SNOW CAPS
MARSHES
SCRUB WOODS
ARCHAEOLOGICAL
0 1 2
KILO
0 1
M
Map prepared from
land survey,
70° 32′
14° 16′
14° 24′
14° 32′
14,900′
Hda. Cori Cori
Cordillera Tumuyo
MACUSANI
13750
Hda. Choqqueusta
+13,400′
Cordillera Pucará
Hda. Aguas Calientes
14,900′
13,900′
Hda. Llulluchani
Cordillera Suchamocco
Hda. Cacsite
Hda. Sipaspuquio
LAKE UTUTO
Cordillera Umacancha
13,000′
Hda. Istarata
RIO CORAHUINA
LIMA
NUÑOA
PERU
Cordillera Huagranchacra
Ayllu Sincata
+13,100′
Hda. Antamarca
LAKE LARIMACA
RIO GRANDE
70° 32′

less than one percent named mestizos, a larger intermediate class termed cholos, and the Indians, or indigénas, who constitute over 95 percent of the population. Social class membership is, of course, based on multiple factors, but the primary ones are degree of westernization and wealth. Biological race appears to be a rather secondary factor in spite of the racial connotations of the terminology.

By Western economic and health treatment standards, this district would be considered very poor. If the mestizo is excluded, per capita income is probably below $200 per year. Medical treatment is limited in the district to a first-aid post. The upper class has access to a hospital in a neighboring district. Yet repeated surveys suggested an adequate diet, and death rates are normal or below normal for peasant communities lacking modern medicine. Indeed, this population must be viewed as being one in near ecological balance with its technology and physical environment.

Superficial archaeological surveys revealed that the central town predated the Spanish conquest and suggested that population numbers have been fairly stable for at least eight or nine hundred years.

From this general survey of the Nuñoa population and its environs, we have concluded that the unique environmental stresses encountered by this population are primarily hypoxia and cold, while other stresses which are more common to most peasant groups include possible nutritional deficiencies, specific infectious diseases, and the problems of living in an acculturating society.

HYPOXIA

At Nuñoa elevations, the partial pressure of atmospheric oxygen is 40 percent or more below sea level values. As noted earlier, such a reduction produces a multitude of changes in the physiology of sea level man at all ages. We, therefore, attempted to evaluate the native Indian's responses to altitude across the life cycle

Demography

A survey of over 10 percent of the population revealed an average completed fertility of about 6.7 children for each female. This is quite a high fertility by modern standards, but is no more than an average figure considering that evidence for voluntary birth control was lacking, and cultural practices appeared in many ways designed to provide maximum fertility. This same survey, summarized in Table 1, failed to show an unusual rate of miscarriage but did reveal two unusual features. First, the earliest ages at which any woman gave birth was 18 in the low valleys and a little older at higher elevations. Average age of first pregnancy was also later at the higher altitudes. Second, the sex ratio was highly unusual in the number of excess males. Furthermore, there was a higher female than male mortality throughout the growth period. In an associated study of newborns, Quechua mothers in Cuzco (3,300 meters) produced infants with higher placenta weights and lower birth weights than comparable mothers near sea level (6). Finally, an analysis of the Peruvian census showed that, as in the U. S., neonatal mortality increases at higher elevations, which

Table 1

Reproductive and Viability Statistics for the District of Nuñoa

Based on a Sample of Approximately 14% of District Population

	Total Sample	Post-Menopausal Sample
Married women (n)	136	31
Mean age in years	36.2	45+
Mean age at first pregnancy	19.5+	20.1
Offspring	608	207
Children per woman (mean)	4.5	6.7
Surviving children per woman (mean)	3.2	4.4
Birth sex ratio	124	113
Surviving sex ratio	129	146
Male mortality	30%	27%
Female mortality	33%	44%

does not appear to be primarily a socio-economic correlate. From the results so far achieved, we conclude that fecundity and survival through the neonatal period is probably adversely affected even in the high altitude native. However, it is clear that a population excess can still be produced by Nuñoans. Our data do not allow an interpretation of whether fecundity and survival are greater than they would be for an immigrant low altitude population (7).

Growth

Intensive growth studies were carried out on over 25 percent of all children between birth and 21 years of age. A number of unusual

growth features appeared shortly after birth. Thus, as noted in Table 2, a slower rate of general body growth is apparent from a very early age. In addition, developmental parameters, such as deciduous tooth eruption and motor behavior sequences, are slow compared to the U. S. standards. For example, the mean number of teeth erupted at 18 months was 11.5 for Nuñoa infants compared with 13 for U. S. infants. The median age at which Nuñoa children sat alone momentarily was 7 months, and the median age of walking alone was 16.2 months. These data were collected with the technique developed by Bayley, who reported that U. S. children had a median age of 5.7 months for sitting alone and 13.2 months for walking (8).

Table 2

The Stature and Weights of Nuñoa Infants
Compared to the United States

	6 mos.	12 mos.	24 mos.
Stature			
Males - Nuñoa	62 cm.	71 cm.	76 cm.
U. S.	66	75	87
Females - Nuñoa	61	69	75
U. S.	65	74	87
Weight			
Males - Nuñoa	6.9 kg.	7.9 kg.	9.9 kg.
U. S.	7.6	10.1	12.6
Females - Nuñoa	6.6	7.3	9.0
U. S.	7.3	9.7	12.3

Some of the growth characteristics in later development are shown in Figures 1 and 2. In these instances, it was possible to compare our results with other cross-sectional data on Indian groups from lower elevations (Huanuco and Cajamarca, 2,500 m., Lima and Ica, 300 m.). We have also collected some semi-longitudinal data in order to evaluate growth rates. These combined data showed (1) the lack of a clear adolescent growth spurt for males, with a late and poorly defined spurt for females, (2) a very prolonged general body growth period, and (3) larger chest sizes in all dimensions at all ages (9).

As an explanation for the unique growth aspects of the Nuñoa population, at least three hypotheses may be suggested: First, that the Quechua have a genetically different growth pattern; second, that malnutrition and disease are the prime causes; and third, hypoxia may be the major factor. Our present data are not adequate for testing these hypotheses. However, a number of reasons suggest that hypoxia is a major explanation. As will be elaborated later, we have been unable to find any evidence of widespread malnutrition or unusual disease patterns. What data are available on the growth of other Quechua show different patterns than we encounter (10), and finally, hypoxia has been shown to affect growth in a number of other animals (4).

Work Physiology

After the first few days at high altitude, the most striking effect on newcomers to 4,000 meters is the reduction in capacity for sustained work. This is best measured by the individual measurement

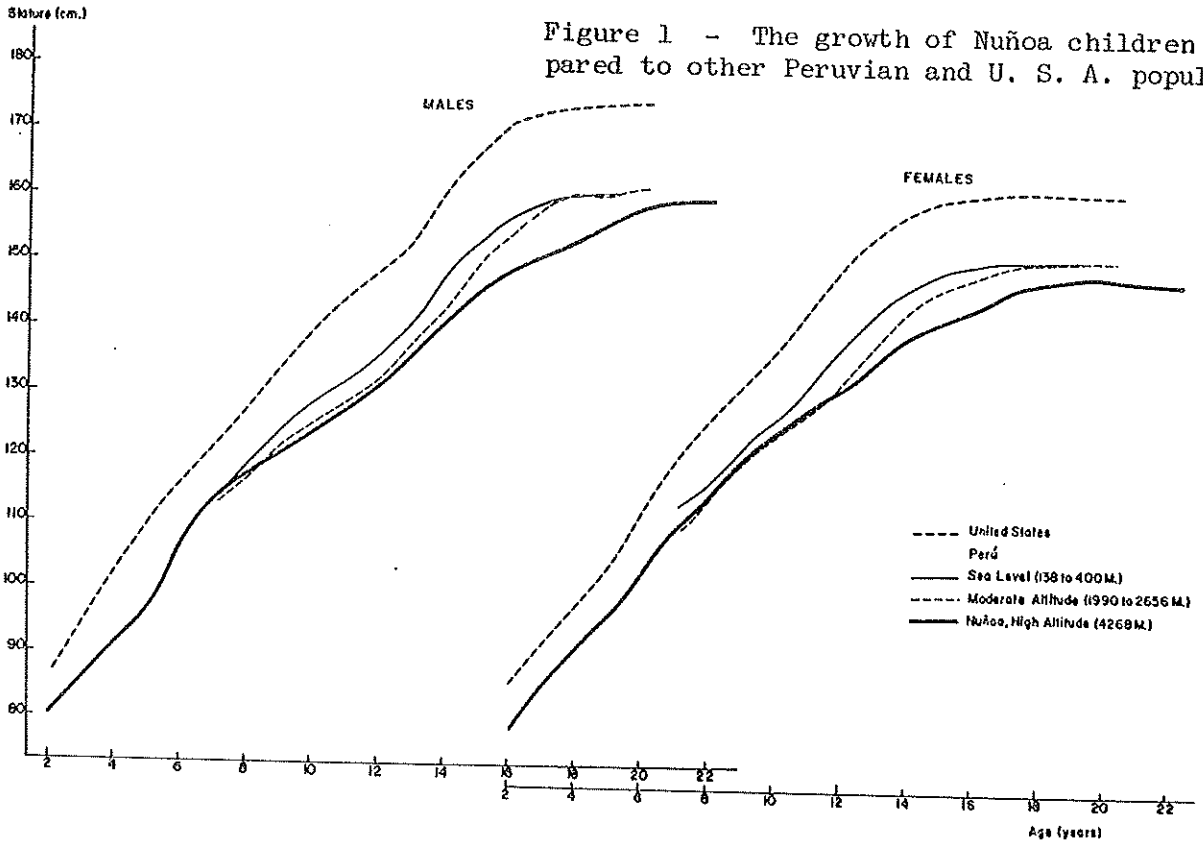


Figure 1 - The growth of Nuñoa children compared to other Peruvian and U. S. A. populations.

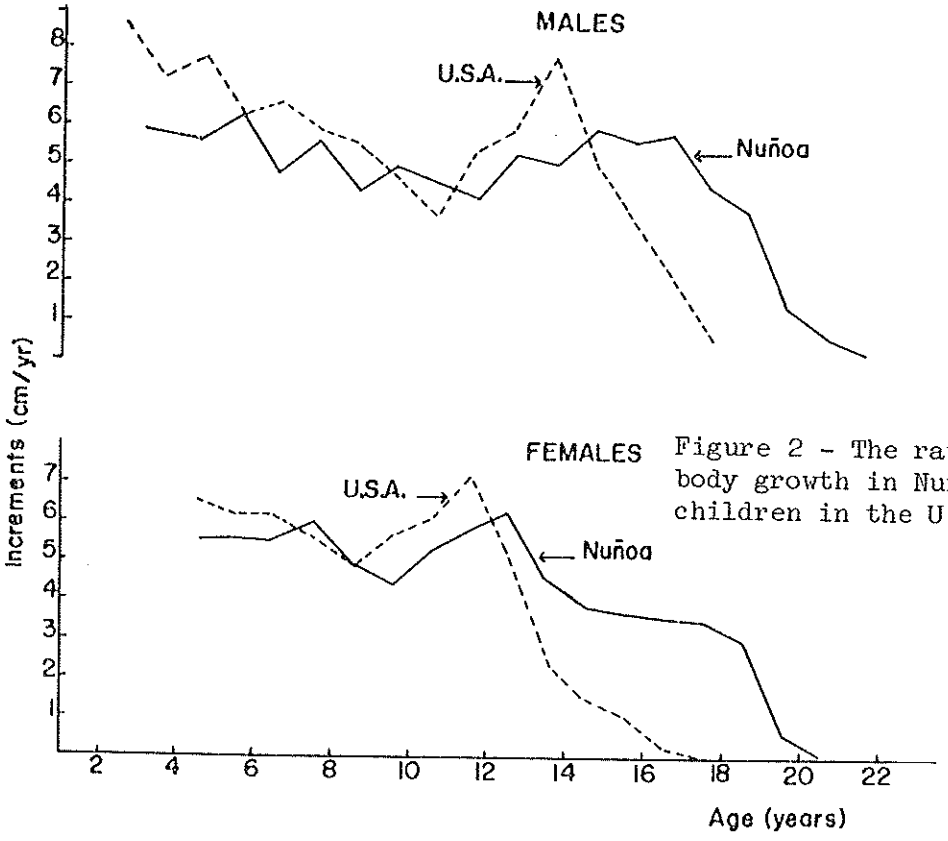


Figure 2 - The rates of general body growth in Nuñoa compared with children in the U. S. A.

of maximum oxygen consumption (Max V_{O_2}). For sea level young men, the reduction is in the range of 20 to 29 percent, with the physically trained men generally showing a greater reduction than the untrained (11). Some rise in Max V_{O_2} occurs during a prolonged stay at high altitudes, but study periods extending up to one year have failed to show a recovery to even near low altitude values for adult men (12).

Max V_{O_2} for any individual or group is controlled by a large number of factors, among which chronic exercise level is a major determinant. Among young men of European descent, mean values range from below 40 ml. O_2 per kg. of body weight for sedentary groups, through 45 ml/kg. for laborers, up to more than 55 ml/kg. for highly trained runners (13). The high degree of variability in this parameter makes it difficult to determine whether the high altitude native has a work capacity different from that of low altitude peoples and makes it even more difficult to determine whether the complex physiology differences between high and low level groups have resulted in a better adaptation of work capacity for the high altitude Quechua.

In order to help clarify these questions, we utilized an identical method for determining Max V_{O_2} on a number of carefully selected samples of contrasting populations. Some of the results of these studies are presented in Table 3. It should be noted that the group referred to as White Peruvian students are so classified on the basis of morphology, and it is quite possible they contain some native Quechua admixture.

Table 3

Some Results of Testing Max V_{O_2} on Contrasting Populations

Data Collected by Use of a 10 Min. Progressive Exhaustion Test Using a Bicycle Ergometer

Group	Nuñoa Quechua	U. S. White Researchers		U. S. White Athletes		Sea Level Quechua		Peruvian Students	
								Quechua	White
Alt. of test	4000 m	300 m	4000 m	300 m	4000 m	100 m	4000 m	3830 m	3830 m
Exposure to alt.	Life	--	4 weeks+	--	4 weeks	--	4 weeks	Life	Life
Subjects									
N	25	6	12	6	6	10	10	10	13
Mean age	25	30	27	20	20	22	22	23.8	23.5
Mean height (cm)	160	183	181	179	179	160	160	162	169
Mean weight (kg)	57	79	75	71	71	62	62	60	61
Responses									
Max V_{O_2} (l./min)	2.77	3.92	2.78	4.58	3.14	3.01	2.67	2.79	2.62
Aerobic capacity (ml/kg/min)	49.1	50.4	38.1	64.2	46.6	49.3	44.5	46.8	42.8
Max. ventilation (l.min)	75	131	91	131	105	108	87	72	74
Vent. equivalent	27.3	33.7	32.9	28.8	33.7	36.2	33.4	25.8	28.2
Max. heart rate (beats/min)	171	185	173	175	172	187	190	188	186
Oxygen pulse (ml/beat)	16.0	21.2	16.6	26.5	19.4	16.7	14.5	15.1	14.2

On the basis of the results obtained on only the students, one investigator surmised that the differences between high altitude and low altitude groups might be only a matter of life-long exposure, plus a high state of physical fitness in the highland Quechua (14). In another article based on partial results, investigators on the program, including the present author, pointed out that trained athletes could achieve the same oxygen consumption per unit of body weight as the Nuñoa native (15). While the presently available data supports the ideas that physical training and life-long exposure to hypoxia act to increase Max V_{O_2} these two factors appear insufficient to explain the total results. The present data, instead suggest that a fairly random sample of Nuñoa males between the ages of 18 and 40 have a vastly greater Max V_{O_2} than a group of reasonably physically fit researchers from the U. S. The Nuñoans also significantly exceeded the oxygen consumption of young native students and equaled a group of highly trained U. S. athletes, who had spent a month at altitude. Furthermore, the Nuñoan did so with a low heart rate and a low ventilation. Nuñoans do walk more than U. S. natives, but nothing in the personal history of the Nuñoa subjects suggested that they had experienced a physical training or selection comparable to that involved in becoming a college level runner. To the author, the data suggest that a high altitude Quechua heritage confers special work capacity on the high altitude recipient. Lacking more precise data, such a conclusion remains tentative. However, the results can certainly be interpreted as showing that the Nuñoa native in his high altitude habitat has a maximum oxygen consumption equal to

or above that of sea level dwellers in their general environments. This agrees with the results obtained by Peruvian researchers (2, 3).

COLD

The Micro Environment

By the standards of fuel-using societies, the temperatures found in the Nuñoa district are not very low; and we would consider the typical daily weather equivalent to a pleasant fall day in the northern United States. However, the lack of any significant source of fuel made us suspect that at least some segments of the population might suffer from significant cold stress. As mentioned previously, the trees found in the district are quite rare and slow-growing. At present, these trees are used primarily for house rafters, and only an occasional member of the upper class uses wood for cooking. The almost universal cooking fuel is dried llama or alpaca dung. This dung provides a hot but rapid fire and is used in a clay stove, which provides little external heat. Since cooking is done in a separate building, only the women and children receive any benefit from the fire. The only occasion on which bonfires are lit are at the times of the ceremonies. Perhaps symbolic to cold, as well as light, the winter solstice is celebrated by a pre-Hispanic ceremony in which a large number of bonfires are lit all over the district.

The native pastoralist's houses, which are made of stacked, dry stone walls with grass roofs, fail to provide significant insulation.

Temperature measurements taken within the dwelling units generally showed temperatures within two or three degrees centigrade of external conditions. This is in sharp contrast to the measurements obtained on the adobe houses used by the upper classes, some agriculturalists in the Nuñoa district, and by all classes in the slightly lower areas of the Altiplano. Adobe houses provide good insulation, with inside temperatures frequently 10°C above external conditions during the cold nights of the dry season.

From this analysis and other observations, we concluded that the Nuñoa native depends upon his own calories for heat and that for heat conservation he relies primarily upon his clothing and some minor cultural traits, such as spending the early evening in bed and putting groups of up to four or five individuals in the same bed. As shown in figure 3, the clothing of the Nuñoa native is layered with high bulk and covered with windproof materials. As such, it provides good insulation for the body trunk. However, the wardrobe does not include items such as gloves, and the only foot coverings found are sandals occasionally worn by men. The effect of native clothing was tested under laboratory-controlled cold conditions. It was found that at 10°C the clothing increased mean body temperature by about 3°C and produced higher hand and foot temperatures in spite of a lack of specific extremity protection.

From the total assessment we concluded that the Nuñoa native probably experiences two types of cold exposure: (1) total body cooling during the hours from sunset until dawn, and (2) severe extremity

Figure 3. A Nuñoa native beside his house during a brief snow squall.

cooling, particularly during periods of daytime snow and rain. To assess the degree of micro cold stress, we measured the rectal and skin temperatures of samples stratified by sex, age, and altitude. These studies indicated that at night the adult women are very little cold stressed, while adult men showed some evidence of cold stress. During the day women, because of lower activity levels, may be slightly cold stressed, while men are not, except for their extremities. Active children do not show evidence of cold stress; however, during inactive periods, such as at night, they show low skin and rectal temperatures. Indeed, during these times, all indices show an inverse relationship between age, size, and body temperatures (16, 17).

Physiological Responses

In order to characterize the Nuñoan's responses to cold, we used three types of laboratory cold exposures. These were: (1) total body cooling on nude subjects at 10°C for two hours, (2) air cooling at 0°C for one hour on hands and feet, and (3) cold water cooling of the feet. The studies were carried out on Nuñoan males and females, North American white males, and Quechua males from low altitude.

Some results of the total body cooling studies are summarized in Table 4. Since the Nuñoa Indians are smaller than either the coastal Indians or U. S. Whites, the data is presented in terms of surface area (18). Such a view of the data shows that the native Quechua at altitude had a higher heat production during the first hour, but were similar to the low altitude groups during the second hour. In contrast,

Table 4

Body Heat Exchange As Exemplified in Heat Production and Loss of Body Heat Content

Average Values for Two Exposures at 10°C, Expressed on the Basis of Body Surface Area (KCAL/m^2)

	Whites N=19	Nuñoans N=26	Lowland Indians N=10
Heat Production (KCAL/m^2)			
1st 60 min.	51.5	58.1	54.7
2nd 60 min.	62.2	65.5	65.5
Total time	113.7	123.6	120.2
Heat loss (not replaced by metabolic activity - KCAL/m^2)			
1st 54 min.*	29.6	51.0	30.1
2nd 60 min.	11.8	12.9	14.7
Total time	41.4	63.9	44.8

*Because perfect equivalence in pre-exposure body temperatures was not achieved, heat loss in the first 4 minutes of exposure has been excluded from this calculation.

heat loss for the Nuñoans was much greater during the first hour and similar to the other groups during the second hour. The latter finding is perhaps the more interesting, since it conforms to two other studies of cooling responses in the high altitude Quechua (19, 20).

When the source of greater heat loss was closely examined, it proved to be almost entirely the product of high extremity temperatures; and, these, in turn, seem to be produced by a high extremity blood flow during cold exposure. When Nuñoa males and females were compared, women had higher hand and somewhat lower foot temperatures. In both

sexes both extremities were significantly above white male subjects. The specific studies of hand and foot cooling further elucidated the subject, showing that the maximum differences in the populations occurred in 0°C air, that the high temperatures were maintained with less temperature cycling than found in whites, and that the population differences were established by at least ten years of age (the youngest group we could test) (21).

Since the oxygen exchange between hemoglobin and tissue bears a close positive relationship with temperature (22), it is clear that maintaining higher peripheral temperatures makes more oxygen available to these tissues. However, we cannot conclude from our data that this is necessary for adequate peripheral tissue survival. Therefore, the high extremity temperatures may be considered not only an adaptation to cold but also a possible adaptation to hypoxia.

NUTRITION AND DISEASE

In the complex web of adaptations, which allow any peasant society to survive, adequate responses to nutritional needs and prevalent diseases are always critical. At high altitude it is also apparent that these responses are important to the interpretations of the native population's responses to altitude and cold.

Nutrition

The analysis of nutritional problems in Nuñoa has proceeded through a number of discrete studies, including a balance study, a household

survey, an analysis of individual food intakes, and a study of the metabolic cost to the community of food production. Of these, the first two have been completed, the third is in analysis, and the fourth in the data collection stage. The results of these studies to date suggest that this population has a very delicate, but adequate, balance between nutritional resources and needs.

The balance study was carried out on six native adult males, chosen randomly. Food requirements were predicted from F. A. O. standards, based on weight and temperature. The food used was entirely constituted from native foodstuffs and was prepared by a native cook. The results showed that these individuals fit quite well into F. A. O. standards and indicated that at least these six men were in good caloric and protein balance at the time of the study (23). The household survey also suggested that nutrition was generally adequate for the group, although the method did not permit statements on the adequacy of nutrition for special subgroups, such as children and pregnant women (24).

The household survey also suggested that some deficiencies might be present in Vitamin A and ascorbic acid. Our more detailed individual surveys now cast doubt on even these inadequacies and suggest that, if malnutrition exists, it is probably no more common than in U. S. society. Indeed, if the modern concept of "over nutrition" is evoked, we might even consider Nuñoans as having better dietary balance than the U. S. population. As noted earlier, the balance is delicate and there must be years and times of the year when certain dietary deficiencies exist. Furthermore, the balance is subtle; to cite but one example,

the basic foods available are very low in calcium. Yet, adequate calcium is obtained primarily by the practice of using burned limestone as a spice in one type of porridge (25).

Disease

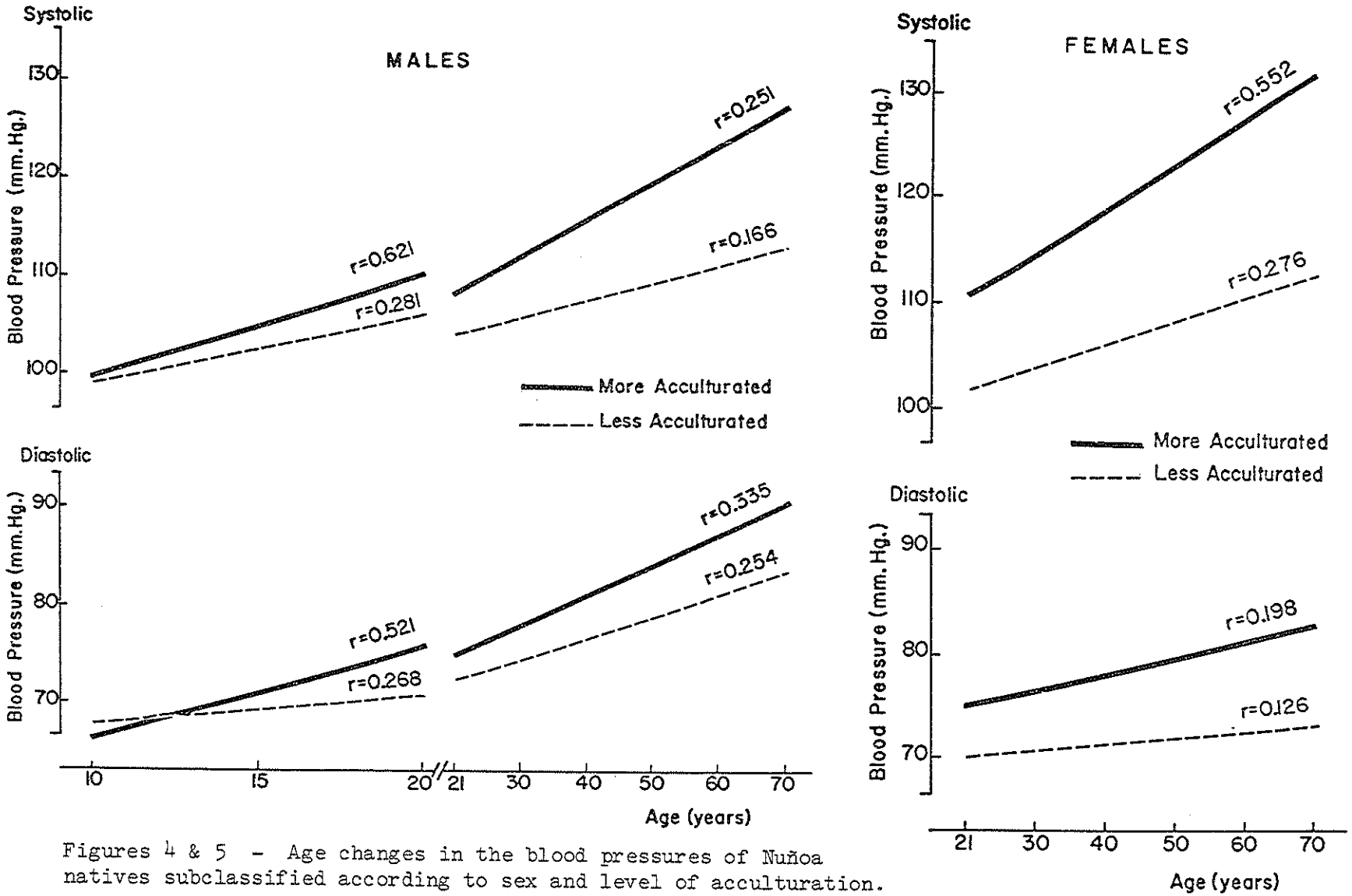
Our data on infectious disease is particularly deficient. Health questionnaires are almost useless since native health concepts are only partially related to modern medicine. Indigénas attribute over 50 percent of all illness and death to susto, which is best translated as fright. As noted earlier, no regular medical treatment is available so records are lacking even on a subsample. In our general survey we encountered the usual variety of infectious disease and had the impression that respiratory ailments, such as tuberculosis and pneumonia, had high frequencies. On the other hand, we did not encounter evidence of deficiency diseases--not even goiters.

Perhaps the most striking results of the survey were those relating to cardiovascular disease. In the survey, heart murmers were common among children, but no evidence of myocardial infarction or stroke were seen. Casual blood pressures were taken on individuals from age 10 to 70+. They revealed a complete absence of hypertension, with the highest pressure encountered 150/90 ml/mg. Other researchers have reported similar results on high altitude populations, and it has been suggested that hypoxia may directly reduce the incidence of hypertension (26). In an attempt to trace the etiology of the low blood pressures, we subdivided our sample into two groups, first into low and high

altitude groups, second urban, rural groups, and third more and less acculturated groups.

Significant differences in the effect of age on blood pressure appear when the sample is divided on any of these three bases. However, it is not possible to assess to what extent the environmental factors are independently related to blood pressure, since the total sample is too small for an adequate analysis of six independent subsamples. Our present belief is that acculturation is the most significant factor since altitude, urban residence, and acculturation are interrelated, and the group differences are most striking when acculturation is the criterion of subdivision. Ten to twenty year olds were classified as acculturated if they were in school, while children in the same age bracket, without schooling, were termed unacculturated. Among adults evidence of schooling, knowledge of Spanish, use of modern clothing and specific material culture items were taken as signs of acculturation.

The results of these comparisons are shown in Illustrations 4 and 5. Certainly, the regressions cannot be taken as evidence that altitude does not affect blood pressure, since even the acculturated group does not reach high pressure levels in old age. However, the analysis does show that within a native high altitude population something associated with the process of acculturation into general Peruvian society leads to significant age increases in systemic blood pressure. Similar results have been reported on peasant and "primitive" populations, and some researchers have attributed this to psychological



Figures 4 & 5 - Age changes in the blood pressures of Nuñoa natives subclassified according to sex and level of acculturation.

stress associated with modern culture (27). Such an explanation might apply to our results, but it does not appear safe to do so before possible nutritional and disease correlates have been carefully examined. The nutritional data we have available is being examined for possible nutritional differences between the groups.

Discussion and Conclusions

From earliest recorded history it has been recognized that men have a wide population variation in physical characteristics and cultures, but it is only recently that the variety of physiological differances between populations has been revealed. The differences so far shown are of the same general magnitude as the anatomical variations. That is, the information suggests a basic commonality in functions such as temperature regulation, energy exchange, and responses to disease. However, comparison of different populations has revealed a number of minor variations in responses to environmental stresses.

Probably the most controversial aspect of these new findings concerns the mechanisms underlying the differences. Because of the time and expense involved, population samples have often been small. Thus, in relation to specific findings, such as the high oxygen consumption capacity reported by some for high altitude natives, it has been suggested that biased sampling explains the difference. Other differences have been explained on the basis of short-term acclimatization or dietary and body compositional variation. Of course, genetic

differences, as well as long-term or developmental acclimatization, have also been suggested; but the short-term processes have been more commonly accepted explanations because they are based on known mechanisms.

We believe that the extensive and intensive method applied to the Nuñoa population is a necessary next step in the search for the sources of population differences in functional parameters. Thus, only a study of growth in the Nuñoa population would probably have led to the conclusion that the growth differences were a product of malnutrition. By combining the growth study with detailed studies on nutrition and other responses, we believe the results instead suggest hypoxia as a better explanation. Similar examples could be cited from other aspects of the program to show that a set of integrated studies on a single population can provide insights not possible with data collection devoted to a single aspect of population biology.

In general, the data are still not adequate for differentiating genetic factors from long-term and developmental acclimatization. To do so would require comparable data on populations which vary in genetic structure, in altitude, and in a variety of environmental backgrounds. Furtunately, such data collection is projected under the Human Adaptability Project of the International Biological Programme. The importance of understanding the sources of population differences seems obvious in a world where the geographical and cultural mobility of peoples is greater than it has ever been in history.

In the high Andes it seems clear that the population is biologically different from the lowlanders, and some of the differences are adaptive to the environment. How well and by what mechanisms a lowland population could adapt to this environment is still inadequately explored. Equally, the biological problems faced by the downward migrant remain almost unknown.

Summary

The high altitude areas of South America are in many ways favorable to human habitation and have supported a large native population over a long time span. Despite these facts, immigrant lowland populations have not become predominant in this area as in other parts of the new world, and lowland men encounter a number of biological difficulties upon going to this region.

In order to elucidate the adaptations which aid the native in survival at high altitudes, an intensive study of a native population is being carried out in the district of Nuñoa in the Peruvian Altiplano. In this area hypoxia and cold appear to be the most unusual environmental stresses. Results to date show a high birth rate and high death rate, with an unusually high female death rate postnatally as well as prenatally, based on sex ratios at birth. Birth weights are low, while placenta weights are high. Postnatal growth is quite slow compared to other world populations and the adolescent growth spurt is diminished compared to other groups. Adult males have oxygen consumption capabilities which do not appear to be impaired by the reduced

atmospheric pressure even though all lowland groups brought to this altitude showed significant reductions in maximal oxygen consumption capacities. The Nuñoa native also shows different responses to cold exposure than lowlanders apparently because of a high level of blood flow in the extremities during cold exposures. Disease patterns are not well known, but respiratory diseases appear common, while cardiovascular disease seems almost totally absent among adults. Systemic blood pressures are very low, particularly among individuals living in traditional native fashion. Nutrition appears to be good, but analysis of this aspect is continuing.

The results are interpreted as showing that some aspects of native adaptation take lifelong exposure to the environmental conditions and may be based on a genetic structure which varies from that of lowlanders.

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5. The data presented in this article represents the work of many scientists on the project. I would particularly like to city the contributions made by Drs. E. R. Buskirk, J. Kollias, G. DeJong, and G. Escobar (Pennsylvania State Univ.), E. Picon-Reategui (Universidad de San Marcos), M. Little (Ohio State Univ.), R. Frisancho (Univ. of Michigan), R. Mazess (Univ. of Wisconsin), and J. Hanna (Univ. of Hawaii). I would also like to note the invaluable assistance provided by Mr. Victor Berreda and the officials of the Nuñoa district. The research is continuing as a U. S. IBP project.

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APPENDIX A

Summary of Weather Data

Nuñoa District

1964 - 1966

	Mean Daily Maximum	Mean Daily Minimum	Monthly Mean	Absolute Maximum	Absolute Minimum	Absolute Range	Mean Diurnal Variation	% Days with Temps. below 32° F.	Precipitation
1964									
August	62.77	28.48	45.63	68	24	44	34.29	90.32	0.01
September	62.73	32.20	47.47	67	25	42	30.60	56.00	1.68
October	63.26	32.74	48.00	68	25	43	30.45	51.61	0.91
November	61.39	33.11	47.25	66	30	36	28.29	50.00	2.16
December	59.48	35.90	47.69	68	32	36	23.87	12.90	3.74
1965									
January	57.29	35.19	46.24	65	26	39	22.10	19.35	6.21
February	59.67	35.48	47.58	64	26	38	23.81	14.81	4.25
March	58.45	35.24	46.85	64	31	33	23.21	13.79	7.21
April	60.21	43.24	47.23	64	30	34	25.97	24.14	2.87
May	61.85	29.69	45.77	66	24	42	32.15	80.77	0.06
June	59.68	24.54	42.11	62	18	44	35.14	100.00	0.02
July	59.77	26.40	43.09	64	21	43	33.37	100.00	0.05
August	62.50	27.39	44.95	67	22	45	35.11	97.43	0.11
September	62.70	30.70	46.70	68	27	41	30.70	56.52	0.66
October	66.06	34.06	50.06	71	30	41	32.06	22.58	1.45
November	64.50	36.23	50.37	71	32	39	28.37	03.33	3.24
December	59.77	37.60	48.69	65	32	33	22.10	03.33	7.22
1966									
January	63.45	37.22	50.33	68	32	36	26.22	03.22	4.99
February	61.64	37.64	49.64	66	33	33	24.00	00.00	3.28
March	61.67	34.32	47.99	65	29	36	27.29	16.00	4.90
April	61.66	30.70	46.18	66	20	46	30.93	80.00	0.24
May	60.56	30.23	45.35	66	21	45	30.33	73.33	1.38
June	62.11	26.22	44.16	65	23	42	35.88	100.00	?
July	---	---	---	--	--	--	---	---	--
August	64.33	28.39	46.36	76	24	52	35.34	86.95	?

Mean Annual Temperature - 46.90

13,150 ft. Altitude
(Nuñoa) Valley floor

	Mean Daily Maximum	Mean Daily Minimum	Monthly Mean	Absolute Maximum	Absolute Minimum	Absolute Range	Mean Diurnal Variation	% Days with Temps. below 32° F.
1964								
August	54.85	29.65	42.25	59	23	36	25.11	80.00
September	54.58	32.34	43.46	63	29	34	22.20	51.72
October	57.45	33.54	45.49	61	28	33	23.58	34.61
November	54.26	33.30	43.78	61	31	30	20.97	33.33
December	53.55	35.06	44.30	61	32	29	18.48	09.68
1965								
January	51.22	36.03	43.62	58	32	26	15.19	06.45
February	52.22	35.39	43.80	58	32	26	16.83	05.55
March	51.93	35.80	43.86	57	32	25	16.13	09.68
April	54.06	36.00	45.03	60	32	28	17.50	03.57
May	55.00	33.64	44.32	58	30	28	21.21	35.71
June	52.90	30.57	41.73	56	25	31	22.33	70.00
July	52.87	29.40	41.13	58	27	31	23.47	100.00
August	53.41	29.65	41.53	60	24	36	24.10	82.75
September	55.20	34.50	44.85	62	31	31	20.70	25.00

Mean Annual Temperature - 43.51

13,900 ft. Altitude
(Llulluchani) Hillside location

1966								
January	56.51	33.26	44.88	63	28	35	23.26	40.74
February	56.00	33.26	44.59	60	26	24	23.09	40.91
March	---	---	---	--	--	--	---	---
April	56.10	27.25	41.67	62	20	42	28.86	89.28

14,100 ft. Altitude
(Chillihua) Valley floor location

	Mean Daily Maximum	Mean Daily Minimum	Monthly Mean	Absolute Maximum	Absolute Minimum	Absolute Range	Mean Diurnal Variation	% Days with Temps. below 32° F.
1964								
August	52.08	26.52	39.30	56	20	36	25.50	92.00
September	52.21	27.17	39.69	61	23	38	25.04	100.00
October	51.33	28.00	39.66	56	22	34	23.31	100.00
November	47.50	27.55	37.53	54	25	29	19.63	100.00
December	48.25	30.00	39.12	57	26	31	18.55	93.54
1965								
January	46.58	29.16	37.87	56	25	31	17.42	100.00
February	47.70	30.79	39.24	52	29	23	16.92	91.66
March	49.29	29.71	39.50	58	28	30	19.58	100.00
April	49.50	29.77	39.63	54	28	26	19.70	100.00
May	50.25	29.68	39.96	54	25	29	20.58	93.54
June	48.10	25.27	36.69	50	20	30	22.83	100.00
July	49.45	25.48	37.46	56	21	35	23.97	100.00
August	50.03	25.04	37.53	55	22	33	24.81	100.00
September	53.09	26.36	39.72	58	23	35	26.73	100.00

Mean Annual Temperature - 38.78

14,900 ft. Altitude
(Llulluchani) Hillside location

CLOUD COVER
in Percents

Nuñoa
13,150 ft. Altitude

K - % of days totally clear
SC - % of days with scattered clouds
PC - % of days partly cloudy (consists mainly of days with clear mornings and clouded afternoons)
HC - % days with heavy cloud cover (completely overcast)

	K	SC	PC	HC
1964				
August	3.33%	23.33%	60.00%	13.34%
September	19.23	34.61	30.77	15.39
October	12.91	38.71	38.71	9.67
November	3.58	39.28	32.14	25.00
December	0.00	45.16	32.26	22.58
1965				
January	0.00	45.16	19.35	35.49
February	0.00	28.57	64.28	7.15
March	0.00	28.57	53.57	17.86
April	31.04	27.58	24.14	17.24
May	26.92	46.15	11.54	15.39
june	82.75	10.35	3.45	3.45
July	36.66	23.33	36.66	3.34
August	65.52	6.90	20.68	6.90
September	24.00	24.00	28.00	24.00
October	25.81	25.81	29.03	19.35
November	16.67	13.33	53.33	16.67
December	0.00	0.00	53.84	46.16
1966				
January	7.15	42.85	17.86	32.14
February	0.00	15.79	36.85	47.36
March	11.54	53.84	30.77	3.85
April	27.59	34.48	27.59	10.34
May	30.77	19.23	23.08	26.92
June	78.57	14.28	7.15	0.00
July	---	---	---	---
August	44.44	33.33	22.23	0.00

NOTE: These data are from the daily observations, which were usually taken once between 9:00 am and 10:00 am each day.

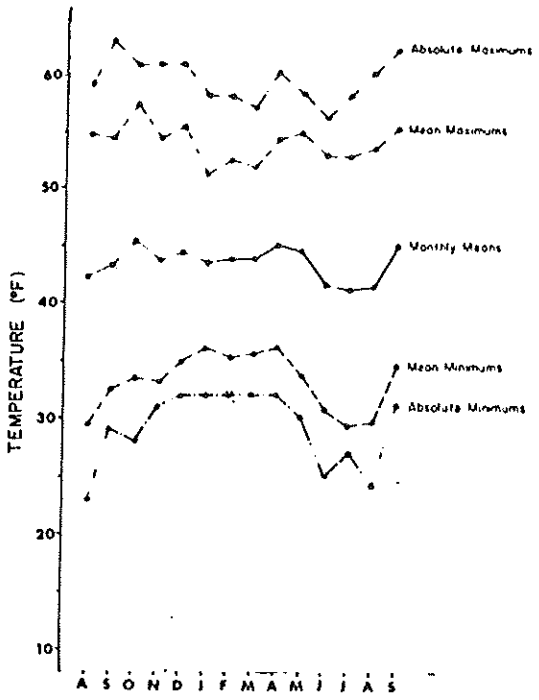
CLOUD COVER
in Percents

Nuñoa
13,150 ft. Altitude

C -- clear days
PC_1 - partly cloudy all day
PC_2 - partly cloudy, but clear $1/2$ the day and cloudy $1/2$ the day
HC - heavy clouds all day

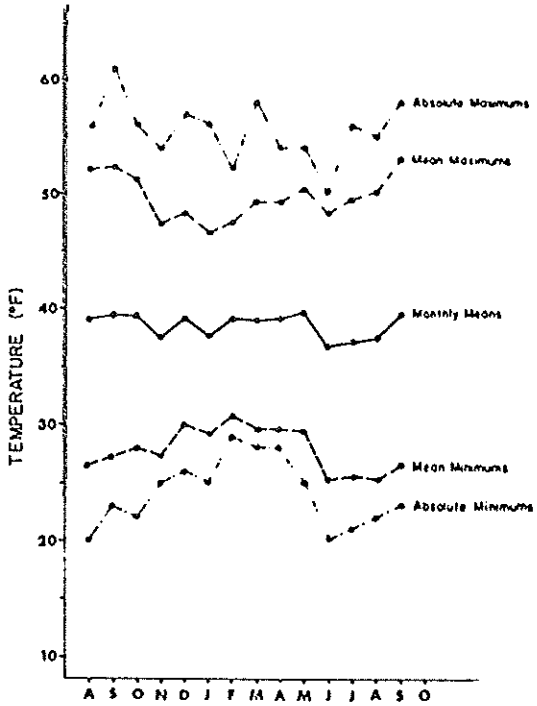
	C	PC_1	PC_2	HC
1964				
August	44.82%	27.59%	24.14	3.45%
September	27.59	41.38	17.24	13.79
October	9.68	35.48	38.70	16.14
November	10.34	20.69	44.83	24.14
December	12.91	29.03	25.81	32.25
1965				
January	6.46	22.58	32.25	38.71
February	3.57	46.43	21.43	28.57
March	12.91	38.70	25.81	22.58
April	23.34	26.67	33.33	16.66
May	54.84	19.35	19.35	6.46
June	76.67	6.67	13.33	3.33
July	41.92	35.48	16.14	6.46
August	48.00	32.00	20.00	0.00
September	7.70	46.15	42.30	3.85
October	35.48	33.34	25.82	6.46
November	16.67	43.33	20.00	20.00
December	3.23	48.38	16.14	32.25
1966				
January	12.91	29.03	35.48	22.58
February	3.57	21.43	39.28	35.72
March	16.66	36.67	40.00	6.67
April	33.34	43.33	16.66	6.67
May	35.48	32.25	12.92	19.35
June	56.67	20.00	16.67	6.66
July	---	---	---	---
August	52.38	28.57	14.29	4.76

NOTE: These data are from a continuous recording Pyrheliometer. Data applied to daylight hours only.



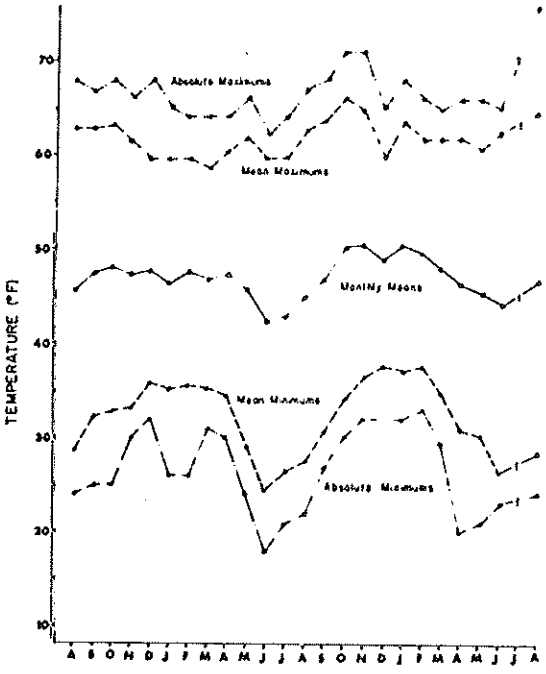
MONTH

Aug 1964-Sep 1965
13,900'



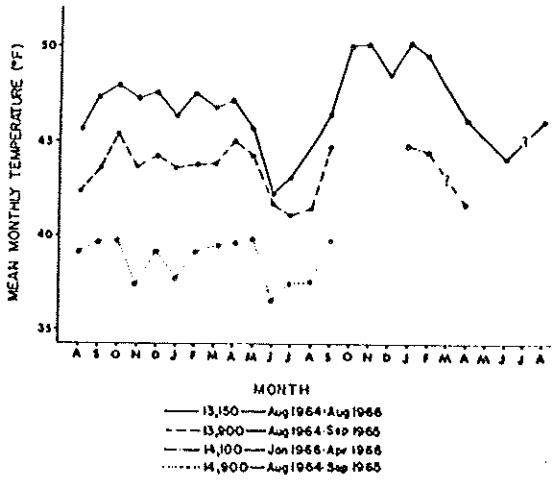
MONTH

Aug 1964-Sep 1965
14,900'

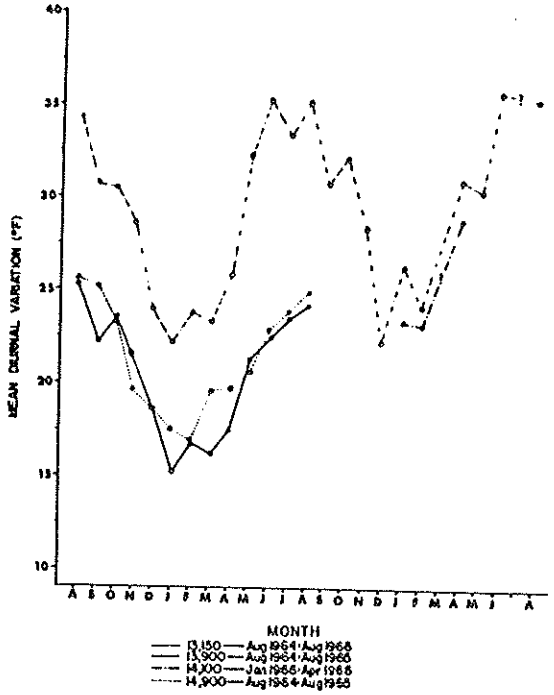


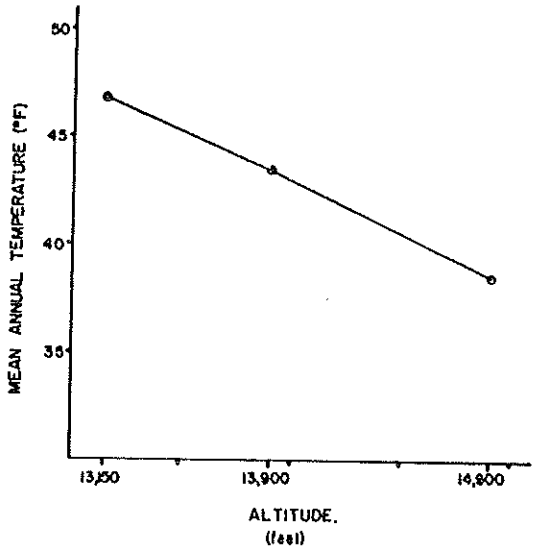
MONTH

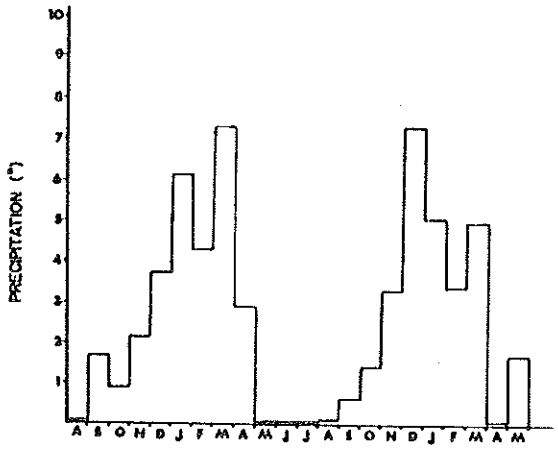
Aug 1964 Sep 1966
13,180'
(Huaca)

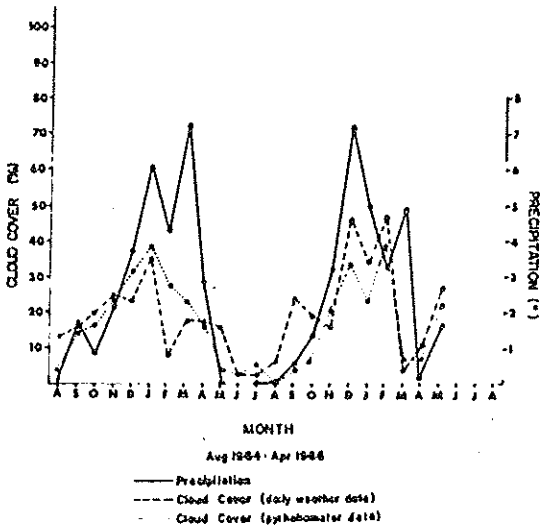


MONTH


MEAN DIURNAL VARIATION (°F)
MONTH
13,150 — Aug 1964-Aug 1966
13,900 — Aug 1964-Aug 1966
14,200 — Jan 1966-Apr 1966
14,900 — Aug 1964-Aug 1965


MEAN ANNUAL TEMPERATURE (°F)
13,150
13,900
14,900
ALTITUDE.
(feet)
13,150 — Aug 1964-Aug 1966
13,900 — Aug 1964-Sept 1965
14,900 — Aug 1964-Sept 1965


PRECIPITATION (")
MONTH
Aug 1964 May 1966
13,150'


CLOUD COVER (%)
PRECIPITATION (")
MONTH
Aug 1964 - Apr 1966
Precipitation
Cloud Cover (daily weather data)
Cloud Cover (pyrheliometer data)

APPENDIX B

Socio-Political Organization of Nuñoa

Gabriel Escobar M

THE SOCIO-POLITICAL ORGANIZATION OF NUÑOA

Gabriel Escobar M.
Department of Anthropology
Pennsylvania State University

Nuñoa is a district of the Province of Melgar in the Department of Puno. It has a population of 8,000 according to the last census. Of this population, about 2,000 live in the town of Nuñoa and the rest are spread throughout a large number of haciendas, a few Indian communities, and scattered number of estancias and cabañas. Ethnically, there are probably about 300 Mestizos, most of them living in Nuñoa and the rest in the haciendas, mines and estancias. In the town itself, there are probably about 200 Mestizos, an undetermined number of Cholos, and the rest Indians. Mestizos and Cholos are bilingual in Spanish and Quechua, and most Indians are monolingual in Quechua, and probably a few bilinguals in Quechua and Aymara. The bulk of the Indian population within the district is fairly stable, but there are yet unknown numbers of Indians and Cholos form the town, the communities and estancias, who travel within the district to the haciendas and mines, and migrate periodically to Cuzco, Puno or Arequippa, working in mines, road-gangs and towns. Most of the Mestizos travel frequently in their commercial activities or for educational purposes. Most of the hacienda owners and their families live in Cuzco, Arequipa, or Lima and come rather infrequently to the district.

Economically, the main activity of the district is the herding of alpacas, sheep, and cattle, and some mining exploitation. Agriculture

is carried out by simple Precolumbian techniques and is mainly for self-subsistence. The main staples are Andean tubers (bitter potatoes, potatoes, papas, lisas, ocas, añus). qañiawa, quinoa, and some barley. Maize is imported form Cuzco.

All the land methods known at present in Peru are used for transportation and travel. Most Indians travel on foot within the district and surrounding area, following traditional paths in the Altiplano. Indians in estancias and communities also have llama herds, which transport mainly manure for fuel to Nuñoa, and some chuño and firewood. Cholos and various wealthy Indians in the estancias also have horses, donkeys and mules. Most of the haciendas and a few merchants in Nuñoa have station wagons and trucks. Twice a week and on Sundays, trucks go by the main road to the large towns along the railroad from Puno to Cuzco, and trucks from the mines cross the district rather frequently. During our stay, we counted about 60 bicycles in Nuñoa, owned by mestizos and Indians, but we assume there are more in the whole district.

Political Organization. Nuñoa is a district within the Peruvian system of administration. As such, it depends hierarchically from the Provincial and Departmental authorities for the majority of political appointments and some services. Since 1963, as in the rest of Peru, it has achieved municipal autonomy and elects its council in national elections every three years. This change, improvements in transportation, education, and sanitation, and the organization of a "communidad indigena" represents recent departures form traditional Andean isolation, the effects of which are just beginning to be felt in the area. However, most of the traditional patterns of social control and stratification still conform tena-

ciously to traditional standards.

The Municipal Council. The council is composed of seven members: The Mayor, the Lieutenant Mayor, and five councilmen that are elected every three years. Each of the councilmen holds an Inspection to distribute the tasks of administration of various services. In Nuñoa, these include: water, electric lights, markets, sanitation, and control of breadbaking, butchering, and pulbic relations. All records of births, deaths, and marriages are kept by the Secretary of the Council, who is a paid employee. Two other people, usually Indians or cholos, are hired for cleaning the town hall and sending messages. A representative of the comunidad indigena is also considered an honorary member of the Council.

Theoretically, the Mayor and the councilmen should be available for their business every morning of the working day and should meet in council every two weeks, but in practice they operate in an extremely informal way. Most of the town business is transacted in informal conversations on a corner in the streets, on a bench in the plaza, or in secret meetings in the dead of night, at which other influential members of the community and friends are accepted. Sporadically, wealthy landowners deal directly with the mayor or councilmen. The revenue of the municipality is relatively small. It receives from the Peruvian budget S/. 50,000.00 Peruvian soles (about U. S. $1,250.00), and it is authorized to collect a tax on breadbaking and butchering, which amounts to about S/. 20,000.00 a year, making a total of S/. 70,000.00 annually. While it is a small amount, it is always a bone of contention for political commentary and accusations of mismanagement between political factions, which is part of the traditional pattern.

The present day members of the Municipal Council of Nuñoa constitute a tight faction of the Mestizos who effectively control the political and economic life of the district, and their political functions go beyond the administration of public services. They have organized themselves as a musical group that has made itself famous in the area for winning a contest in Puno in 1964 and recorded a long-play record of native music. They are members of the "Club Juventud Nuñoa" and play vigorous volley-ball and soccer in local and regional competitions, and are at present at practically every ceremonial event in the community.

The Governor. The governor is, in theory, the main political authority of the district and is appointed from the Provincial capital. The extent of tenure varies very much with the whims of national politics, and the appointment is usually secured through influential patronage. The only obvious function of the office of governor is that of representing the President of the Republic in the locality. However, the role of governor has been confused with those of the police and the justice of the peace, and, as such, it has a measure of influence in maintaining public order. At present, as in the past, the governor still exerts some arbitrary power over the Indian population at the same time that he acts as intermediary between Indians and Mestizos. He is helped in his tasks by lieutenant governors, usually Indians or Cholos forced to serve as messengers and delegates to the surrounding area.

The Justices of the Peace. Due to its large population, Nuñoa has three Justices of the Peace, who are appointed from the court in the Department capital from a roster of experienced local citizens. The appointment usually goes to no more than 6 people, who alternate as

local lawyers when they are not in office. While the appointment is honorary, they get a small fee for each case that is transacted and usually receive presents from litigants. They hold office in their homes, and manner of holding court varies from extreme informality to extreme formality and complicated paperwork. Most of the cases they judge are the settlement of quarrels, petty robbery, torts, and small land transactions. In theory, they follow a body of regulations stabilized by Peruvian law; but, in practice, they probably follow a code of informal and unwritten law that still needs to be studied. This usually informal code reflects the different degrees of sophistication of the individual judges. Most of them have been scribes and hangers-on in provincial courts before settling in the town. The judges are always Mestizos and are both feared and respected for their legal abilities and influential connections with lawyers and judges in towns and cities. There is some evidence to believe that they are appointed throughi the influence of hacendados in the national courts, due to the importance of land litigation in the Peruvian highlands. In their functions they are usually helped by young scribes, sometimes relatives, who eventually train themselves for the major job.

The Indian Community. The "Communidad Indigena de Orqorara" is a local sui generis organization that was established in Nuñoa in 1953 as a consequence of the struggle between two political factions among the Mestizos in their attempts to control the Municipality. As a survival of Colonial times and the encroachment of the haciendas, the town of Nuñoa had still a large extension of land surrounding the town. These

lands were used for the support of local authorities, common grazing in times of horse and mule transportation, and were under the control of the Municipality. It is claimed that the faction in power in 1953, allegedly with urbanization in mind, were selling the land for their own profit. The opposing faction of mestizos organized the Indians and provided them legal help and were able to register the community under the protection of the Law of Indian Communities, which was passed in 1922 for the protection of Indian communities from the encroachment of haciendas and to avoid litigation between communities (Escobar, 1959; Dobyns, 1966). Since its inception, the officers of the communidad are a group of Indians or cholos who know how to read and write in Spanish. By law, they consist of a Presidente, a Personero (legal representative), Secretary, Treasurer, and a number of Vocales (members at large). One of them represents the Communidad in the Municipal council.

In Nuñoa, all the adult members of the town, both Indians and Mestizos, are recognized as members of the comunidad and, as such, the Mestizos are influential in the management of their business. In theory, all members should pay a fee of S/. 10.00 a year to support the officers, but in practice this fee is paid only by the Indians. In this way they establish their right to receive a masa (about a third of one hectare) of agriculture land in the outskirts of town that they cultivate for their subsistence. Furthermore, the comunidad owns the stone and earth quarries at the west of town and charges a small fee for their exploitation. The cemetery, the race course, and the soccer field have been "donated" by the comunidad to the town.

The control that the mestizos exert on the communidad makes it a potential mechanism for further political developments, both in terms of improvements of services and political factionalism and as a way to tap labor for local works in terms of "popular cooperation." However, at present the comunidad in Nuñoa does not perform the functions that are known to be performed in other parts of the country.

The Police Post. The police force in Nuñoa is appointed from Police Headquarters in Puno and is usually composed of a sergeant, a corporal, and three or four policemen, all of whom are outsiders. Their main function is that of maintaining order. They have a post which houses the men, an office, a yard, and a jail, where mostly Indians accused of petty crimes are housed. While the policemen are always accused of arbitrariness and violence to Indians, they obviously are able to maintain order in the district, that has a long history of violence. In general, they have been able to suppress wholesale cattle-rustling and frequent murders among Indians and Mestizos. They are respected and feared; and, in general, they maintain very good relations with all the Mestizos.

The Church and Priest. Probably due to its isolation, the church and priest in Nuñoa still hold a measure of political functions that have been lost in less isolated places. The priest appoints an economo (manager of church property), and a mayordomo for attending to the church buildings from among the Indian population and usually forces the individuals to accept these jobs. Performance of the priest's religious office implies not only receipt of fees but also traditional presents of sheep, chickens

and pigs, which are always demanded forcefully. Indians and mestizos who make religious vows are required to record them with the Justice of the Peace and are fined in case they are not able to honor them.. For the fiesta of the Patron Saint in October, these vows are posted on the church door a month in advance. Due to his clerical connections, the priest is usually extremely influential in local politics, although he is sometimes viewed with some hostility. A great deal of his influence seems to emerge from the fact that, whether by supernatural pressure or force, he potentially can gain the support of the Indian population.

Political Processes. Tentatively, we can postulate that political participation in Nuñoa serves three main purposes: provision of local services, public works, and social control. The last purpose seems to be the most important but the "game of politics" is manifestly played in terms of the other two; and factionalism and conflict, real and potential, depends on the way in which these two things are managed.

Symbolically, public works and services at the rural level in Peru means "progress" (Escobar, 1968, MS), and as such they constitute the only platform that is used at the local level. Although elections and local autonomy have existed only since 1963, and the conumidad indigena since 1958, public works have been constructed in Nuñoa long before that date by means of the influential patronage that the appointed authorities of the past could gain from deputies and senators, and by means of "popular action" and public charitable activities organized for the purpose. In such a way, many new things have been added to the town in the last fifty

years, such as the race-track, the soccer field, the cemetery, and the building of the Town Hall. The present administration is said to be responsible for building the drinking water reservoir and piping it into the town, the acquisition of an electirc motor donated by the government, the opening up of the secondary coeduaational school, and the promotion of a Sunday fair as a way to attract commerce to the town.

The execution of any project of services or public works for the town usually takes a long time, even in cases in which they have the labor and the funds for the purpose. This is due to the fact that organization of the project, technical knowledge and compliance with government regulations is usually haphazard and incomplete; there is mistrust in the use of funds and lack of confidence in outside help. It appears that, in fact, sometimes funds and materials have been embezzled, as is pointed out in the case of the construction of the new stone tower for the church. This lack of trust is evidenced in the fact that in almost all cases the opposing faction of Mestizos always accuses the people in office of misappropriation of funds; and these accusations are always made, not only in gossip, but also in pamphlets and newspaper publications, and usually degenerate into long-standing quarrels and feuds between individuals, their families, and their friends.

The maintenance of social control and public order in political life in Nuñoa has as its main purpose the aviodance of open conflicts between factions and across the social strata and the maintenance of isolation by preventing the interference of elements from the outside that would interfere with the interests of the mestizos or the security of the

Indians. For these reasons, while factionalism may be intense and passionate to the point of degenerating into open viloence, an effort is made to maintain order in social life by a kind of generalized ritualism and ceremonial in social relations, which expresses itself in every day life in terms of very courteous forms of address, florid language, and conversation that emphasises the superficial exchange of news and gossip. In most cases, whatever hostility there is, is manifested in sarcastic joking and telling of anecdotes about certain individuals who are chosen as scapegoats. In the cases in which during fiestas and drinking parties, some individuals quarrel to the point of physical violence, every attempt is made to insure that these quarrels do not develop into law suits and long-lasting quarrels between families or factions which, according to local legend, in the past used to lead to civil war which would involve the national government.

Public ceremonials, whether political, religious, educational, or social, provide opportunities for leisure and entertainment, but also opportunities for social display and an indication of forced forms of reciprocity which, when broken, may upset the public order and the quality of interpersonal relations. These ceremonials need to be studied further; but from what has been observed so far, they also serve as indicators of the kinds of changes that have been happening in the community in the last ten years. One good example of this is seen in the sporting events that usually accompany political ceremonials: teams in competition usually represent groups striving for social recognition and training grounds for potential leaders and organizers who wish to stand out individually.

In terms of inter-village or inter-district relationships, the ideological orientation of the Mestizos of Nuñoa is ehtnocentric and isolationistic. The most common phrases that an outsider hears from Nuñoeños in conversation are usually, "Nunoa, republica independiente," and "Nuñoeno mata-gente" (people killers) as a proud and adequate description of thier characteristics. The first phrase refers to the fact that, allegedly, their "progress" has been due to their own efforts, and the second to the fact that, during the 19th Century, they gained control of the lands of the district and the Indian population through bloody internal strife and successfully prevented further encroachemnt of outsiders. At present, this ethnocentism manifests itself at every opportunity in which Mestizos from Nuñoa participate in sporting, musical, or educational events outside of their town, which usually lead to hurt feelings and accusations of foul play.

This picture would be incomplete without a reference to the hacienda system and its relevance to the political life of the district. Although it still needs to be documented, it is said that all the violence that existed in Nuñoa until the Twenties was due to the forceful and violent way in which outside Mestizos dispossesed and bought out the Indian communities and then quarreled among themselves for grazing lands and boundaries. In the past, under the pretext of defense from alpaca and cattle rustlers, every landowner maintained armed bands of zambos imported from Arequipa. This has disappeared with the increased control exerted by the state by means of the army and the police. Intermarriages between members of hacienda owners' families, urban residence, and litigation have replaced armed

violence. Labor legislation and public attention to Indian problems prevents them from exploiting the peasants, and most of them are free to leave the haciendas if they wish. There are still many Indians attached to the estates, but nowadays most owners prefer to hire temporary labor for shearing or butchering of alpacas. The drop in the price of alpaca wool in the national and international market and the effects of inheritance, litigation, and higher costs is gradually forcing some changes. Some of these are the conversion from alpaca to cattle herding and the organization of commercial corporations increasingly dependent on outside financing.

Whatever political influence the landowners may have at the local level, this is exerted at a second remove by participation in national politics and influential patronage to prevent passing of legislation that would affect their estates. Whenever they come to their estates or to the town, the local authorities entertain them to motivate them to make donations for public works or services in a competitive fashion, or to ask them to exert their influence in higher circles of government. Some of the members of their families who cannot run their estates anymore are seeking other avocations like mining or commerce, and they incorporate themselves in the mestizo group in town in influential positions.

The fortunes of the hacienda system depend at present on national political processes due to the passing of the Law of Agrarian Reform in 1963. The law has been slow in application, but it may eventually affect the estates in the whole Department of Puno.

The Economic Organization of Nuñoa.

The Economy of the peasants. Most of the peasant population of

the district, Indians, cholos, and some mestizos, have a subsistence economy supplemented by commercial activities to dispose of small surpluses and provide food, clothing, and ceremonial necessities. The bulk of the peasant population is distributed among the haciendas, estancias (small cattle estates), and a few Indian communities. In the haciendas, besides taking care of the owners' herds of alpaca, cattle or sheep, most of the Indian families are allowed to keep their own herds of alpacas and cultivate small plots of land. The extent of their herds is a good indicator of differences in wealth. Most of the Indians in the haciendas are at the subsistence level, but many of them can be considered wealthy or well-to-do by local standards. In the past, there was considerable pressure to expend their accumulated wealth in ceremonial displays, but today there are indications that some of them are looking for investments in commercial occupations and probably migration to other centers.

In the estancias, the major economic occupations are herding of alpacas and cattle and whatever subsistence agriculture is possible. An estancia has usually two or three houses, a series of corrals fenced with fieldstones, and adequate extensions of grazing land for small herds of alpacas, cattle or sheep. Sometimes there are some plots of agricultural land. Scattered in the grazing land, there are small huts or cabañas to tend the cattle. Houses and cabañas are not occupied all the time, for people shift habitation with the routine of occupations. Estancias are o owned usually by Indian, cholo or Mestizo families, who hire additional labor by means of mink'a (a small salary plus food, coca leaves, alcohol, and tobacco) or ayni (reciprocal exchange of labor) in times of need.

Alpacas and cattle provide for most of their subsistence and wealth accumulation needs.

The wool of sheep and llamas is sheared for weaving their own clothing; alpaca wool is sheared to be sold to merchants in Nuñoa, where it is taken to the markets in Sicuani or Ayaviri. When alpacas are killed, the whole hide is sold to the pelters for the tourist trade in Sicuani, Juliaca or Cuzco. About twenty estancia owners also have houses in Nuñoa, and most of them have cattle that are butchered weekly in town to be taken to the markets of Sicuani and Ayaviri.

Estancia owners can be considered wealthy or well-to-do by Indian and mestizo local standards; and, in general, they are well-fed and dressed, most of them own bicycles and transistor radios, and spend liberally on alcohol and ceremonial displays. All of them are good horse riders; and the wealthier are beginning to invest in buying trucks for commercial acitivites within the area.

The economy of the Indians in the few Indian communities that exist within the district can be considered entirely a mixed subsistence economy of herding and agriculture. A good example of these communities is Sincata. Here, 153 people own small plots of agricultural land around a lake and grazing lands that go up to the surrounding hills. Each family has two or three plots of land that are rotated every year and small herds of cattle, usually from 2 to 10 head, tended by all the members of the family. The margin of subsistence seems to be low, and both men and women usually go to work on estanicas and haciendas to supplement their living. The small surpluses they have are sold to the town of Nunoa. Men and women, usually on Sunday, take small quantities of chuno, potatoes,

fresh cheese, and a few other things to town, to barter or sell in the stores in exchange for alcohol, coca leaves, cigarettes, salt, sugar, peppers, candies, and a few other essentials (needles and thread, herb medicines).

The range of occupations and abilities of the peasants in Nuñoa corresponds to what Richard Schaedel calls a generalized mode of adaptation to the ecological conditions of the area (1959). The only part-time specialists are probably curers, and distinctions in division of labor are only subtle distinctions based on the energy that a task may require. All men, women, and children, spin wool while they are traveling or tending cattle. All adult men and women know how to weave, and difference is mainly in the kind of loom they use: women weave belts, blankets, ponchos, and sacks on the Precolombian Inca loom. Men weave, when they do, on the Spanish loom, the bayeta cloth that is still used for their own clothing. All other occupations we have been able to observe, such as shearing and butchering, wall building and house roofing, store tending and marketing, baking and knitting, were being carried out apparently without distinction as to sex and age.

The Economic Organization of the Town. The bulk of the economy of the town depends on the commercial activities of the Indians, Cholos and Mestizos. Commercial activities link the economy of the district to that of a larger area, extending from the city of Cuzco to Juliaca, Puno and Arequipa, following the railroad and automobile highways and branches that crisscross the area, linking the coast, the Altiplano, the Cuzco and Urubamba valleys and the Montaña to the East.

In Nuñoa there are about ten large stores belonging to Mestizos who import food (flour, maize, rice, sugar, salt, canned fish and fruit, biscuits and candies), some clothing, coca leaves, cigarettes, primus stoves, candles, and other urban conveniences. Besides these ten stores, Indians and cholos have smaller stores that usually sell alcohol, bread, rice, sugar, coca leaves, matches and fruit in smaller quantities, Pending further verification, it can be said that about 20 to 40 percent of the trade is based on the expenditure of sugarcane alcohol for the Indian population and beer for the Mestizos. The alcohol is imported from the coast, and the beer is brought from Cuzco or Arequipa, either by agents from Arequipa and Cuzco who come with their trucks to the town, or directly by the merchants in trips to Sicuani and Juliaca. Most of the trade is conducted in retail for small everyday quantities and usually paid in small coins and bills. Most of the stores extend small credit to Indians in town or to Mestizos on the basis of familiarity. Prices on sugar, coca leaves, and rice are controlled by the agency of the Bank of the Nation in town (the former Caja de Depositos y Consignaciones), but most of the other prices depend to a certain extent on supply and demand.

A brief comparison of prices in Nuñoa with those in Juliaca and Ayaviri shows that local merchants do not charge the Indians exorbitantly. Most of them overcharge from about S/. 00.20 to S/. 1.00 per equivalent unit. A moderate amount of goods, such as sporting shoes and balls, matches, leather jackets, bicycles, watches, playing cards, are imported illegally from Bolivia and Nuñoa through the merchants or in trips they make to Juliaca.

In an effort to increase commercial activities, since June 1967, the Municipal council has established a Sunday market in the main plaza of the town. The number of merchants is still very small, but it seems to be growing steadily. Most of the retail products marketed are bread, fruits from the montaña and coast (oranges, bananas, avocados, grapes) according to the season, folk medicines, a few chifle (peddler) stands that sell needles, mirrors, wallets, dies, tire sandals, Every two or three w weeks, merchants from Puno or Juliaca come with their trucks bringing some special products from the coast: Wine and pisco from Tacna, molasses from Arequipa, dry yellow and red peppers from Cuzco or Arequipa, and maize and dry fish that are eagerly bought by the Indians.

Two other commerical activities are important in Nuñoa: baking and butchering. Baking is done with imported flour in about ten traditional ovens fired with cattle and llama manure. About 60 men and women rent the ovens from their owners and bake variable quantities of bread that are distributed in town through the stores, and to the rural area by peddler merchants who also sell alcohol or other things like coca leaves, salt or sugar. Butchering is done by Indians and cholos who have some cattle and sheep in the grazing lands around town but who also buy the cattle from the haciendas or the estancias. Meat is butchered twice a week to be sold to agents that come from Cuzco and are used to make chalonas (jerkings) or to sell the meat as mutton in Cuzco or Quillabamba. The entrails are sold to the Indians or given as payment and are used mainly in their fertility rituals in the rural areas.

The Indian population in town earns its living by hiring themselves

for wages in a variety of occupations, such as butchering, house building and roofing, laundering and ironing, and a few working as servants for the Mestizos. A daily salary is S/. 25.00 without food, and S/. 12.00 with food and alcohol and coca. Hired work being scarce in town, both men and women travel to haciendas and estancias for additional work, and an unknown number of Indians have been migrating to places as far as Cuzco and Arequipa and the surrounding mines.

Since the enlargement of school and police facilities, a few mestizos have been giving room and board facilities to schoolteachers and policemen, and the few travellers that pass through town can find room and board in case of need in two places in town.

In most houses in town, all people have chickens, guinea pigs, and pigs that are sold when a need for ready cash arises. Almost all Indians and some mestizos use alpaca and llama manure for cooking. Manure is acquired from Indians in the communities and estancias who come two or three times a week to town with their packs of llamas or donkeys and take the manure directly to the houses of the purchasers.

The Economy of the Haciendas. According to one informant, there are more than 50 large haciendas in the district. Most of them are administered directly by their owners and are in charge of Mayordomos who supervise the herding and curing of the herds. A large corporation, the Ganadera del Sur, administers three or four large estates mainly for the production of cattle. Two or three times during the year, under the supervision of the owners, alpacas are sheared and the wool is shipped directly to Arequipa.

It is said that, due to a very sharp drop in the market price of alpaca wool, many hacienda owners are increasing their cattle herds, but we have not yet enough information about this change. Some of the haciendas also produce high quality cheese that is sold in Cuzco. What agriculture there is in the haciendas, is for the subsistence of the Indians, although most haciendas cultivate bitter potatoes to make chuño and moraya (two varieties of frozen potatoes) that is taken to the owners' stores in Cuzco, Arequipa, or Puno. Potentially, the haciendas could produce more, but the extent of the market in the area and lack of technological knowledge and the leisure habits of their owners prevent this. Although the standard of living of the owners is high, it does not seem that they are able to accumulate enough wealth to make substantial investments in the improvement of their properties or other capitalistic enterprises. Litigation and partitioning, and dependence on the national and international market seem to make their economic position in the area relatively insecure.

APPENDIX C

Demography and Research with High Altitude Populations

Gordon F. DeJong

Abstract

Demography and Research With High Altitude Populations

by
Gordon F. De Jong
The Pennsylvania State University

An understanding of how people live and work in high altitude environments has only recently become a topic of scientific research. Yet there are an estimated 20 to 25 million persons, mostly living in economically underdeveloped areas, who reside above 10,000 feet altitude. If all these people were citizens of one nation, the total would be larger than the population of nearly 85 percent of the nations of the world today.

Demographic data on births, deaths, and migration indicate much about the process of adaption to these extreme environmental conditions. General observation and a few research reports, principally from studies on animals, indicate that the lack of oxygen at high altitude tends to reduce fertility and increase the infant mortality. This paper reviews the present research on the relationship between high altitude residence and demographic trends, and presents a conceptual framework which includes biological, social, and demographic factors. From this framework some research possibilities are suggested.

Demography and Research With High Altitude Populations

Within the history of science, research on how man lives and works in high altitude is of recent vintage. Yet there are an estimated 20 to 25 million people who live above 3,000 meters altitude. If all these people were citizens of one nation, the total would be larger than the population of nearly 85 percent of the nations of the world today. In very unique ways, however, these people may be a distinct breed. The biological effects of altitude are only slowly being identified, but enough is known to suggest some influences on population growth and demographic balance in these primarily economically under-developed sections of the world.

As is the case for many problems which face man, the issues related to life at high altitude cut across the boundaries of several scientific disciplines. Human biological, physiological, medical, psychological, anthropological, economic, and socio-demographic causes and consequences frequently are interwoven into a complex mosaic. For the researcher the challenge is to broaden his horizons by exploring other fields with the purpose of forging new research syntheses. Such efforts are dogged by numerous difficulties, not the least of which is communication - the definition of terms, concepts, research perspectives, goals, and methods. These and related difficulties dissuade but should not subdue synthesizing efforts. This paper is an attempt to delineate some of the ways demography contributes to the study of high altitude populations. Toward this goal several points will will be considered: 1) the demographic perspective, 2) a review of

past research on demographic variables and high altitude populations, 3) the development of a research framework which incorporates human biological and demographic factors, and 4) some research possibilities which emerge from the above considerations.

The Demographic Perspective

The term "population" is common to many disciplines and it is perhaps not surprising that the term is used in different ways. Most certainly not all researchers who deal with "populations" consider themselves demographers. Population here refers to an aggregate of human organisms which inhabit a specified area. The focus on human aggregates as the unit of analysis, instead of individual members who constitute the aggregate, is a key to the perspective of the demographer as compared to other researchers. The distinction will perhaps be clarified by considering a definition of demography. Following Hauser and Duncan (1959), demography is the study of the size, territorial distribution, and composition of population, the changes therein, and the components of these changes which are natality, mortality, and migration. To these basic elements Hauser and Duncan add social mobility (change of status such as from single to married), however, this factor would seem to be of a different order compared with the other components of the definition.

From this definition several features of the demographic perspective emerge. First, the demographer is interested in population change -- whether an increase or a decrease. This interest necessitates time series data of sufficient quality to permit comparisons of nations and smaller geopolitical units which have different social, economic, and cultural bases. Second, the demographer investigates

structural components of the population: most notable the age and sex structure. While an elementary observation, it is well to note that age and sex characteristics of a population can be highly important in explaining biological as well as behavioral variations between population units. This is one reason the demographer frequently calculates age and sex, specific birth, death, and migration rates. A third interest of the demographer, then, is the components of population change. The relationships between these components are defined by the "demographic equation":

Net population change = (births - deaths) + (immigration - emigration). The core of demographic analysis is the interrelationships of the sturctural and process variables in time and space dimensions (Davis, 1948).

The concern for understanding spatiotemporal trends leads to the search for factors which influence demographic processes. Besides age and sex composition, a host of population traits such as race, family characteristics, education, occupation, intelligence, etc. may be significant. The "decomposition" of population change data by investigating substrata of the population is illustrated in the many studies of differential natality, mortality, and migration. Race, education, or religion differences in natality, for instance, indicate how various parts of the aggregate contribute to total population change. The investigative logic of the decomposition and then the recomposition of the rates of population change into a new "balance sheet" are a natural research consequence of demographic theory which seeks to explain and predict population growth and

decline. The addition of social, economic, psychological, biological, ecological, and other variables in demographic research is indicative of the broadened search for explanations of population change. For high altitude populations, demographic structure and processes may be attributable in part to atypical biological factors.

Demographic data are, of course, a function of the discipline's frame of reference and are primarily observational as distinguished from experimental. Two major sources of observational data are the census and the vital registration systems of an area. The former provides information on population size, composition, and distribution while the latter contributes data on births, deaths, marriages and divorces. Only a few nations have direct measures of migration through continuous population registers. A fourth source of demographic data is population samples which can be used to validate and augment census data as well as to provide totally new information. The Current Population Survey in the United States is an example of such a demographic survey. The availability, completeness, and quality of current and historical demographic data are of immediate concern for scientific as well as political issues. It is not surprising, then, that a wide variety of demographic techniques are oriented toward completeness and accuracy of data.

Demographic methods follow the general logic of science, with an emphasis on measures which are applicable to population aggregates. Some well-known examples are median age, sex ratio, growth rates, crude birth and death rates, cause of death rates, dependency ratios, and population pyramid models. Besides a variety of more analytical rates, ratios, and indices, demographic methods include standardization procedures, which adjust for the influence of varying population

structures on summary vital rates, and the life table, which eloquently explicates the relationship between age structure and mortality. Closely allied to life table methodology is the stable population concept which is useful in generating intrinsic natality and mortality rates where type of population structure is controlled. One of the more recent methodological developments is the analysis of cohorts. Here attention is focused on longitudinal as opposed to cross-sectional analysis. An example would be natality patterns of age or marriage cohorts (groupings) of women where the data are arranged to show the completed or cumulative natality at specific stages of childbearing. In this as well as most demographic studies, generlizations are derived primarily from comparative analysis of different population units. Finally, demographic methods include increasingly sophisticated techniques for population projection. While the pressure for population estimates stems primarily from planning and practical issues, the advances in projection methodologies are, in some respects, a synthesis of theoretical, methodological, and statistical developments across the entire range of demographic research.

In sum, the demographic perspective focuses on the aggregate of individuals in time and space; the basic structural features of the population, particularly the age and sex composition; and how the aggregate is changed through the processes of natality, mortality, and migration. (Ryder, 1964) It is the application of this perspective in studies of high altitude populations to which we now turn.

Research on Demographic Variables in High Altitude Populations

Other than a few descriptive accounts of national populations

in high altitude regions of the world, there have been very few demographic studies which explicitly considered altitude as a variable. The few studies there are have tended to focus on natality. The major demographic dialogue is encompassed within a series of four articles which have appeared since 1963.

The exchange began with a study by Stycos of regional natality differences in Peru. (1963) Based on 1940 census data, the author reported that the observed regional differences were almost entirely explained by the proportion of women who became mothers. When urbanization, literacy, and language were introduced as control variables, the correlation analysis indicated that Indian-speaking areas tended to have a high incidence of mothers but low motherhood natality. The net result was to produce the highest natality in Spanish rural areas, the lowest in Indian urban areas. These findings were interpreted as due to differences in cultural factors related to mating patterns by Indians and mestizos. It was suggested that the Indians have more permissive norms concerning sex relations, establish cohabiting rela tions later than do mestizos, and that such unions are less stable than mestizo unions. The effect is to decrease the total exposure to the risk of conception.

The cultural natality differential thesis of Stycos was tested by Heer (1964) for Ecuador and Bolivia as well as Peru. Using census data it was again found that the populations in Indian-speaking, higher altitude areas had lower natality than those in lower altitude, more prosperous, Spanish-speaking areas. Heer's data indicated, however, that Indian areas also had a high proportion of females in

the labor force, and this suggested to the author that there may be a conscious attempt to control births, possibly by means of abortion or infanticide.

Subsequently, James (1966) introduced a different twist into the debate by hypothesizing that natality differentials between the Spanish and Indian-speaking populations of Andean countries were due to the physiological effects of altitude rather than to voluntary socio-cultural factors. Using census data from twenty-one Peruvian departmentos, nine Bolivian departmentos, and eighteen Ecuadorian provincias, James' data showed a strong negative relationship between mean altitude and measures of natality. A multiple analysis of language, altitude, and natality supported the thesis that altitude was a most powerful explanatory variable and that it may be due to physiological effects rather than birth control factors.

The research by James prompted Heer (1967) to re-evaluate his original conclusions by adding altitude and recalculating the original correlation analysis. Altitude was the most important variable in accounting for natality differences in Peru but not in Bolivia or Ecuador. On the basis of these four demographic studies it perhaps can be concluded that the relative contribution of socio-cultural and attitude factors to natality differences in Peru, Bolivia and Ecuador is still in need of considerable elucidation.

Demographic research on high altitude populations has not been restricted to natality. Mortality, and in particular infant mortality, has garnered some attention. Most of the previously cited studies noted that the child/woman ratio measure of natality could be affected by differences in infant mortality. (Robinson 1963) Several studies

including Mazess (1965), Grahn and Kratchman (1963), and Lichty (1957), have used census and survey data to support the hypothesis of a positive relationship between infant mortality and altitude.

Biological and physiological research on high altitude populations has also studied natality and infant mortality. A major stimulus has come from clinical observations concerning birth weight, prematurity, neonatal mortality, and physiological stresses on the mother. Monge's work (1945, 1948) indicates that observations on the relationship between altitude and natality have historical dimensions. The Spanish chroniclers of the sixteenth century noted that no child of Spanish blood was born during the first fifty years of Spanish occupation of the Peruvian highlands. Not unrelated was the subsequent decision of the Spaniards to move their capital from the moutains to the seacoast.

Data on the biology of altitude and reproduction are more abundant from animal than human experiments. (Donayre, 1966; Van Liere and Stickney, 1963) Based on studies in actual or simulated altitude environments, the natality-depressing effects of altitude seem to be related to circulatory system adjustments to hypoxia, to the functioning of the hypothalamic and endocrine systems, to germ cell production, to copulation, to gestation, to birth weight, and to early mortality. (Opitz, 1950; Moncloa, et. al., 1965; DeBias, 1966; Monge, 1945; Weihe, 1962), However, the direct transfer of these findings to human natality depends on further scientific evidence. A significant step is the research by Sobrevilla (1967) which identifies reduced estrogen excretion as an important distinction between a high and low altitude sample of pregnant women.

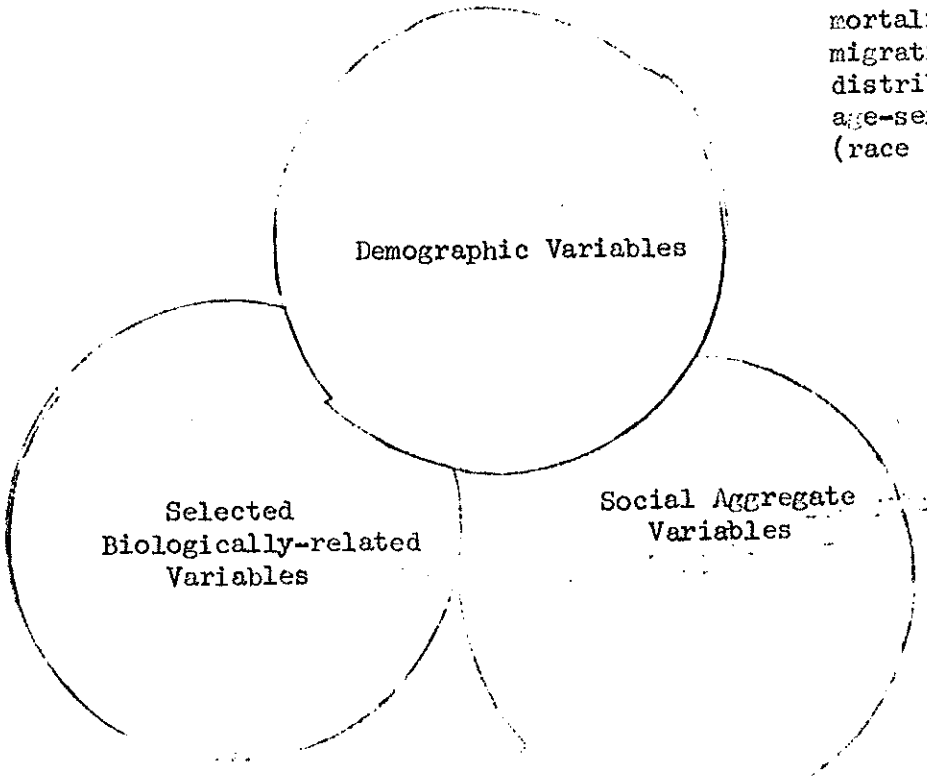
Migration has been involved in a few studies of high altitude populations. Migration is related to the study of gene flow and evolutionary forces, but variability in gene flow is more closely linked to isolation and secondarily to migration which often provides a vehicle for dissipating isolation. (Spuhler, 1959; Matsunaga, 1965) An example of such research with a high altitude population is provided by Cruz-Coke and others (1966, 1967) in a sample of communities in Chile. Migration was found to be a predominant force in the study of an optimal evolutionary model.

This brief parallel review of demographic and biologically-related research not only indicates the current stage of findings but also provides a backdrop for considering further research possibilities.

A Conceptual Framework for Research

Toward a synthesis of demographic and biological research on high altitude populations, a conceptual framework is proposed. As presented in Figure 1, the framework is composed of three sets of variables. The first is the demographic set which includes population change, the components of population change (natality, mortality, and migration), and the basic population structural variables of population size, age-sex composition, and population distribution. To this list can be added race if it is considered from a physical rather than a social perspective. The goals and character of demographic analysis have been discussed earlier in this paper and need not be considered again here. Suffice to say there are casual and consequential relationships among the factors which can be altered when any one factor is related to a varibale outside the demographic system.

Figure 1. A Conceptual Framework for Demographically-Related Research in High Altitude Populations



Population change
- natality
- mortality
- migration
- distribution
- age-sex composition
- (race composition)

Hypoxic, genetic and nutritional effects on:
- birth weight
- sperm production
- maturation and aging
- infectious disease susceptibility
- pulmonary function
- endocrine function
- cardiovascular function

- ethnic background
- race
- marital status
- language
- family and kinship characteristics
- labor force participation
- occupation
- industry
- education
- income
- religion

A second set of variables can be termed the social aggregate components of a population. These are primarily achieved as opposed to ascribed population characteristics which can be aggregated for descriptive and analytical purposes. Much demographic research focuses on developing reliable and valid generalizations about how social aggregate veriables affect and are affected by basic demographic variables. An elementary example is the influence of the religious composition of an area on natality trends. In turn, the natality trends often alter various compositional features of the population.

Social aggregate variables can provide an index of behavioral expectations. If the degree of education influences migration, this is assumed to indicate something about the attitudes and behavior of people with high as compared to low education. Social aggregate factors, then, provide a conceptual link to the social and cultural base of the population. The logic of this linkage is demonstrated quite well in the previously cited Stycos-Heer-James debate on factors explaining Indian-Spanish-speaking population natality differences in Peru, Bolivia, and Ecuador. It should be recognized, however, that many social and cultural factors are not measured directly by social aggregate population traits. But it is equally true that correlations between altitude and birth rates do not directly measure the effects of hypoxia. They may also reflect the ability of people to make social, cultural, and economic adjustments to environmental conditions. In other words, the intergration of variables at different levels of analysis depends in part on understanding of linkage mechanisms. (Ford and De Jong, 1967)

The third set of factors in Figure 1 are biological variables related to high altitude. While the items included are not mutually exclusive and certainly not exhaustive, they are indicative of the concepts used in past and present theory and research. Delineating some research possibilities may illustrate ways in which these three sets of factors may be related in research problems.

Some Research Possibilities

There are two basic approaches to the analysis of the relationship between demographic and biological variables in high altitude populations. Demographic factors may be viewed as independent variables which offer explanations for biologically-related phenomena. The influence of population isolation on gene exchange illustrates this type of relationship. The second approach treats demographic factors as the dependent variable, with the object of explaining the effects of biologically-related altitude factors upon them. A study of the influence of hypoxia on mortality rates illustrates this approach. While it is clear that reciprocal influences are involved, the research possibilities which follow will emphasize the latter approach.

The review of past research indicates both social and biological influences are significant in differentiating high and low altitude population natality trends. The question can be asked: By what mechanisms is natality affected by each of these sets of variables? The following set of so-called "intermediate variables" linking natality levels to social organization and social norms has been suggested by Davis and Blake. (1956)

I. Factors Affecting Exposure to Intercourse

a. Those governing the formation and dissolution of unions in the reproductive period.

1. Age of entry into sexual union.

2. Permanent celibacy: proportion of women never entering sexual unions.

3. Amount of reproductive period spent after or between unions.

a) When unions are broken by divorce, separation or desertion.

b) When unions are broken by death of husband.

b. Those governing the exposure to intercourse within unions.

1. Voluntary abstinence.

2. Involuntary abstinence (from impotence, illness, unavoidable but temporary separations.)

3. Coital frequency (excluding periods of abstinence).

II. Factors Affecting Exposure to Conception

a. Fecundity or infecundity (physiological impairment), as affected by involuntary causes.

b. Use or non-use of contraception (any voluntary means for avoiding conception).

1. By mechanical or chemical means.

2. By other means.

c. Fecundity or infecundity, as affected by voluntary causes (sterilization, subincision, medical treatment, etc.).

III. Factors Affecting Gestation and Successful Parturition

a. Fetal mortality from involuntary causes.

b. Fetal mortality from voluntary causes.

In western societies the degree and efficiency of contraceptive use explain many of the trends and comparative differences in natality rates. For high altitude populations this may not be the case - for socio-economic as well as biological reasons. What is required are more careful studies which show how biological factors affect natality of high altitude populations. But in addition, such studies must be combined with social variables so that the relative contribution of each can be assessed. At present only the crudest estimates of this type are available.

Numerous possible conbinations of social aggregate and biological variables, as outlined in Figure 1, could be studied in relation to natality through the intermediate variables mentioned above. An exemplary list might include social class differences in natality of populations at the same and different altitudes; the effect of women working on natality and gestation; birth weight, neo-natal mortality and education of the population; maturation, aging and kinship groupings in length of reproduction; copulation, fertilization and social status, religion, marital form, or labor force characteristics.

A complementary list could be offered for the study of mortality and migration. Again biological and social aggregate variables can be related to demographic trends and differences. For example, prevalence of disease, education, and life expectancy; hypoxia, race and occupation; nutritional level, physical fitness, social class, and age-sex specific mortality. For migration studies, gene exchange

could be related to isolation, marital form, social class, language, race. Other migration studies might focus on the cause of death of migrant populations to and from high altitude areas, or the fertilization of women with different social characteristics who migrate from low to high areas and vice versa. Another interesting study would be the possible relationship between hypoxia, social aggregate variables and sex ratio at birth.

The strategy for these types of studies will differ with individual researchers as well as with discipline perspectives. For the demographer, the approach may begin by explicitly including altitude as an areal variable along with other social and economic factors which help explain trends and variations in natality, mortality, and migration. The biological researcher may focus more on the ways altitude is translated into the physiology of human natality and mortality. Common to research from either perspective will be an appropriate sampling and research design concern for variations in the degree of altitude, in length of time spent at altitude levels, and in whether or not the populations are native of the area. The awareness of conceptual and factual overlap combined with an increased synthesis of research findings is a basic step toward understanding man and high altitude.

Conclusions

The modest goals of this paper were to delineate some of the ways demography contributes to the study of high altitude populations. Deliberately avoided have been a wide range of social, cultural, psychological, political, economic, technological, and environmental issues which selectively could be included in high altitude research. Most notable is the influence of the family system -- the social structure unit perhaps most immediate to natality, mortality, and migration. One approach to research synthesis involves the interrelationship of demographic, social aggregate, and biological variables in common research designs, Again it must be recognized that goals, designs, and methods may differ. However, the challenge concerns man at high altitude. For the social scientist, biological influences on human behavior seem to be far out-weighed by economic development, political power, social status, motivation, land tenure systems, and a host of similar attitude and behavioral correlates. In part this view reflects the fact that most of the world's high altitude population can be classified as economically underdeveloped. The apparent uniqueness of high altitude biology would seem to offer outstanding opportunities for biological scientists to show the behavioral relevance of the variables in their bailiwick. Convincing the social scientist of their behavioral significance is dependent upon the careful differentiation of biologically-based causes from socio-culture adaptations that man has made to life at high altitude.

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APPENDIX D

Reproduction and Viability in a Highland Peruvian Indian Population

Charles J. Hoff

A C K N O W L E D G E M E N T S

The author would like to thank Dr. Paul T. Baker for providing him with the opportunity to utilize data collected during two field seasons in the highlands of Southern Peru. The demographic study was part of a larger investigation of a human ecosystem in which adaptations to environmental stresses are being analyzed in terms of biological and cultural parameters. The project was financed by the U.S. Department of the Army, Surgeon General Contract No. DA-49-193-MD-2260.

Thanks are also due to Dr. Paul T. Baker for his guidance and suggestions in analysis. Further support was provided by Dr. Gordon F. DeJong, to whom the author is also grateful for providing insight into the method and procedures of demography.

Finally, the author wishes to thank William F. Stinner for his help and suggestions in demographic analysis, and Miss Joan Heppenstall of Oxford for providing an excellent critique of style.

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CHAPTER I

INTRODUCTION

General Statement of the Problem

When the Spanish conquistadores invaded the Peruvian highlands (altiplano) in the 16th century, it was discovered that the fertility of both European men and most domestic animals was reduced (Monge, 1948). In fact, it was 53 years before the first Spanish child was born at the colonial-founded "Imperial City of Potosi" at 13,200 feet (ca. 4000 m) above sea level (De la Calancha, 1639). According to De la Calancha it was for such reasons that the capital was finally moved to Lima on the coast. It has now been clearly established that a large variety of sea-level indigenous mammals suffer impairment in fecundity upon prolonged residence at high altitude (Van Liere and Stickney, 1963 : 193-194). Yet at the time of the conquest there was a flourishing population of Quechua and Aymara Indigena in the Andean zone that "had an ability to work and reproduce" at a level greater than the Spanish and other coastal populations (Negro and Amerind) that the Spanish introduced to this area (Baker, 1966 : 296). It would appear, then, that the Indigena have successfully adapted to the stresses of high altitude. Whether this has been by biological or cultural means or both is the subject of present investigations of which this thesis forms a part.

Evidence that hypoxia affects the major organ systems of sea-level living mammals is well documented by a wide variety of investigators such as Van Liere and Stickney (1963), Weihe (1964) and W H O

(1966), to name a few. Experimental studies in the laboratory or the natural setting demonstrate that for animals, such as rats, pigs, and ewes, there are to various degrees pathologies at the cytological level in the reproductive organs and endocrine glands (Sundstroem and Michaels, 1942: Gordon et al., 1943:Altland and Highman, 1951; Van Liere and Stickney, 1963). However, Moore and Price (1948) failed to find significant differences in the gonadal histology of rats subjected to continuous residence at 6,000, 7,500, 9,600 and 14,260 feet of altitude (1830, 2290, 2920, and 4350 m, respectively). Donayre (1966) suggests that this is due to the date of sacrifice and examination, 30 days after onset of the experiment. He believes that the acute process had been reversed by this date. Gordon, Tornetta and Charriper (1943), upon exposing adult male rats to a simulated PO_2 of 25,000 to 28,000 feet (7620 to 8530 m), discovered that there were pathologies in the gonadal tissue as well as pathologies of associated structures. Both morphological and physiological alterations occurred in the anterior pituitary lobe with greater than normal gonadotrophic hormone output. There appears to be some variance in the effects of hypoxic exposure on the ovarian cycle of females of various mammalian species. Donayre (1966) finds that hypoxic stress disrupts the normal ovarian cycle causing sustained estrus.

Nelson and Berril (1944), Moore and Price (1948), Altland (1949a), 1949b), Altland and Highman (1951) have found little effect of hypoxic exposure on either the gonads of females or on their ovarian cycle. Altland and Allen (1952) corroborated these findings but observed that rats exposed to hypoxic stress at 25,000 feet (7620 m) demonstrated

aspermatogenesis. Donayre (1966), studying effects of high altitude exposure on nonresident humans, noted reduced sperm counts with an increase in abnormal sperm. There is little disagreement among most authorities that fertility is reduced with a concommitant greater neonatal death rate suggesting reproductive organ malfunctioning during pregnancy. This has been demonstrated for rats, where a high degree of foetal reabsorption has been noted (Altland, 1949a, 1949b). Whether or not the case applies to other nonhuman animals is difficult to say. From the structural standpoint, maintenance of the mammalian embryo-foetus requires a proper hormonal balance and a sufficient oxygen supply. The amount of oxygen diffusion across the placental membrane is itself a result of exposure area, rate of blood flow, and oxygen saturation of the blood (Ganong, 1965). Grahn and Kratchman (1963), Mazess (1965), and Cruz-Coke et al.(1967) have found a correlation between altitude and neonatal mortality in the United States and Peru and Lichty et al. (1957) have established that there is an increase in prematurity rates and decrease in birth weight with altitude. It is almost certain that one component of the reduced viability post partum is in utero maintenance inefficiency as well as environmental stress after birth (Chiodi, 1953). It is evident that for the sojourner at high altitude there has to be both gross morphological and physiological adjustments in order to ameliorate the effects of environmental hypoxia. Since the embryofoetal biological system is in symbiosis with that of the mother it must be assumed that it has to make some adaptations of its own to hypoxia. It has not been proven that the maternal biological system can maintain foetal homeostasis alone (Acheson et al., 1957).

It is known that the foetus has a high tolerance to hypoxia (i.e., by adult norms) (Montagu, 1962). This is partially a result of the HbF production. HbF has a greater O_2 bonding capacity than HbA (Windle, 1950: Gruenwald, 1953; Ganong, 1965). The greater apparent fertility of the Indigena may be a result of a greater foetal or maternal tolerance to hypoxia or both. The etiology of this phenomenon may be genetic or acclimatizational in origin.

Hurtado (1964) compared residents of Morococha at 14,750 feet (4500 m) above sea level with Lima residents with respect to pulmonary and arteriovenal concentrations of oxygen. He found that, although the vascular-tissue oxygen gradients are lower for the highlander, the amount of oxygen concentration of the tissue is below that of the lowlander. However, it has been suggested that enzymatic functions involved in cell metabolism may alleviate the apparent tissue hypoxia of the highlander (Monge and Monge, 1966). If this condition has a genetic etiology, then it may be present in the developing embryofoetus, conferring greater survival value under hypoxic stress in utero. It must be noted that the physiology of reproduction is not completely understood for humans at the present time. Caution must be taken in extrapolating from the results of laboratory animal situations to humans.

Also, man with his possession of culture is probably the most adaptable of animals. Thus, the resultant fertility of the Indigena may be a direct consequence of cultural mores towards large families to offset wastage that occurs in response to the environmental stresses.

The problem that presents itself to the investigator is how to determine the efficiency of the reproductive component of adaptation.

In the light of the present dearth of information on comparative reproductive physiology of highlanders and lowlanders, one can only deduce differentials in capability to tolerate hypoxia by examining the vital statistics of the former.

This study is part of a larger project being carried out by the Department of Anthropology, The Pennsylvania State University, under the direction of Dr. Paul T. Baker, to study a highland Peruvian ecosystem, a small rural community and its environs (see Baker *et al.*, 1965). Both the demographic study and the project are in keeping with the goals of the International Biological Programme (IBP) which has set as one of its tasks, investigations of human adaptability to various of the world's ecological niches (Baker and Weiner, 1966).

The Peruvian *altiplano* was selected for study for several reasons. First, in this part of the world it is still possible to find human communities whose communication with Western civilization is weak and whose way of life has deviated little from that of their pre-Conquest forefathers (Mason, 1961). Second, the high altitude with the resultant cold, hypoxia, limited flora and fauna, and the natural physical factors provide a set of consistent environmental stresses subject to limited cultural amelioration. Therefore, the *altiplano* provides an excellent laboratory to study the interaction of biology, culture and environment.

It is the purpose of this thesis to analyze the fertility of a sample of women residing within the defined ecosystem (District of Nuñoa, Peru) and to investigate the viability of offspring. Analyses will be carried out in the light of various physical and cultural parameters within the ecosystem. The fertility and viability statistics for the

area as a whole will be compared to the larger altiplano political district within which it lies and to world norms and those norms for societies at similar subsistence levels (where pertinent and possible).

Theoretical Considerations

Man has been studying and writing about population size and growth for more than 3,000 years (Cole, 1957 : 1). Many of the civilizations of antiquity have at one time or another taken censuses for the purposes of levying corvées, taxes and carrying out other practical functions of government. Still, as a science concerned with analysis and prediction and cause and effect, the study of population dynamics is a fairly recent development. One of the first treatises on vital statistics was Graunt's "Bills of Mortality," published in England in 1662. Graunt's successors calculated life tables based on mortality data from parish records and attempted an estimate of population growth. From this beginning developed the discipline of human demography, which until recently has been primarily the province of social scientists interested in the dynamics of Western societies.

Much attention is now being focused upon the study of population dynamics of non-Western peoples by both social and biological scientists. For three-quarters of a century field studies on such groups were primarily the province of the ethnographer. Now, within an ecologically oriented theoretical framework, scientists in such diverse disciplines as physical anthropology, demography, genetics, and medicine are turning their attention to these societies. The rationale for such studies is two-fold: (1) Hunting and gathering and peasant societies are at

present undergoing or will soon undergo radical change, as they come into the sphere of modern Eurasiatic civilization (W H O, 1964). Therefore, it is urgent to study these societies while they still exist. (2) The more complex a culture the more obscured are the dynamic interrelationships within an ecosystem. So-called primitive societies offer a natural setting in which to study the conditions under which man has lived for the greatest part of his evolutionary history (Neel et al., 1964; W H O, 1964; Ginsburg and Laughlin, 1966). It goes without saying that science has much to gain by observing the effects of culture change upon these human societies.

Broadly defined, ecology is the study of the interaction between biotic communities and the environment (Bates, 1964). The recent reassertion of man's affinities with the rest of the animal kingdom and a welding of theories from the biological and social sciences have provided the basis for human ecology. Human ecologists posit the thesis that a human society's genetic composition, culture and environment are inextricably interrelated (Bates, 1953; Baker, 1962, 1965). They feel too much has been made of man as a unique creature whose capacity for culture sets him apart from the animal kingdom and nature in general (for an extreme viewpoint in this vein see White, 1949, 1959). Human ecology, then, provides a "clearly formulated experimentally verifiable, conceptual scheme" within which to study man's evolution and his present racial variation (Washburn, 1951).

The ecological balance or degree to which a population remains in equilibrium with its environment is reflected in its demography

(Alee et al., 1949; Odum, 1963). The most important of the demographic parameters are:

Fertility - the reproductive rate, the result of the interaction of general fecundity and the environment--biological, climatological and sociocultural.

Mortality - the rate at which individuals are eliminated from the population by disease, old age, etc.

Migration - the addition to or deletion of individuals from the population by geographical movement, a function of cultural dictates, personal idiosyncracies and the vagaries of the environment.

Of the three, mortality is the most stable. On a yearly basis, fertility may be subject to large fluctuations; migration is the least predictable, or for that matter, ascertainable (Thomlinson, 1965). Population distribution in space and age composition are functions of the three major parameters, with the environment playing a role in spatial distribution.

Specific Objectives

The object of the study is in the nature of an enquiry rather than the testing of any hypothesis or hypotheses. This is due in part to the limited data that were collected and lack of knowledge about fertility at high altitude and its bases in Andean and other high altitude populations. Thus, this is to be considered as a pilot study. The objectives are as follows:

1. To determine the demographic statistics relating to fertility and viability of the offspring of a sample of Indigena women and to compare the sample with the Andean highland and other societies and world norms where possible and pertinent.

2. To establish whether there are differentials in fertility and viability between two focal subsamples within our sample clustered around 13,000 (3960 m) and 14,000 feet (4270 m) above sea level.

3. To establish whether type of community of residence is related to said differentials, comparisons being made between the town-living Indigena and the rural Indigena. The latter either work as pastoralists on the Mestizo owned haciendas or practice some mixed farming and pastoralism in Indian owned communities known as ayllus.

4. To determine whether significant correlations exist between fertility and age at first marriage and duration of marriage.

Objective 1

The calculation of crude demographic statistics will throw light on the efficiency of reproductive adaptation and augment our knowledge of high altitude demography. The sample will be compared to (1) two political districts (Puno and Juliaca) within the larger political (and geographical) area in which Nuñoa lies (Department of Puno), (2) two

other Andean communities (Cerro de Pasco, Peru and Huallatire, Chile), (3) some other societies at a peasant level of subsistence (all at low altitude), and (4) Western society and world norms. This will be carried out on various vital statistics as reported from censuses, government surveys and other studies of a demographic nature. As Neel (1958) points out, an ideal comparative study is only valid if one analyses like societies (i.e., hold as many underlying variables as constants, except the ones that the investigator is concerned with). Due to the present state of demographic data on the world's societies, this is not possible. It goes without saying that the conclusions derived from the type of analysis as carried out in this thesis' study must remain as tentative and to a degree speculative.

Objective 2

"As the oxygen pressure falls with increasing altitude the rate of transfer [of O_2 to the arterial system] decreases proportionately" (Weiner, 1964 : 478). However, "the curve relating percentage saturation of the O_2-carrying power of the Hb to the [environmental] PO_2 has a characteristic sigmoid shape" (Ganong, 1965 : 519), such that at altitudes up to about 8,000 feet (2440 m) above sea level there is sufficient O_2 carried in the blood stream to support the normal physiological functioning of the body's various organ systems. At altitudes above this a lowland-living human faces ever increasing stress on his physiology as he ascends, unless various adaptive mechanisms come into play (haematological, cardiovascular, respiratory, etc.). Even though native highlanders may be adapted to a degree to hypoxia, a positive

1,000 foot (305 m) differential at high altitude may exert a proportionately greater stress than a similar increment at low altitude. If true, this may be reflected in reproduction and viability differentials between the two focal Nuñoan populations at 13,000+ (3960 m) and 14,000+ feet (4270 m) above sea level. This will be investigated by a comparison and testing of statistics from the two subsamples at these altitudes.

Objective 3

Although the sample is, apparently, completely Indigena there may exist reproductive differentials between the three types of communities of residence to be found in the district of Nuñoa. In other words there might exist subtle sociocultural, behavioral or biological differentials inherent in these three different communities. In pre-conquest times the ayllu was the fundamental and social political group - a form of peasant communism (Kirchhoff, 1949; Mason, 1961). The structure of the ayllus today has been modified. The land within and about the community is owned by individual families and not parcelled out by the community. The modern-day ayllu is no longer the fundamental sociopolitical group. Its origin is pre-conquest, but it has been changed by modern influences. With one exception, the ayllu dwellers are primarily pastoralists. The hacienda Indigena is also a pastoralist; for the service of grazing hacienda herds of llamas, alpacas, and sheep with his own, he is allowed the use of hacienda land. The activity pattern is different for the town-living Indigena who may perform a number of subsistence roles; e.g., pastoralist, construction worker (male), weaver, cultivator, etc.

The role of the town woman probably does not differ greatly from that of her rural counterpart, vis à vis domestic duties, but she is less active and does not generally partake of as much of the pastoral activities as the rural female. The reduced activity pattern and the greater chance for access to medicines may affect foetal and infant wastage among town women.

Objective 4

Demographers point out that there is quite often a significant correlation between age at first marriage, duration of marriage - and fertility in primitive societies (Lorimer, 1954; Davis and Black, 1956). Both of these parameters are related to exposure time to copulation. It is hoped that these two parameters will throw light on fertility - actual and potential within our sample.

CHAPTER II

METHODS AND PROCEDURES

General Method

It is obvious that to clearly understand the relationship between a population and its environment using demographic variables as criteria for evaluation, both the total population and all contingent factors must be examined (the evaluation of a larger sample is one of the goals of continuing demographic research in Nuñoa). However, such a complete study was infeasible in the initial stages of the project (1963 and 1964). Both biological and sociocultural data were taken at the same time. Therefore, the composition of the sample from which fertility statistics were derived is influenced by the sample utilized in biological sampling in the town laboratory and in the field (rural Nuñoa). Due to the cultural (and apparently biological) homogeneity of the population it is felt that the sample is representative of the Indigena inhabitants of the district.

In order to achieve the goals of the study, data were collected on the biological and sociocultural background of married females. The design was implemented as follows:

1. Eleven local resident sites within the district were selected as locations for collection of pertinent data. These included the town of Nuñoa, two ayllus, and eight haciendas. The residential sites ranged from 13,100 to 14,900 feet (4000 to 4550 m) above sea level.

2. In general, information was taken from male heads of household during the period of biological testing. Interviewers were provided with questionnaires in Spanish and Quechua which facilitated the interviewing (see Appendix A). Informants were paid for supplying the pertinent information.

3. Other data used to compare Nuñoa with the altiplano were taken from several of the Peruvian national censuses.

4. Analysis of the data was undertaken using appropriate statistical methods.

The Area

The district of Nuñoa is located in the altiplano of the southern highlands of Peru at approximately 14° 27' south latitude 70° 35' west longitude. Physiographically, the altiplano is a broad plateau, a result of the convergence of two Andean ranges. The topography varies from low valleys that bisect the plateau at 12,000 feet (3660 m) above sea level to peaks rising over 18,000 feet (5490 m) above sea level. The human inhabited area of the district lies between 13,000 (3960 m) and 16,000 (4880 m) feet.

The number and type of indigenous fauna and flora are limited. The plateau is covered with abundant grasses with occasional scatterings of the native Andean tree "quena." Fauna include both feral and domestic types -- feral: cameloid vicuña, several species of rodents, fox, fish and a large variety of birds (e.g., flamingo and condor); domestic: cameloid alpaca and llama and the non-indigenous sheep.

As a result of the geographical position of Nuñoa (tropics) there is only a limited seasonal variation in climatology (a wet and dry season). It is for the same reason that the snow line does not commence until around 17,000 feet (5180 m) above sea level. During the day solar radiation is high. At 13,000 feet (3960 m) diurnal temperature ranges on the average, from around 20° to 40°F., depending on cloud cover and the season. Mean temperature decreases as a function of increasing altitude, such that the mean temperature at 14,000 feet (4270 m) averages about 3°F. less than at 13,000 feet (3960 m) (Baker et al., 1965).

The Community

The town of Nuñoa is both the political and socioeconomic center of the district. Here are situated the church, offices of political officials such as the governor of the district (a federal appointee), the alcalde (elected mayor) and the guardia civil (state police). The central plaza is the focus of both social (fiestas) and economic activity. There is daily commerce being carried on (most stores are about the plaza or within a block of it), and market is held here once a week. Rural residents travel many miles to town to participate in these activities. It is their major point of contact with modern Peruvian society.

The People

There are three major social groupings to be found residing in the district of Nuñoa: the Mestizos, Cholos, and Indigena. The first group comprises the hacienda owners, major political functionaries and store

owners in the town. This group is Western in outlook and dress. From the genetic standpoint, this group ranges from individuals possessing a high degree of Indian heritage to individuals of more than one-half European ancestry. Therefore, the criteria for defining this group are more socioeconomic than racial. The Cholo group is primarily of Indian ancestry, though there has been, undoubtedly, some admixture with Europeans. This group wears traditional semi-European dress that is distinguishable from that of the Indigena, and they are more Western-oriented (see Baker, 1966). The Indigena make up the bulk of the population. They are chiefly pastoralists, with some secondary practice of cultivation. Rural residents, with few exceptions, are culturally and genetically Indigena. This is the social grouping with which the study is concerned.

Biologically, the Indigena of the district of Nuñoa characterize the highland resident type found throughout the Andes. These people belong to the Quechua ethnic stock and are direct descendants in most part from the peasants of the pre-conquest era. It is believed that they have been resident in the altiplano for several thousand years. Therefore, it is assumed that there has been genetic continuity, temporally and spatially, with the rest of the southern highlands of Peru (Baker et al., 1965).

The Sample

The sample used in the analysis of the fertility statistics consists of 136 married (past or present) women and their offspring. These females range in age from the late teens to post-menopause. The offspring and their vital statistics are considered as the analog model

of the population, i.e., projections will be made from their vital statistics to the population at large. The age range of the offspring is from several days to late adulthood. Of course, the age distribution of the offspring will not be representative of the total district, but this does not prevent the computation of crude rates and validating their projection and extrapolation for the district if mitigating circumstances are considered. Migration data are lacking and there is little doubt that migration affects the structure of the population, but it is not possible at the present time to assess its importance.

Women in the sample were drawn from eleven sites within the district. The names, type of community of residence and altitude are presented in Table 1. The ayllus samples are limited to the lower altitude. However, the haciendas are found at both "low" and "high" altitudes.

Residential Sites Within the District of Nuñoa

Name	Type of Community	Altitude (in feet and metres above sea level)	
Sincata	town	13,200}	
Acclamayo	ayllu	13,100} (ca 4000 m)	"low
Istarata	"	" }	altitude
Sipaspugi	hacienda	13,400} (4100 m)	sample"
Barreña	"	" }	
Amcalla	"	14,200} (4320 m)	
Naqtuiyri	"	" }	"high
Chillihua	"	14,700} (4500 m)	altitude
Imatuta	"	" }	sample"
Huaychu	"	14,900} (4500 m)	

Table 1

Techniques

The data collected on marital, reproduction, viability and age parameters of the mother and offspring were converted to a predetermined IBM card format compatible with the IBM 7074 computer (see Appendix B).

Pertinent programs were written in FORTRAN II to compute crude demographic rates, means, standard deviations and to perform t-tests between the specified subsamples of the population. Pennsylvania State University library programs were utilized to perform correlation analyses of reproductive and various biocultural parameters.

Chi-squares were run by hand on several groups of parameters to compare Nuñoa with the altiplano at large and to examine pertinent internal differentials not feasible for analysis by other statistical procedures.

CHAPTER III

RESULTS: DEMOGRAPHY OF THE DISTRICT OF NUÑOA

Sociocultural Characteristics

Initially, it was decided to analyze the sociocultural parameters that had been collected on each family of the members of the sample (possessions and social attributes such as dress, education, etc.) in order to determine if there are sociocultural differentials present within the sample. Though the Indigena population is apparently homogeneous ethnically, it was necessary to investigate the possibility of differentiation, and it was felt that this might be demonstrated by a variation in sociocultural levels, however subtle. Therefore, there might exist fertility correlates and it would be necessary to investigate them. William Stinner (1967) undertook a Guttman scale analysis of degree of acculturation to Western society in order to determine if there were sufficient grounds to warrant a ranking of members of the sample. Admittedly, there is a certain arbitrariness to this approach, but it is difficult to sort out distinctions in traditional lifeways of the Indigena. Stinner examined all such data assayed from heads of households. Only five of the items fitted the Guttman criteria (less than 80% uniformity throughout a given sample). They were (1) degree of education, (2) knowledge of Spanish, (3-5) possession of three Western items.

It was only feasible to use one-half of the sample for Guttman analysis since pertinent information was missing on at least one item for the other 68 women.

Stinner found the sample to be quite homogeneous on the Guttman scale of these items. Concommitantly, the high uniformity on the other sociocultural items implies a great deal of homogeneity. There is no reason to suspect that this is not true for the other 68 women in the sample. This homogeneity and its maintenance is probably a result of the social matrix within which the Indigena lives. The Mestizos occupy the top social stratum, once the province of the Inca overlords (and consequently own most of the land and control the political institutions). Although there was an initial post-conquest hybridization of Spanish and native culture (primarily in dress), the present society is a peasant one with lifeways similar to that of pre-conquest times (Mason, 1961). Communication between the Mestizos and Indigena is in the native Quechua and this tends to isolate the latter from modern Peruvian society. Thus, the Indigena is not integrated into the dominant society and retains a great degree of provincialism. In the over 300 years of post-conquest era this subculture has stabilized into its present social state (Kubler, 1952). Thus, for the purposes of this study this society is assumed to be socioculturally homogeneous.

Although existing at a low peasant level of subsistence, it appears that this population receives an adequate nutritional intake. Two studies carried out by Mazess and Baker (1964) and Picon-Reategui (1967) found that the Indigena (male) ingests about 2700 kcal./day. Picon reports that the diet is high in carbohydrates and low in fat and animal protein (though the latter is adequate). In the light of the sociocultural homogeneity, it is possible that there are not significant nutritional differences between the various population foci within the district.

Marital State and Reproduction

In the sample of 136 "married" women only three have borne no children. However, since all three of these women are under 25 years of age, it is not possible to assume infertility due to impaired fecundity on the part of them or their mates.

Mean reported ages at first pregnancy and first marriage are 19.5 (±3.5) and 19.7 (±4.3) years of age, respectively. It would appear that the marital union is solemnized either legally or consensually at the onset of the first pregnancy. These ages are rather late for a non-Western society (see Nag, 1962), and it is not known whether or not this phenomenon reflects later cohabitation practices. Baker et al. (1965) have found that physical development is retarded by U. S. white standards. It is possible that there is a concommitant lag in development of both the male and female reproductive systems and adolescent sterility may cease later. Cruz-Coke (1967) found in his study of Huallatire, Chile (altiplano) that mean age of the onset of menarche was nearly 15 years of age, while age at first pregnancy was 18.7 years. The respective values for lowland Chile were 13.3 and 20 years of age. Sobrevilla (1967) observed delayed menarche in the Cerro de Pasco population of the Peruvian altiplano. Cruz-Coke also notes that the onset of menopause is earlier than in the lowlands (44 vs 46.5 years). Considering these data it is highly probable that the reproductive span (i.e., range of fecundity) in the altiplano is less than in most low altitude populations. However, this may be alleviated (at least for Huallatire) by a shorter delay time to first pregnancy.

Marriages are particularly unstable among the Nuñoan population. This appears to be typical for this culture area (Price, 1965). This is especially true for the first marriage. It was found that 29.4% of the sample had terminated the first union. Only 17.6% of this group remarried at a mean age of 24.9 (±11.2) years. Of this group 25% terminated the second union (only one woman in the sample was married three times). Average times between unions was about 3 years, but since this mean was derived from a smaller sample of 19 women, it is open to question. The "exposure" values[1] for first and second marriage are 38.0 and 28.0 with the mean for the sample being 34.5. These values are not exceptionally high (Stinner, 1967), but still higher than Cruz-Coke (1967) found in Huallatire (34.5 vs. 23). It is not possible to state that this marital instability affects exposure time of the women and plays a role in lowering net fertility. Second unions may result from "premarital" cohabitation and, therefore, some women may be exposed to copulation during the interim between first and second union.

In summary, it is not yet possible to assess the effect of marital instability on net fertility.

Reproduction and Survival

The reported age range of the 136 "married" females of our sample is from 18 to 83 years. Caution must be taken in accepting these ages at face value. This is especially true for the older women. Ages were

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1. The mean ratio of children per duration of 100 years of marriage.

recorded as reported by women in the sample, and age estimates were made by the interviewers. There was a close correlation of estimated with reported ages of younger members of the sample. A second check was run on birth records of women under 25 years and, again, there was a close correlation with reported ages. However, it was not possible to accurately assess or validate reported ages with women over 35 years. The derivation of fairly accurate age data from informants in a non-literate society is one of the problems of ethnographic censuses. However, if we present our data according to broad age intervals and utilize gross statistics such as means, etc., the error is vitiated to some degree, but this is still a problem in accurate assessment.

The calculated mean age of the sample was about 36 years (see Table 2). This is probably a fairly accurate indicator of true mean age. Since there was some question of age of mothers and offspring, not withstanding missing information on age for some of the children, it was not feasible to utilize the fertility ratio[2] as an indicator of fertility.

Reproductive and Viability Statistics for the District

	Total Sample	Post-Menopausal Sample
Married women	136	31
Mean age	36.2	45+
Mean age at first pregnancy	19.5 (±3.5)	20.1 (±3.7)
Offspring	608	207
Child-woman mean	4.5 (±3.0)	6.7 (±3.0)
Surviving child-woman mean	3.2 (±2.2)	4.4 (±2.1)
Secondary sex ratio	124	113
Surviving sex ratio	129	146
Male mortality	30.0%	27.3%
Female mortality	33.3%	43.8%

Table 2

2. The number of children under 5 years of age per 100 women aged from 15 to 44 years (Bogue, 1965)

Therefore, in order to assess the fertility of this population, it has been necessary to rely on such gross demographic rates as child-woman mean[3], exposure and total fertility (child-woman mean at the end of reproductive period). Age specific rates of fertility and mortality will not be utilized in an analysis of this population's reproduction and viability statistics.

According to Weiner (1964 : 498) if it is assumed that the reproductive span is about two decades in length (i.e., period of exposure), total fertility should be about 8.[4] Allowing for temporary sterility and miscarriage, this implies a 2.5 year parity span. In a society with a high mortality rate, population stability can only be maintained by a total fertility in the range from 6 to 8 (Lorimer et al., 1954 : 198; Clark, 1958; Nag, 1962).

It has not yet been established at what age onset of menopaus occurs in this population.[5] In keeping with common demographic techniques

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3. Mean number of children ever born per women.

4. The maximum reproductive span in human females is slightly over 30 years and it has been calculated that about 390 eggs are ovulated during this period, of which 60% are capable of being involved in normal conjugation with sperm and resulting in a live delivery at term (Pincus, 1965). This confirms Weiner's hypothesis of 20 years as a more accurate measure of the fecund period of life because of some temporary sterility and losses in utero due to reproductive organ malfunction, etc. (1964 : 498). Henry's (1961) estimate of a potential maximum mean family size of 10 for most human populations is probably too high, although some have been reported with values above this, e.g., the Hutterites (Eaton et al., 1953).

5. "In women the menses usually become irregular and cease between the ages of 45 and 55" (Ganong, 1965 : 344). Normal (and viable) egg production may cease prior to menopause. It has been demonstrated there is a high incidence of abnormal egg production, e.g., Down's Syndrome, with advancing age (Montagu, 1962).

(Thomlinson, 1965) the sample of women of (reported and estimated) ages 45 years and over (N = 31) were used to compute total fertility and other statistics on completed family size. Forthwith this sample will be referred to as the post-menopausal sample. Total fertility was found to be 6.7. This is similar to the total fertility for Huallatire, 7.3 (Cruz-Coke, 1967). The mean parity was computed to be 2.7 (±3.0) years utilizing those individuals reporting age of offspring (N = 71) (See Table 3).

Intervals Between Births

Interval[6]	Parity Span		N
	Mean	S. D.	
1	1.4	±4.8	71
2	2.9	±2.4	50
3	3.0	±2.0	40
4	3.0	±1.8	34
5	4.0	±2.5	22
6	2.4	±1.0	16
7	3.0	±2.3	13
8	3.4	±4.7	14

Table 3

The child-woman mean for the total sample (N = 136) is 4.5 (±3.0), a relatively high figure (this value is 4.6 if we omit the three women having no offspring). It would appear that for the women constantly exposed to copulation there is a high net fertility. Nuñoa demonstrates similarity in the child-woman mean with the Cerro de Pasco population

6. The first interval is from age at first marriage to birth of the first child, the second interval from first to second child, etc. Due to the decreasing sample size, this was not carried out beyond the eighth interval.

which showed a value of nearly 5.0 (Sobrevilla, 1967). If the Cerro de Pasco and Huallatire populations demonstrate normal reproduction statistics for the altiplano we can assume Nuñoa's consistency with altiplano norms due to its similarity to both of the above groups.

The median parity interval (3.0) is probably a more accurate estimate of birth spacings. Still, this is a small interval and supports the thesis of a high potential fertility.

In order to assess viability and mortality of the offspring, wastage[7] was estimated and percentages were calculated on reported births and subsequent deaths. Due to the fact that this was a study of a small sample of women and offspring, and information on males and all attendant existent relatives was incomplete, it was not possible to calculate crude death rates. However, an estimate was attempted.

Wastage was estimated to be about 30%, but with the questionable validity of age data, this must remain as tentative. Consideration must be taken of the possibility of under-reporting on stillbirths, miscarriages and perinatal deaths. The percentage of in utero deaths as reported is 0.6%. This value is highly suspect. Penrose (1959) calculates that the world norm for stillbirths alone is 3% and 15% for miscarriages. If anything, then, wastage is higher than estimated. The world mean (ca. 13%) is less than one-half the Nuñoan value. Data from other peasant societies are lacking, but there is little doubt that wastage in the Nuñoan sample is significantly high. This is especially so in the light of the conservative nature of this estimate (30%).

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7. Losses in utero until the age of five years post partum.

The post-menopausal sample shows a mortality of 34.8% as contrasted with the value of the total sample of 28.5%. This is a considerable mortality and the greater proportion of it occurs prior to the age of reproduction (ca. 90% for offspring of the total sample).

The age data on the younger children were considered to have the greatest degree of reliability. Neonatal mortality rates[8] were calculated. The figure for our sample is 85.5. This is very similar to the value for Peru in 1961, 82.3 (U.N., 1965), though it is considerably higher than that calculated from the 1959 vital statistics survey of Nuñoa, 50.5 (Ministerio de Hacienda y Comercio, 1961). It would appear that the highest mortality occurs in the post-neonatal period.[9] This value is 116.8. It was not possible to compare this with other data from Peru, but it is quite high. In Nuñoa the highest mortality occurs in the first year of life. Cruz-Coke, Cristoffanini et al., found a similar phenomenon in Huallatire, Chile (1967 : 429). Over one-half of the mortality of the Huallatire sample (ages: 0 to 44 years) were in the first year of life (6.8% vs a total of 12.8%). A ratio was calculated of post-neonatal to neonatal mortality rates to compare our data with that derived from the 1959 vital statistics survey of Nuñoa. The values are 1.37 and 1.34, respectively. This lends further support to the supposition that the sample is representative of the district, and is experiencing a high mortality as compared to non-literate societies at large.

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8. Deaths in the first four weeks of life per 1000 children born alive.

9. Between the first month and one year of age.

Data were collected as to cause of death (reported by the mothers). Nature of cause of death and their percentages of the total mortality are presented in Table 4. The validity of these values are questionable due to a lack of corroboration in diagnosis by a qualified physician. The major cause of death appears to be diseases and/or pathologies of a respiratory nature. This is consistent with Peruvian vital statistics data (U. N., 1965, 1966, 1967), though it is usual to have a high mortality due to gastrointestinal causes. Hellriegel (1967), in a study of hospitalized

Age and Cause of Death

Cause of Death	Percent of Mortality		Mean Age at Death (years)	
	Males	Females	Males	Females
Gastrointestinal	1.1	1.2	0.0(B)	0.3
Respiratory	47.3	28.1	1.0	2.7
Fright (shock?)	9.9	1.2	1.1	0.0(B)
Measles	1.1	1.2	1.8	0.1
Whooping Cough	2.2	6.1	5.0	0.4
Accident	2.2	0.0	11.0	-
Other	11.0	12.2	9.3	15.5
Not reported	25.2	50.0	1.0	2.2

Table 4

B = Birth

infants in the Peruvian altiplano (La Oroya, 6,500 infants admitted per year) found that respiratory complications accounted for about 40% of infant deaths with bronchopulmonary disorders as the chief mortality determiners in infancy and childhood. Marticorena et al. (1967) have

investigated cardiopulmonary pathologies in high altitude residents (Peru) and suggest that much of the mortality in the foetal and neonatal periods of life in the altiplano is due to cardiovascular malfunction induced by hypoxia. It would appear that hypoxia affects the pulmonary-cardiovascular organ systems to such a degree as to significantly affect viability in the early post-natal stages of life. Thus, the high mortality due to respiratory orders in the Nuñoan sample is consistent with results of prior demographic and physiological studies of altiplano populations.

Although one must still invoke a caveat about the validity of the age and percentage figures derived from the Nuñoan sample, several are worthy to point out and comment upon.

1. Gastrointestinal disorders are particularly relevant as causes of death at about the time of birth, and
2. A similar situation is observed for "fright," whooping cough and measles for female offspring.
3. The mean age of death of females in the "other" category is 15.5 years and this might reflect mortality during pregnancy or while giving birth. In the post-menopausal sample the mean age at death in this category was nearly 18 years of age. This hypothesis must be considered as a speculation.

Davis and Blake (1956) have listed several factors (intermediate variables) affecting exposure to intercourse. Since these may influence a society's fertility levels, it was thought pertinent to analyze those two for which we had data - age at entry into sexual union (assuming age at first marriage as an indicator) and duration of marriage.

Two r-correlation analyses were set up to test the relationship: (1) age at first marriage against the exposure index - number of children per years of marriage ratio, and (2) duration of marriage against net number of children produced. Both were significant at the .05 level. ($N = 86$, $r^2 = 0.55$ and 0.50, respectively).

Distribution of Offspring by Age of Mother

Age of Women	N of Women	Child-Woman Mean
16 - 20	10	0.75
21 - 25	23	1.96
26 - 30	21	3.06
31 - 35	21	4.32
36 - 40	26	5.31
41 - 45	8	5.80
46 - 50	9	6.00
51+	18	6.90

Table 5

Examination of the child-woman mean, i.e., net production by 5 year age intervals shows a nearly linear reproduction rate (mean increment: 1.15 children per 5 years) until the sixth interval and beyond (see Table 5). The reduction in increment is in the neighborhood of onset of menopause.

The significance of the above evidence, notwithstanding its consistency with demographic hypotheses, is that it demonstrates a high and continuous reproduction throughout the normal reproductive span of the women in the sample.

In order to check the normality of total fertility (6.7) a regression line of number of children (Y-axis) was run on reported ages (X-axis) of

those women who were married at the time of the investigation and who reported duration of marriage (N = 86). The mean age of this subsample was 32.9 (±1.3) years and it had a child-women mean of 4.2 (±3). The r-value of Y on X was .65. The equation of the least square line (see Appendix B) of number of children (Y) on reported age (X) is

$$Y = .173X - 1.522$$

Two estimates as to total fertility were made assuming age at onset of menopause at 45 and 50 years of age. They are 6.3 and 7.1 children, respectively. Thus, we see that the Nuñoan total fertility (6.7) is consistent with the projected estimate of 6.3 to 7.1. Needless to say, this further supports the thesis of continuing reproduction until menopause.

The Sex Ratio

One of the most interesting characteristics of the Nuñoan sample is the pattern of the differentials in reproduction and mortality rates for males and females.

The sex ratio of any given population usually varies between 90 and 110 (males per 100 females) (Clarke, 1965 : 73). A population's sex-composition is a result of the secondary sex ratio (i.e., at birth), differential mortality of the sexes, and to a lesser degree selective migration. The tertiary sex ratio (i.e., at adulthood) for a monoparous and (usually) monogamous species such as Man is ideally 100 if there is not to be a wastage of individuals (vis à vis reproduction) who cannot find mates. Over a period of many generations this can reduce a

population's gene pool variation and consequently lower its genetic adaptational potential.

In order to maintain an optimal equilibrium between the sexes during the reproductive span in the face of higher male mortality at all ages, natural selection has favored genetical systems conferring a secondary sex ratio (SSR) greater than 100 (Fisher, 1958 : 158-160). According to Kirby et al. (1967 : 139), the world SSR is 106. This has certainly been demonstrated to be the norm for most large "westernized" populations, e.g., Britain, the U. S. A., and Japan (Ciocco, 1938; Montagu, 1962 : 137; Clarke, 1965 : 73). However, values as low as 101 (Cuba) and as high as 115-117 (Korea) have been reported (Yung Sun Kang et al., 1962; Harrison, 1964 : 117).

The SSR of our sample is 124. If this is typical of the district or the altiplano, it would be one of the highest ever recorded for a population. Examination of the reported surviving offspring shows an even higher sex ratio of 129. Female mortality exceeds that of males after the first year of life and net mortality of females is higher, 30.1% vs 27.1% for males, ergo, the surviving sex ratio is greater than the SSR. This phenomenon of higher female mortality is even more pronounced if we examine offspring of the post-menopausal sample. The SSR is 113, while the surviving sex ratio is 146: The male and female mortalities are 27.3 and 43.0%, respectively. As has been hypothesized in a preceding section, this may be a result of death of females at risk during pregnancy or at the time of giving birth. Since diagnostic data as to age and cause of death are dubious or lacking, this hypothesis must be considered as purely speculative.

It is not yet clear whether the high sex ratios to be found within our sample are typical of the district of Nuñoa or the altiplano at large. Examination of the vital statistics records of Puno and Juliaca for the year 1963 showed an SSR of 127 (source as quoted in Table 6, N = 2668), a value similar to that of Nuñoa, 124. Neither of these values is consistent with the SSR derived from the vital statistics records of Nuñoa for the year 1959, 98 (N = 407) (Ministerio de Hacienda and Comercio, 1964). It is possible that the disparity between these figures is due to inaccurate reporting and/or lack of reporting of birth data to government officials in Nuñoa, notwithstanding possible bias within our sample. This awaits further clarification, but due to the consistency of our sample with the two other altiplano communities on gross reproduction statistics a high sex ratio may be the norm for some highland communities, especially for those who are Indigena.

In order to see if there was a relationship between altitude and SSR, urban centers (populations 2,000 inhabitants and over) reporting vital statistics for 1963 in Peru were grouped into intervals of 1,000 feet above sea level and SSR's were calculated (see Table 6). It was not possible to include all of the cities and the jungle districts were excluded. The SSR of all the cities used in the compilation of SSR by altitude is 110. This is slightly higher than the norm for the nation of Peru, 105 to 106. Table 5 does not demonstrate a relationship between altitude and SSR. However, these figures are all from urban centers (hospitals, etc.) and such related factors as socioeconomic status, ethnic origin and others may be influencing these SSR's. It is possible that under more primitive conditions there may be a greater female mortality

in utero or perinataly at the higher altitudes. The etiology of this could be climatological, biological, and/or cultural.

Altitude and SSR

Altitude (in feet)	N of Urban Centers	Males	Females	SSR
0000- 1000	68	59043	52524	112[10]
1000- 2000	3	2449	2158	113
2000- 3000	2	768	696	110
3000- 4000	0	-	-	-
4000- 5000	2	372	380	98[11]
5000- 6000	1	132	160	83[11]
6000- 7000	3	912	800	114
7000- 8000	8	4088	3981	102
8000- 9000	5	1212	1304	93
9000-10,000	4	2415	2233	108
10,000-11,000	18	3634	3477	105
11,000-12,000	9	2437	2384	102
12,000-13,000	7	1640	1552	106
13,000-14,000	2	955	918	104

Table 6

(Figures taken from Ministerio de Salud Publica y Asistencia Social, 1965)

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10. SSR of Lima, over one-half of this sample, is 106.

11. These are probably unreliable due to the small sample size.

Differentials by Birth Order

In the analysis of birth data of Western populations it has been observed that there is a decline in SSR with successive births (Cohen et al., 1956; Novitski et al., 1957; Colombo, 1958; Novitski et al., 1958; Montagu, 1962). Like analyses on non-Western populations are non-existent due to lack of adequate data on SSR and other reproductive and viability parameters according to parity (Colombo, 1958). The Nuñoan parity statistics, compiled in Table 7, certainly are at variance with Western norms, where there is a nearly linear decrement in SSR from 105 or 106 to values approaching 100.

Parity Differentials in Reproduction and Viability

Birth order	1	2	3	4	5	6
N	133	112	91	77	58	43
Secondary sex ratio	115	107	140	114	152	169
Surviving sex ratio	96	120	148	125	216	155
Male mortality	33.8%	27.5%	24.5%	26.9%	20.0%	37.0%
Female "	21.0%	35.2%	29.0%	33.3%	43.0%	31.3%

Table 7

How much of this is due to the smallness of the maternal sample size (133) is impossible to ascertain. Therefore, these statistics must be considered as highly tentative and no attempt has been made to extrapolate to the district at large. The parity statistics demonstrate a partial cycling phenomenon that is difficult to explain. It is held

that the decrease in SSR is due to age-attendant factors of one or both parents (re: Cohen et al., 1956). If this is true and our statistics are typical of the highlands, other biological (or climatological) agents must be invoked. Perhaps, these may be of an antigenic nature (re: Kirby et al., 1967).

With the exception of the first and sixth births the surviving sex ratio exceeds that of the SSR. No values were computed for births beyond sixth parity, and obviously as parity order increases from the first birth, values become less reliable due to the decrease in sample size. The major pertinence of these statistics to the study is that they indicate a norm of an unusually high SSR and even higher surviving sex ratio as a result of a greater female mortality.

The demographic phenomenon, that lowest mortality rates are found among the second births, (U. S., 1954; Nag, 1962), was not observed in this population. Rather, the lowest rates were found among the third births. The reasons for this also remain obscure and may be partially a result of the sample size.

Differentials by Type of Residence

Stinner's analysis presented evidence supporting the hypothesis that the population is quite homogeneous socioculturally. Still, it is possible that subtle differences exist between the town of Nuñoa, the ayllus, and the haciendas that influence fertility, e.g., activity patterns, nutrition, social mores regarding family size and others. It was not possible to ascertain if such distinctions existed due to the

limited time allowed in the demographic and sociocultural survey (though a separate analysis of nutrition levels was carried out). Nevertheless, it was deigned expedient to examine fertility and viability rates in order to determine if differentials existed. Age data on the mothers were submitted to a t-test, and the data used to compute ratios and percentages to a chi-square analysis (see Appendix B).

Reproductive and Viability Differentials by Type of Residence

Married Women	Town	Ayllu	Hacienda
N	24	38	74
Mean age	35.2	38.0	35.6
Mean age at first pregnancy	18.6(±4.4)	19.6(±2.9)	19.7(±3.4)
Offspring			
N	107	177	324
Child-woman mean	4.5(±3.1)	4.7(±3.3)	4.4(±2.8)
Surviving child-woman mean	2.9(±2.0)	3.3(±2.3)	3.2(±2.3)
Secondary sex ratio	129	133	117
Surviving sex ratio	133	136	124
Male mortality	33.3%	28.7%	24.0%
Female mortality	36.2%	30.3%	28.9%

Table 8

The results are presented in Table 8. None proved to be statistically significanly different within conventional limits (.05 level). However, some of the differences are noteworthy (and lack of significance may be a function of sample size, i.e., higher standard deviations).

1. The town's mean age at first pregnancy (18.6) is about a year earlier than that of the rural population (ayllus - 19.6 and haciendas -

19.7). This may explain why, though we have a younger town sample (35.2), the child-woman mean is near the norm for the two rural samples.

2. The town's mortality proportions for both males (33.3%) and females (36.2%) is higher than that of the ayllus and haciendas. Thus, the town shows the lowest surviving child-woman mean (2.9).

3. The secondary and surviving sex ratio of the haciendas is considerably lower than that of the ayllus and the town.

Differentials by Altitude

An analysis of the two focal populations at 13,000+ (3960 m) and 14,000+ feet (4270 m) above sea level was imperative in the light of evidence of the effect of altitude on reproduction. As stated (in Chapter II), the 1000 feet interval, although not a large physiographic differential, may result in a proportionately greater stress on human biological systems at high altitude than the same interval at lower altitudes. Throughout, the emphasis has been placed upon hypoxia as the critical agent interacting with the functioning of reproductive organ systems. There is much evidence to support this thesis (Van Liere and Stickney, 1963), but it must be noted that other altitude related factors, e.g., cold and radiation, may also play a role in affecting human biology and ergo, reproduction. T-tests and chi-square analyses were run on the results of the data from the "high" and "low" altitude populations within the district (see Table 9) according to the procedure described in the preceding section

Reproductive and Viability Differential by Altitude Foci

Within the District

Married Women	Low Altitude	High Altitude
N	82	54
Mean age	36.3	36.1
Mean age at first pregnancy	18.8(±3.4)	20.5*(±3.3)
Offspring		
N	369	239
Child-woman mean	4.5(±3.1)	4.4(±2.9)
Surviving child-woman mean	3.3(±2.2)	3.1(±2.2)
Secondary sex ratio	129	115
Surviving sex ratio	132	126
Male mortality	26.4%	28.1%
Female mortality	27.3%	34.2%

Table 9

Only one of the parameters tested was found to be significantly different (t-test), but some non-significant differences are noteworthy.

1.q The high altitude sample shows an age at first pregnancy nearly over one and one-half years later than the low altitude sample and is significant at the .05 level. This is interesting since the child-woman means are similar, 4.4 and 4.5 respectively.

2. The secondary sex ratios are notably different: low altitude - 129, high altitude 115; while the surviving sex ratios are not quite as disparate, 132 and 126, respectively. This is a result of the higher female mortality in the high altitude sample.

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* Significant at .05 level (t-test)

In all other parameters the five subsamples by residence and altitude are quite similar and thus representative of the norms postulated for the district on the basis of the total sample.

CHAPTER IV

DISCUSSION, CONCLUSIONS AND SUMMARY

Discussion

Demography, Ecology and Genetics

The majority of the Nuñoan sample's reproductive and viability statistics (with the exception of sex differentials) showed concordance with the altiplano: Peruvian censuses and vital statistics surveys and the two demographic studies of Cerro de Pasco, Peru and Huallatire, Chile. It was also observed that in total fertility rates, Nuñoa falls at the high end of the range for peasant societies at large. The fact that the statistics of this sample do not demonstrate consistency with world averages or the norms for Western or other non-Western societies is not particularly unusual or unexpected in the light of ecological theory. Any society, especially an isolated one, small in numbers possesses attributes in terms of demography (and other biocultural features) unique to it as a consequence of the ecological interaction between its culture, biology and the natural environment. This Indigena "community" is a cultural isolate due to its insularity from mainstream modern Peruvian (i.e., Western) society. Like other high altitude populations throughout the world it is a geographical/ecological isolate from the 99+% of humanity living at altitudes below 10,000 feet (3050 m)[12] and thus a partial genetic isolate due to the ecological inhibitions imposed on the migration of unadapted lowlanders to high

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12. The estimated number of people inhabiting regions over 10,000 feet (3050 m) above sea level is 20 - 25 million (De Jong, 1967 : 1).

altitudes as a result of the deleterious effects of ecological agents (e.g., hypoxia) on their biology. The specifics of the Nuñoan Indigena sociocultural matrix have not been discussed in detail because it has not been possible to discern the relationship between pertinent features and differentials in reproductive behavior within the sample. This society is highly homogeneous socioculturally and is unique vis à vis other peasant societies not only in its ecology, but in the historical and cultural context - being an amalgamation of 16th century Spanish and Inca peasant culture. Since biology is a component of a community's ecological interaction it has relevance to demography. Evidence has been presented showing the existence of biological (morphological and physiological) differences between the altiplano Indigena and Amerind and non-Amerind lowlanders (see Monge and Monge, 1966). It is a certainty that many of the distinctive phenotype features (especially those related to respiration and cell metabolism, ibid) are adaptations to high altitude. It is a moot point whether these features are due solely to genetic plasticity and acclimatization or are partially the result of an adaptive genotype conferred by natural selection. The pertinence of this to reproductive biology, fertility and viability shall be discussed below.

Evidence supporting the thesis of a relationship between altitude, biology and reproduction and viability come from two distinct types of sources: human demographic studies and controlled experiments on non-human animals. Studies demonstrating a relationship between altitude and human fertility have been carried out by James (1966) and Heer (1967) and between altitude and early mortality by Lichty et al. (1957), Grahn and Kratchman (1963), and Mazess (1965). The implications derived from these

investigations are that the human organism is at greater risk *in utero* and *post partum* at high altitudes. Experimentation in the laboratory on various non-human animals and observations in the natural setting have provided evidence that high altitude affects reproductive biology and thus plays an important role in influencing population growth and demographic balance. As one social demographer points out, "based on studies in actual or simulated altitude environments, the natality-depressing effects of altitude seem to be related to circulatory system adjustments to hypoxia, to the function of the hypothalamic and endocrine systems, to germ cell production to copulation, to gestation, to birth weight and to early mortality" (De Jong, 1967 : 8). If altitude has such a pronounced effect on reproductive organ systems and their functioning, fertility should be affected. Therefore, it would not be unrealistic to assume some genetic adaptation (i.e., selection) in a population living at high altitude (McClung, 1967). Neel suggests that "fertility is to some extent genetically determined ... natural selection is therefore to some extent involved in fertility" levels and differentials between populations (1958 : 50). The effect of natural selection on the net fertility of a population has been illustrated by Fisher who has shown mathematically that if a population contains 3% individuals of a (genetically conferred) high fertility and 97% of a low fertility, within 10 generations the former will comprise 97% of the population (Neel, 1958 : 50). Nuñoa certainly conforms to a reproductive pattern of a population undergoing natural selection. The sample demonstrates a high fertility with a concomitant high mortality. The former is a partial consequence of continuous exposure throughout the reproductive

span for the majority of females in the sample. In the light of the high perinatal, and assumed in utero mortality[13] it would appear that this is a highly fecund population. When we compare this population's fertility to that of the colonial Spaniards and other intrusive lowlanders and consider the effect of hypoxia on reproductive biology the manifest differentials in reproduction and viability at term imply a degree of variation in genetic potential to cope with the high altitude environment. The intent of this thesis is not to state that there is a genetic etiology. This awaits further research; but Neel, Fisher and others have put forth arguments supporting a relationship between this type of population's reproduction, gene pool and the vagaries of the environment.

Evidence that high altitude and hypoxia affects postnatal mortality is demonstrated by the prevalence of respiratory complications (with a probable combined pulmonary-cardiovascular etiology) reported as cause of death in the Nuñoan sample and Andean highlands of Peru at large. Thus it would appear that the high wastage is a function of hypoxia, as well as lack of proper medical facilities. This has evolutionary implications for the population in terms of general viability throughout the life span and is the subject of part of the investigation of which this demographic study forms a section.

Notwithstanding the influence of high altitude on the mechanics of reproductive biology and general viability is the effect on the

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13. The number of reported miscarriages is lower than expected for even a Western society and world averages (U.N., 1954) and is hardly credible in the light of the effects of hypoxia on reproductive biology - maternal and foetal.

reproductive span in males and females. Baker et al. (1965) have shown that the Nuñoan population lags behind U. S. whites in physical growth and development. The late age at first pregnancy (as compared with other non-Western societies, Nag, 1962) may be a manifestation of this phenomenon, i.e., a retardation in development of the male and/or female reproductive systems. Even within the sample there is a significantly later age at first pregnancy in the higher focal subsample. There is not much evidence to support the thesis that the onset of menopause is earlier in Nuñoa and most high altitude populations, although this is a distinct possibility. Cruz-Coke (1967) suggests that the onset of menopause was 1.5 years earlier in a highland sample of Chileans as compared to a lowland sample. Nonetheless, it appears that a less than normal reproductive span by world norms is probable for Andean highlanders. In the light of the Nuñoan sample's high fertility this also implies an extremely high fecundity. In general, in order to maintain population stability under the stress of high altitude ecological agents and other effects on the mechanics and length of reproduction this population has made adequate adaptations, although the etiology of these adaptations can only be surmised at present.

Sex Differentials

The most extraordinary phenomena observed in this sample are the differentials in reproduction and viability of males and females. The SSR for the total sample was 124, one of the highest yet recorded, and the surviving sex ratio was 129. Examination of the post-menopausal

sample showed an SSR of 113 and surviving sex ratio of 146! The higher surviving sex ratios are a result of a higher net female mortality throughout the lifespan from birth through adulthood. Both the high SSR and higher female mortality are unusual in comparison to world norms.

It is believed that at conception the primary sex ratio is much higher than at birth (U. N., 1954; Colombo, 1958, and many others). In fact, this value may be as high as 300; the U. N. (1954) reports values of 224 in the first month with a steady decrease in sex ratio until term. If this is true, then some factor or factors must be reducing *in utero* male mortality as compared to female mortality or increasing net female mortality prior to parturition. What these factors may be and their mode of operation on populations reporting unusual sex ratios is the subject of much conjecture at present. At least twenty-five different agents[14] have been suggested as factors influencing the sex ratio in Man and other mammals. (see Appendix C). Several pertinent factors shall be discussed *vis à vis* the Nuñoan sex differentials in reproduction and viability:

1. Sociocultural milieu.
2. Maternal age and parity.
3. Genetic systems, radiation and immunological factors.
4. Hypoxia.

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14. An extensive bibliography of studies on various agents affecting the sex ratio may be found in the papers by Cohen *et al.* (1956) and Kirby *et al.* (1967). Refer to Appendix C for a list of some of the more important of these characteristics (as derived from the above two sources.)

It is impossible to accurately assess the effect of the socio-cultural milieu on the high sex ratio and high female mortality. Comparable data on similar societies are lacking, and the vital statistics surveys and censuses of Peru show such inconsistency from year to year and with expected norms, that these data do not provide an adequate demographic background against which to compare Nuñoa.[15] The vital statistics survey of the Puno-Juliaca urban area (1962-1963) showed similarity in SSR, but the computation of SSR's by altitude (from vital statistics surveys or urban areas, 1963) did not show a rise in SSR with altitude. In fact, the SSR's of areas over 10,000 feet (3050 m) above sea levels were close to the norms for the nation of Peru. The manifest differences between the Nuñoa, Juliaca and Puno area and the rest of the high altitude areas of Peru (which are in the same geographic zone) may reflect differentials in ethnic group and sociocultural parameters (as well as ecological zones). It is certainly conceivable that the altiplano Indigena possesses genetic differences that affect the sex ratio as well as fertility in this harsh ecological zone.

Analysis of data collected in "westernized" societies have revealed a relationship between maternal age and sex ratio (Myers, 1954; Takahashi, 1954; Novitski et al., 1958; Montagu, 1962). It has been found that as age of the mother increases the primiparous SSR decreases. The reasons for this phenomenon are obscure and open to controversy (e.g., paternal

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15. As an illustrative example, the crude death rate is reported as 37.6 in 1953 (U.N., 1955) but in 1960-1965 is quoted as varying between 12 to 14 (U.N., 1967). Needless to say, this value is close to the norms for modern Western nations - but Peru has a high Indigena population living at high altitude with a known high mortality rate, and it is therefore suspect.

age may be a factor), but one hypothesis is that this may be a function of age changes in the uterine environment causing a reduction inthe primary sex ratio (i.e., differential selection rates for XX and XY zygotes at conception or during nidation). Also, it has been established that there is a decrease in SSR with succeding births (ibid.). There is a possibility of a causal relationship between these two phenomena. Due to the smallness of the sample it was not feasible to run an r-correlation in primiparous SSR and age of mothers. However, the primiparous SSR (115) was less than the mean (124) and only the SSR for the second birth was lower (107).[16] Thus, it appears that Nuñoa is inconsistent with Western (and purportedly world) norms for these two phenomena.

There is evidence to support the thesis that exposure to X-ray and hard radiation affect the SSR by the creation of X-linked lethal mutants (Schull et al., 1958; Scholte et al., 1964; Thompson and Thompson, 1966). When both parents are exposed to radiation, SSR values are found to be reduced. This is apparently a result of higher comparative male death rates in utero due to the fact that in males X-linked recessives are expressed as if they were dominants (the Y-chromosome is non-homologous with the X). The Nuñoan population is exposed to five to six times as much cosmic radiation as those living close to sea level. The cosmic radiation at 13,200 feet (4000 m) above sea level is nearly 200 mr/year (Cruz-Coke, Cristoffanini et al., 1967 : 423), while cosmic radiation at sea level is about 33 mr/year (Grahn and Kratchman, 1963). The total

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16. Actually, the SSR for the fourth birth is 114, but this is not significantly different. All the rest were higher.

environmental radiation (including terrestrial) in the states of Ohio, Indiana, Illinois and Wisconsin is 103 mr/year, of which 37 mr/year is of cosmic origin (ibid.). The amount of terrestrial radiation in the district of Nuñoa is not known at present, but it may be high due to the nature of the geological faulting (and instability) of the altiplano region. It is probable that total environmental radiation is at least three times that found at sea level. Assuming the end of the reproductive span at 45 years of age the Nuñoan has been exposed to about 13 r. It is known "that a given radiation exposure, delivered over a long period of time, produces less biological effect than when delivered over a long short period of time" (Comar, 1962 : 344). However, there is a partially cumulative effect to radiation on somatic and genetic biology and although comparative data are lacking this low level radiation may affect genetic systems. Thus, if there is any effect of radiation on the sex chromosomes, a low rather than a high SSR would be expected, unless some co-adapted gene systems had evolved to alleviate a low SSR. At the present, the effect of radiation on genetic systems and the sex ratio must remain in the realm of speculation.[17]

An interesting hypothesis regarding immunological systems and the primary sex ratios and SSR's has been recently put forward by Kirby et al. (1967). He and his colleagues have observed that in laboratory mice "zygotes that are antigenically dissimilar from the mother are favored at implantation (nidation)" (ibid. :139). Therefore, in consanguineous

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17. There is probably not sufficient environmental radiation to affect fertility since it takes at least 150 r to induce temporary sterility (Comar, 1962).

marriages it would not be unusual to find high SSR's since the antigens carried on the Y-chromosome would make the male more immunologically dissimilar. This appears to be true for numerous samples of first-cousin marriages[18] and Bonné'(1963) reports this phenomenon for the highly inbred Samaritans of Palestine. However, normal SSR's have been reported for a sample of consanguineous marriages in Chicago (Slatis et al., 1958) and Eaton et al. (1954) found no evidence of abnormal SSR's in the inbred Hutterites. Although it is not possible to determine if the Nuñoa population is highly inbred and the SSR values are a result of consanguineous marriages, it is conceivable that there may be a relationship between altitude and immunological systems in utero that affect sex ratio. It has been suggested that there are genes directly involved in the determination of sex ratio that operate via the endocrine system (Bernstein, 1951, 1952). In other words, the more of a specific sex hormone produced the greater the chance for selection of the zygote of that sex during conception. At least in lowland females journeying to high altitudes there is a reduction in estrogenic hormone production (Donayre, 1966) which might affect the sex ratio, but low estrogen levels have not been established for altiplano Indigena women.

The thesis that there is an increase in SSR with an increase in altitude due to lowered blood pH (and assumed uterine acidity) is based primarily on laboratory rats subjected to experimental hypoxia (see McWhirter, 1956). As it stands, this theory is probably not relevant to

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18. Marcallo et al. (1964) report unusually high SSR's by parity of inbred Brasilian families as compared with outbreeding families.

the altiplano Indigena since it has been shown that the highlander's blood pH is similar to sea level norms (Mithoefer, 1966). However, it has been suggested that malformations of the CNS which are a chief cause of mortality in utero "affect more often the female sex."[19] Thus, it is possible hypoxic induced abnormalities of the CNS may cause the high SSR found in the Nuñoan population. The higher net female mortality has been discussed above, but it cannot be totally explained by death during child bearing, though this may be important (see Chapter III). There appears to be a strong relationship between total mortality and hypoxia.

It must be admitted that, although numerous ecological and biological theses have been proposed to explain this phenomenon involving sex ratio and differential viability, the actual mechanisms involved still remain unclear. Nevertheless, the evidence that has been presented tends to support the thesis that there is a genetic as well as environmental component to sex ratio phenomena (Bernstein, 1951, 1952; Fisher, 1958; Trichopoulos, 1962).

Conclusions

It may be concluded that this population has adapted to the exigencies of life at high altitude in terms of demographic resolution. In order to maintain population stability and temporal continuity in the face of high altitude-specific environmental pressures this population maintains a high fertility to offset the wastage of a high mortality. The latter appears to have manifest hypoxia-induced components. Although

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19. Colombo (1957 : 201) referring to bibliographic sources in an earlier paper of his (Colombo, 1955).

human biological adaptation throughout the life span from conception to late adulthood is severely stressed and viability as compared to lowland Western populations is reduced, fertility variables suggest that this population is highly fecund. The parity span is short and a large number of live individuals are brought to term. In the light of the evidence of the detrimental effect of hypoxia on normal uterine development, this is somewhat remarkable, and worthy of further investigation. It is still not known if this adaptation is genetic in nature or entirely due to acclimatization. Since this population had lowland living ancestors, there is much evidence to support a case for genetic as well as acclimatizational adaptation. It is not yet possible to conclude that this population is typical of highland populations since there is a dearth of comparative studies and the sex ratio phenomenon is difficult to explain. The implications of this population's reproduction and viability to the biology of human adaptability, evolutionary, and genetic theory are worthy of further research.

Summary

The present study concerned itself with an analysis of the demographic parameters of a highland Peruvian Indian population. The major focus of this investigation was to determine the degree of adaptation of this population, *via* its reproductive capabilities, to the stresses imposed by residence at high altitude, i.e., hypoxia, cold and radiation. Therefore, the results were discussed in terms of ecological theory and the implications for human genetics and evolutions outlined.

The case for assuming hypoxia as the primary stress agent on human biology rests upon results derived from laboratory animal experiments and from the evident physiological changes that occur in lowlanders who are taken to high altitude. Indirect evidence of the effect of hypoxia on reproductive biology comes from the demonstration of suppressed fertility levels in sea level native Man and domestic animals living at high altitude. This phenomenon has further been elucidated by recent demographic studies in the Andean area by two social demographers. James (1966) and Heer (1967) have investigated human fertility by altitude and agreed that differentials between the Spanish and Indigena populations were a correlate of altitude of residence and not socio-economic factors as inferred earlier by Stycos (1963). Since culture can provide techniques to ameliorate the altitude attendent stresses such as cold and solar cosmic radiation, but not hypoxia, it would appear that this would be the major stressor - as postulated above.

The particular region under study (Nuñoa) and its people (Indigena) were selected for study for several reasons. The population has been long resident in the altiplano (at least several thousand years) and, thus, continually subject to the stresses of high altitude. This is a simple peasant society and an isolate from the standpoint of genetics and culture, and it has adapted to this harsh ecosystem in the sense that it has maintained a continuous "community" throughout many generations. The analysis undertaken by Stinner (1967) provides more evidence supporting the thesis of the inherent sociocultural uniformity of this population and its insularity from modern Peruvian Society.

The sample utilized for the demographic analysis consisted of 136 "married" women, 133 of whom had borne live children - totaling 603 offspring. The sample was drawn from three different residential community sites (town, ayllu, and hacienda) that were to be found within the district of Nuñoa. The two former community types were situated in the valleys and low plateau of the district at altitudes of about 13,200 feet (4000 m) above sea level. The haciendas were situated in this lower region and on the district uplands at altitudes between 14,200 feet (4320 m) and 14,900 feet (4550 m) above sea level. Thus, the sample was further distinguished by two focal populations separated by a mean differential of 1000+ feet (305+ m) in altitude of residence.

Data were collected from the women on their age, marital status, number of offspring born alive, their sex and their age and/or the number of offspring who had died after birth and the cause and age at death. From these data, demographic statistics were computed (and estimated in some cases) pertinent to an analysis of reproduction, viability and adaptation of this high altitude population.

Those women reporting ages 45 years and over were examined as a subsample in order to elicit "completed family" demographic statistics (e.g., total fertility). It was assumed that women of this sample were nearly all post-menopausal. Analyses were also carried out on differentials in reproduction and viability between the three subsamples by residential site and between the subsamples representing the two focal populations situated at different altitudes within the district.

Age data on the offspring were held to be of questionable validity and the ages as reported by the older women of the sample were also

considered to be of dubious validity. Therefore, the statistics presented by age were considered as tentative as well as those statistics estimated by the author.

It was found that the sample of women showed a mean age (ca. 36 years) slightly over one half of the way through the minimum reproductive span (ca. 19 to 45 years) estimated from reported age at first pregnancy and assuming the onset of menopause at 45 years. The mean of the reported age at first pregnancy was late by the norms for most non-industrial non-Western societies (ca. 20 years). There was a statistically significant differential (at the .05 level) between the two focal populations by altitude. The age at first pregnancy at the high altitude _haciendas_ was over 1.5 years later than the low altitude _haciendas_, _ayllus_ and town combined. There were no significant differentials by residency type alone, though the age at first pregnancy in the town was about a year earlier than in the two rural sites. The post-menopuasal sample reported a mean age at first pregnancy of 20 years which was the norm for the district. The child-woman mean for the district was 4.5 and the subsamples demonstrated an internal consistency at levels equal or close to this figure.(town and low altitude - 4.5, _ayllus_ - 4.7, _haciendas_ - 4.4, and high altitude - 4.4). The surviving child-woman mean was 3.2 and, again, no significant differentials were to be found within the district, though the town's value was 2.9 which is low considering the earlier age at first pregnancy.

The most noteworth results from the sample are the high SSR and the even higher surviving sex ratio that were found. The SSR was 124 _vs_ a surviving sex ratio of 129. The SSR was similar to that of the

Puno and Juliaca districts, but was not consistent with the Peruvian altiplano at large, 104. Within the district the lowest SSR was recorded in the "high" altitude subsample, 115. However, the surviving sex ratio was 126, close to the district norm.

The trend throughout the district was that of a greater net female mortality. The onset of this phenomenon appeared to be after the first year of life - but since the amount of unreported information on age (and cause) of death is large and the reported mortality is of a dubious nature, this must be considered as speculative. The differential mortality by sex was even more pronounced when we examinedthe offspring data from the post-menopausal sample. The result was a surviving sex ratio (146) much higher than the SSR (113)! This would support the thesis that throughout their lifetime females are at a greater risk than males. How much of this is incurred during the reproductive span is a matter that should be investigated more thoroughly.

In terms of exposure and fertility this population approached maximum limits as postulated by Weiner (1964). The total fertility (completed family size) was nearly 7 and the parity span was about 3 years vs a minimum for a highly fertile population of 2.5. The thesis that there was a high continuous reproduction was borne out by the significant correlation between (1) age at first marriage and the exposure index, (2) duration of marriage and child-woman mean, and (3) the computation of a regression line of age of mothers married at present and resultant children and its extrapolation to post-menopause women and approximation with total fertility as reported by the post-menopausal women.

Thus, this population has a high fertility and apparently substantial mortality. Such a demographic phenomenon may be typical of highland Indigena populations since Nuñoa appears to be similar in many features of its reproductive capabilities and in resultant postnatal viability to two Andean communities (Huallatire, Chile and Cerro de Pasco, Peru) which have been studied by Cruz-Coke (1967) and Sobrevilla (1967), respectively. The appearance of what appears to be an unusual sex ratio throughout the life cycle may be typical of other highland populations, but this must be studied in more detail.

It is important to note that comparing Nuñoa with world norms and in comparison within the district there appears to be a higher female mortality with increasing altitude. The etiology of this phenomenon remains obscure, but it may be due to a variety of biological and climatological factors indigeneous to life at high altitude.

The opinion of this author is that this population is subject to a greater climatological stress than most human populations. Whether or not the mode of adaptation (and this population has adapted since the high fertility evident at present more than balances the mortality) has been through selection operating on the gene pool or through inherent genetic plasticity, i.e., acclimatization, is not possible to say as yet. More demographic research must be carried out on like and unlike populations at low and high altitude. At the same time, genetic and phenotypic parameters must be assayed to determine the mode of adaptation of high altitude populations.

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APPENDIX A

Pertinent Information Derived From Informants in IBM FORMAT

Master Card MC

Columns	Information	Parameters, significance
1- 2	Card identification	MC
3- 6	Subject number	nnnn
7- 9	Family number	nnn
10-11	Site number	01=Hcda Barreda (134) 02=Ayllu Sincata (131) 03=Ayllu Acclamayo (131) 04=Hcda Waychu (149) 05=Hcda Imatuta (147) 06=Hcda Naqtuiyri (142) 07=Nuñoa (132) 08=Hcda Amcalla (142) 09=Hcda Chillihua (147) 10=Hcda Istarata (134) 11=Hcda Sipaspugi (134)
12-14	Altitude (in hundreds of feet)	(see corresponding numbers above)
15-16	Initials of interviewer	XX
17-20	Date survey taken	0864 e.g., Aug. 1964
21	Sex of subject	M or F
22-24	Estimated age	nn D=Days M=Months Y=Years
25-27	Statistical age	nn

DATA CARD 07 MARITAL INFORMATION CARD

IBM COLUMNS	POSSIB	INFORMATION
1- 2	07	Subject number
3- 6		Subject number
7	Y or N	Living with anyone at present = are you married
8-11		Subject number presently married to
12		Total number of marriages
13		Type of marriage
14-15		Age when married
16-17		Duration of marriage
18-19		Number of children
20-26		(This data is for previous marriage - repeat items 13-19)
27-28		Reason for termination
	01	Death
	02	Separation - no reason
	03	Infidelity - adultery
	04	Jealousy
	05	Economic reasons
	06	Character - fighting, no good
	07	Other
29-37		This data is for previous marriage antedating 20-28 Repeat items 20-28

DATA CARD 08 — FERTILITY DATA

IBM COLUMNS	POSSIB	INFORMATION
1- 2	08	Card no.
3- 6	nnnn	Subject number
7- 8	nn	Total number of children (living & dead)
9-10	nn	No. of living children
11-12	nn	No. of dead children
13	Y or N	Any adopted children
14-15	nn	No. of adopted children
16-17	nn	Age at first pregnancy
18	Y or N	Pregnant now?
19	n	How many months
20	Y	If miscarriage preceded first child
21-21	M or F D	Sex of first child
22-24	nn M Y	Age of first child
25	1 or 2	1 if living, 2 if dead
26-27		If dead, cause of death:
	01	Gastrointestinal
	02	Respiratory
	03	Asusto (fright or shock?)
	04	Recognizable childhood disease - measles
	05	Mumps
	06	Whooping cough
	07	Accident
	08	Other
28-30		Age at death
31	1 or 2	1 if single, 2 if twin
32-43		Repeat for second child
44-55		Repeat for third child
56-67		Repeat for fourth child

DATA CARD 09 FERTILITY DATA

IBM COLUMNS	POSSIB	INFORMATION
1- 2	09	Card No.
3- 6	nnnn	Subject No.
7-18		Child information fifth child
19-30		Sixth child
31-42		Seventh child
43-54		Eighth child
55-66		Ninth

AND SO ON FOR CARD NO. 10, 10th - 14th CHILD

APPENDIX B

Statistical Tests and Formulae

1. The Standard Deviation (SD).

$$SD_i = \sqrt{\frac{\Sigma Xi^2 - (\Sigma Xi)^2 / N}{N - 1}}$$

2. The T-test

$$t \quad t = \frac{|\bar{X}i - \bar{X}j|}{\hat{\sigma}} \qquad \text{where } \hat{\sigma} = \sqrt{\frac{SDi^2}{Ni-1} + \frac{SDj^2}{Nj-1}}$$

Degrees of freedom: $df = \dfrac{\hat{\sigma}^4}{\frac{SDi^2}{(Ni-1)(Ni+1)} + \frac{SDj^2}{(Nj-1)(Nj+1)}}$

3. The Chi-square test (4-cell, df = 1)

a	c
b	d

$$\text{Chi-square} = \frac{(|ac - bd| - \frac{1}{2}N)^2 N}{(a+b)(a+c)(b+d)(c+d)}$$

where $N = a + b + c + d$

4. The r-correlation (PSU LIBRARY PROGRAM N-COR)

$$r_{xy} = \frac{N\Sigma XY - \Sigma X \Sigma Y}{[N\Sigma X^2 - (\Sigma X)^2]\,[N\Sigma Y^2 - (\Sigma Y)^2]}$$

5. The equation of the least square line

$$y - \bar{y} = r_{xy} \left(\frac{SD_y}{SD_x}\right) (x - \bar{x})$$

Taken from Theory and Problems of Statistics by Murray R. Spiegel, copyright 1961 by the Schaum Publishing Company : New York.

APPENDIX C

Factors Reported to Influence the Human Sex Ratio

Biological Factors

A Sex of the first born and parity
B Family size
C Age of parents at time of conception
D Ancestral longevity
E Physiological and biochemical factors
  1. Action of genes *via* endocrine system
  2. Immunological factors between foetus and mother
  3. Blood groups
  4. Blood pH
  5. General physique, skin color, etc.
  6. Inbreeding
F Race
G Time of conception during the menstrual cycle
H Frequency of intercourse

Environmental Factors

A Seasonal and monthly variation
B Geography
C Climate (e.g., altitude and blood pH)
D Radiation

Sociocultural Factors

A Illegitimacy
B Parental occupation
C Socioeconomic status and environment
D Urban *vs* rural habitation
E War and other psychological stress periods
F Other differences of a sociocultural nature

APPENDIX E

Summary of Unpublished Data on Maximum Oxygen Consumption Testing at the Nuñoa Laboratory

Abbreviations Used in the Appendix that Follows:

STPD: Standard Temperature and Pressure

$\dot{V}_{O_2}$: The STPD volume for oxygen intake per unit time.

O_2/Wt.: The oxygen intake per unit body weight.

$\dot{V}_E$: The volume of the expired air per unit time. V_E is given at standard temperature and pressure

Vent. Eq.: Ventilation volume per unit oxygen uptake during a given time period. This measure reflects the relative efficiency of the ventilation in supplying oxygen.

O_2/Pulse: The oxygen intake per heart beat per unit time.

N: Total number of individuals examined

n: Number in sub-samples. Appears where observations are less than the total N.

S.D.: Standard Deviation for small sample size.

NOTE: The tables that follow represent the group differences that exist for maximal exercise performance at altitude. All four groups were tested under similar conditions at the field laboratory in Nuñoa, Peru. Maximal Exercise is a test involving progressively increased work loads. The subjects start at a moderate work load, which is increased periodically by increasing the breaking resistance on an ergometer. The stopping point is determined by the subjects inability to continue the exercise (See E.R. Buskirk 1967).

The groups are as follows: Nuñoan (highland Quechua living at high altitude in Nuñoa), Sea Level Quechua (living in Mollendo on the West Coast of Peru), U.S. Non-Athletes, White males (consisted mainly of professors and students not directly involved with athletics), and U.S. Athletes (University students from The Pennsylvania State University who directly were envolved in intercollegiate sports).

Nunoan Males Tested at Altitude
Maximal Exercise Test
Total N = 25

Variables	Mean	S.D.
Weight (kg)	56.60	5.46
$\dot{V}_{O_2}$ (l/min.)	2.77	3.64
Heart Rate (B/min.)	170.58	9.01
$\dot{V}_E$ (l/min.)	75.15	14.20
Breath (Br/min.) n = 12	54.50	6.01
O_2/Wt. (ml/min./kg)	49.07	5.80
Vent. Eq.	26.29	2.38
O_2/Pulse (ml/beat) n = 12	15.66	2.17

Sea Level Quechua Males Tested at Altitude
Maximal Exercise Test

	1 s t W e e k N = 10		4 t h W e e k N = 10	
Variables	Mean	S.D.	Mean	S.D.
Weight (kg)	61.35	10.83	61.17	9.92
$\dot{V}_{O_2}$ (l/min.)	2.63	0.228	2.67	0.229
Heart Rate (B/min.)	180.6	12.44	190.2	14.26
$\dot{V}_E$ (l/min.)	84.01	8.65	87.48	6.71
Breath (Br/min.)	55.85	6.15	55.44	6.41
O_2/Wt. (ml/min./kg)	43.62	5.85	44.49	6.56
Vent Eq. n = 8	31.64	2.76	n = 7 33.50	3.58
O_2/Pulse (ml/beat) n=8	14.49	1.92	n = 7 14.11	1.78

U.S. Athletes, White Males, Tested at Altitude
Maximal Exercise Test

Variables	Mean	S.D.		Mean	S.D.
	1 s t W e e k N = 5			2 n d W e e k N = 6	
Weight (kg)	67.13	5.28		67.67	4.90
$\dot{V}_{O_2}$ (l/min.)	3.28	.264		3.15	4.04
Heart Rate (B/min.)	175.00	13.78		---	--
$\dot{V}_E$ (l/min.)	96.78	6.91		100.3	10.81
Breath (Br/min.)	---	--		---	--
O_2/Wt. (ml/min./kg)	48.83	2.11		46.55	4.70
Vent. Eq.	29.20	3.53		30.58	4.03
O_2/Pulse (ml/beat)	17.81	2.13		---	--
	3 r d W e e k N = 6			4 t h W e e k N = 6	
Weight (kg)	67.68	4.90		67.68	4.90
$\dot{V}_{O_2}$ (l/min.)	3.111	0.37		3.14	0.252
Heart Rate (B/min.)	---	--		172.40	10.57
$\dot{V}_E$ (l/min.)	102.25	11.24		104.72	6.66
Breath (Br/min.)	---	--		---	--
O_2/ Wt. (ml/min./kg)	46.15	6.17		46.59	4.27
Vent Eq.	31.82	3.37		33.84	1.96
O_2/ Pulse (ml/beat)	---	--		18.12	0.99
	5 t h W e e k N = 5			6 t h W e e k N = 6	
Weight (kg)	69.13	3.76		67.67	4.90
$\dot{V}_{O_2}$ (l/min.)	3.31	0.34		3.39	0.37
Heart Rate (B/min.)	---	--		---	--
$\dot{V}_E$ (l/min.)	105.70	6.65		109.4	8.40
Breath (Br/min.)	---	--		---	--
O_2/Wt. (ml/min./kg)	47.94	4.37		50.22	4.95
Vent. Eq.	30.04	2.99	n = 4	31.14	1.57
O_2/Pulse (ml/beat)	---	--		---	--
	7 t h W e e k N = 6			9 t h W e e k N = 3	
Weight (kg)	67.68	4.90		64.96	5.06
$\dot{V}_{O_2}$ (l/min.)	3.512	0.343		3.23	0.177
Heart Rate (B/min.)	164.5	14.64		161.7	14.50
$\dot{V}_E$ (l/min.)	110.08	9.75		101.33	11.58
Breath (Br/min.)	---	--		---	--
O_2/Wt (ml/min./kg)	52.14	6.54		49.96	6.19
Vent. Eq.	29.20	3.53		31.12	2.97
O_2/Pulse (ml/beat)	17.81	2.13		20.05	1.42

U.S. Non-Athletes, White Males, Tested at Altitude
Maximal Exercise Test

Variables	Mean	S.D.		Mean	S.D.
	1 s t W e e k N = 11			3 r d W e e k N = 8	
Weight (kg)	74.39	8.14		72.38	8.71
$\dot{V}_{O_2}$ (l/min.)	2.71	0.49		2.52	0.389
Heart Rate (B/min.) n = 9	178.78	15.25	n = 2	157.00	9.90
$\dot{V}_E$ (l/min.)	89.65	13.73		86.64	10.58
Breath (Br/min.) n = 4	62.25	16.36		---	--
O_2/Wt. (ml/min./kg)	36.27	4.19		35.06	5.16
Vent. Eq. n = 9	30.88	1.18		32.18	5.12
O_2/Pulse (ml/beat) n = 9	16.67	1.56		---	--
	4 t h W e e k			6 t h W e e k	
Weight (kg)	73.04	8.14		72.15	11.41
$\dot{V}_{O_2}$ (l/min.)	2.78	0.339		2.74	0.447
Heart Rate (B/min.)	173.30	19.44		---	--
$\dot{V}_E$ (l/min.)	90.94	11.75		100.66	15.17
Breath (Br/min.) n = 4	58.63	11.03		---	--
O_2/Wt. (ml/min./kg)	38.10	3.35		38.19	5.22
Vent. Eq.	30.49	2.76		35.58	1.06
O_2/ Pulse (ml/beat)	16.30	2.06		---	--
	7 t h W e e k N = 6			9 t h W e e k N = 5	
Weight (kg)	74.14	8.27		69.79	9.83
$\dot{V}_{O_2}$ (l/min.)	2.87	0.247		2.79	0.40
Heart Rate (B/min.)	163.33	16.97		165.20	16.04
$\dot{V}_E$ (l/min.)	100.25	10.82		94.22	13.47
Breath (Br/min.)	---	--		---	--
O_2/Wt. (ml/min./kg)	39.05	1.48		40.03	3.91
Vent. Eq.	33.74	2.54	n = 4	32.66	2.52
O_2/Pulse (ml/beat)	16.99	2.67	n = 4	16.93	2.56
	1 9 t h W e e k N = 4				
Weight (kg)	67.14	7.57			
$\dot{V}_{O_2}$ (l/min.)	2.34	0.297			
Heart Rate (B/min.)	---	--			
$\dot{V}_E$ (l/min.)	82.95	13.01			
Breath (Br/min.)	57.00	8.04			
O_2/Wt. (ml/min./kg)	35.01	4.67			
Vent. Eq.	35.22	1.61			
O_2/Pulse (ml/beat)	---	--			

APPENDIX F

Exercise Performance at High Altitude (4000 meters) in Peru

Richard B. Mazess

EXERCISE PERFORMANCE AT HIGH ALTITUDE (4000 METERS) IN PERU

RICHARD B. MAZESS

Department of Anthropology and Radiology
University of Wisconsin, Madison, Wisconsin

INTRODUCTION

It is well recognized that both acute and chronic hypoxia result in a diminution of exercise performance (15,25). This has been demonstrated clearly by the reduction of maximal oxygen intake, decrease of endurance in submaximal work, and prolongation of recovery from exercise in altitude newcomers. Also exercise heart rates and ventilation are increased at altitude. In contrast, the extent to which sustained exposure and acclimatization modify exercise performance remains largely unknown. Presumably the fairly extensive human populations living and working permanently at elevations above 3000 meters are fully acclimatized to the ambient hypoxia, and in fact there have been some suggestions that certain populations of altitude dwellers, notably Andean Indians (20,26), possess distinctive adaptive responses to hypoxic stress. Natural selection operating over many generations could produce a race of altitude adapted man. Many casual observers, mountaineers, and scientific investigators have noted an apparent ease of exercise performance in residents of the Andes and the Himalayas compared to the labored efforts of altitude newcomers. The Andean Indian has been described as having a greater endurance, a higher aerobic capacity, and even a greater mechanical efficiency than sea level dwellers. Long-term acclimatization and genetic adaptation may be important to exericse performance at altitude, but there is only

minimal experimental information on the responses of altitude residents, and even less information is available on lowlanders sojourning for months or years at altitude. This report describes some major responses of various groups of trained and untrained altitude residents and sojourners during both maximal and submaximal exercise. Previous studies dealing with the relative effects of altitude on residents, sojourners, and newcomers sometimes used non-uniform testing conditions and procedures, and employed heterogenous samples differing greatly in genetic and developmental background, morphology, physical condition, and extent of altitude exposure. This preliminary examination was undertaken to control for some of these factors in order to better evaluate the nature and extent of racial and acclimatizational influences on exercise responses of human groups at altitude.

METHODS

Methods: Exercise experiments were done in Puno (3830 meters; P_B = 485 mm Hg) and in Nuñoa (4000 meters; P_B = 473 mm Hg) in the southern Peruvian highlands. The basic methods and procedures have been described (7,8,22). A brake-type bicycle ergometer was used for exercise testing; pedalling frequency was maintained close to 60 rpm and the revolutions pedalled were recorded. An open-circut system was used for measuring gas exchange; the subject breathed monitored room air through a high-flow valve and the expired air was collected in plastic Douglas bags. Gas volume was measured with a dry gas meter and oxygen content with a Beckman E-2 paramagnetic analyzer.

Procedures: Subjects rested at least one-half hour before exercise testing. A short (about 5-minutes) progressive workload test was used for maximal capacity. The initial workload was 1050 kpm/min; this increased by about 165 kpm/min every minute after the second minute of work, and concomitant gas collections and heart rate determinations were taken. The test-retest correlation for maximal oxygen intake was 0.94. In addition, a longer (30-minutes) test at an essentially constant workload of 850 to 900 kpm/min was done. Oxygen intakes in this test amounted to from about 75 to 95% of the subjects aerobic capacity. Gas collections and heart rates were taken at five 1-minute intervals in the course of the test, and also for 5 minutes during recovery.

Subjects: Young male university students, permanently resident at high altitude, were tested in Puno. One group of 13 students was largely of

southern European descent (WHITE STUDENTS) and the other group consisted of 10 students of Peruvian Indian descent (INDIAN STUDENTS). The INDIAN STUDENTS engaged in athletic activities to a greater extent than the WHITE STUDENTS , but the groups were otherwise similar in background of altitude exposure and morphology. Physically conditioned young males from an institute for physical education teachers were also tested, but at the slightly higher elevation of Nuñoa. Seven of these subjects came from low altitudes of from 0 to 2500 meters (LOWLAND TRAINED), while another group of 9 subjects were permanent residents at altitude (HIGHLAND TRAINED). Both groups of TRAINED subjects had lived at the institute for 8 months prior to the experiments and hence shared a common background of nutrition and activity immediately prior to the study. Five highland Peruvian Indians from the town of Nuñoa (RURAL INDIANS) were also tested, as were a group of 5 sedentary U.S. whites (U.S. WHITES) who had been resident at high altitudes for from 4 to 16 months.

RESULTS

Physical characteristics: The characteristics of the six groups are given in Table 1. Noteworthy is the general similarity of the STUDENT and TRAINED groups. The latter groups were intermediate in body size to the small RURAL INDIANS and the relatively large U.S. WHITES. The large morphological divergence between whites from western societies and the rural altitude natives could complicate interpretation of exercise results in tests dependent on body size.

Table 1. Physical characteristics and responses during and after exercise.

	STUDENTS		TRAINED		RURAL	U.S.
	WHITE	INDIAN	LOWLAND	HIGHLAND	INDIAN	WHITES
[a]	13	10	7	9	5	5
A. Physical characteristics						
Age (years)	23.5	23.8	21.3	21.1	24.2	26.4
Stature (cm)	169	162	165	167	156	177
Weight (kg)	61.2	59.8	60.2	63.0	52.4	67.5
Hemoglobin (g/100ml)	18.4	18.2	18.2	19.1	17.8	18.7
Hematocrit (%)	51.7	49.7	51.2	51.1	50.8	50.9
Forced vital capacity (ml)	4744	4655	4878	5252	4426	5070
Maximal volunt. vent. (l/min)	180	169	206	214	153	241
B. Responses in maximal work						
Maximal oxygen intake (l/min)	2.62	2.79	2.78	3.03	2.58	2.52
Aerobic capacity (ml/kg/min)	42.8	46.8	46.2	48.2	49.2	37.4
Maximal heart rate (f/m)	186	188	194	193	185	170
Maximal ventilation (l/min)	146	143	165	162	151	172
Ventilation equivalent	55.9	51.2	59.3	53.6	58.6	68.2
Oxygen pulse (ml/beat)	14.1	14.8	14.3	15.7	14.0	14.8

[a] Hemoglobin and hematocrit were determined in small samples of finger blood; forced vital capacity and maximal voluntary ventilation (for 15-seconds) were measured on the Jones Pulmonor dry spirometer.

Table 1. (continued) Physical characteristics and responses during and after exercise.

	STUDENTS		TRAINED		RURAL	U.S.
	WHITE	INDIAN	LOWLAND	HIGHLAND	INDIAN	WHITES
C. Responses in submaximal work[b]						
Oxygen intake (l/min)	2.19	2.22	2.32	2.26	2.23	2.32
Mechanical efficiency (%)	21.1	20.9	21.4	21.8	20.6	20.9
Relative workload (%)	84.6	80.4	81.4	75.2	86.5	88.5
Heart rate (f/min)	168	178	176	173	174	144
Ventilation (l/min)	113	105	123	105	119	154
Ventilation equivalent	51.4	47.1	52.9	46.6	53.2	66.4
Oxygen pulse (ml/beat)	13.0	12.5	13.2	13.1	12.8	16.1

[b]Results on 3 RURAL INDIANS, 2 U.S. WHITES, and 4 LOWLAND TRAINED only. Mechanical efficiency calculated assuming 4.9 kcal per liter excess oxygen intake, and 426.7 kpm = 1 kcal.

Maximal exercise: Responses of the various groups are outlined in Table 1. The INDIAN STUDENTS had a somewhat higher aerobic capacity than the WHITE STUDENTS, but this difference corresponded to the group difference of activity background and conditioning. The other differences between these two STUDENT groups, for example in maximal heart rate or ventilation, were minimal and seemed to reflect the greater conditioning of the INDIAN STUDENTS.

There were also minimal differences between the LOWLAND and HIGHLAND TRAINED groups, and both groups had similar values for aerobic capacity, maximal ventilation, and maximal heart rate. The major group differences here were the higher oxygen pulse and lower ventilation equivalent of the HIGHLAND TRAINED. It is interesting that these TRAINED groups had an aerobic capacity only 5 to 10% greater than that of the STUDENT groups; the TRAINED groups also showed higher maximal ventilation and heart rate than the STUDENTS.

The aerobic capacity of the RURAL INDIANS was equivalent to that of the TRAINED groups. These RURAL INDIANS, however, had a maximal heart rate closer to that of the STUDENTS, while maximal ventilation was intermediate to that of the TRAINED and STUDENT groups. In comparison to the other permanent altitude residents the RURAL INDIANS had a relatively high ventilation equivalent in maximal work.

The U.S. WHITES had the lowest aerobic capacity of the six groups tested. These partially acclimatized subjects had a high maximal ventilation and a distinctly higher ventilation than the other groups. In contrast to the other groups, including the partially acclimatized LOWLAND TRAINED, the U.S. WHITES had a low maximal heart rate; the other groups had heart rates equivalent to those observed in maximal work at sea level. Four subjects in this group had been resident at altitude for only 4 to 7 months and these subjects had an average maximal heart rate of 165 f/min whereas the remaining subject of this group who had been at altitude for 16 months had a heart rate of 192 f/min.

Submaximal work: The mean values for the six groups are given in Table 1. The RURAL INDIANS and both groups of STUDENTS had similar workloads, and the oxygen intake during work consequently was similar for these groups. The U.S. WHITES and both groups of TRAINED subjects exercised at a slightly higher workload; the oxygen intakes of these latter groups were also alike, though higher than those of the STUDENTS and INDIANS. The calculated mechanical efficiency for work, based on the oxygen intake above the seated resting value during both work and the 5-minute recovery period, was very similar in all six groups (21.2%). The standard deviation for all subjects combined

was only about 1% and the coefficient of variation was about 5%. The TRAINED groups appeared slightly more efficient than the other groups, and subjects of Indian ancestry tended to be less efficient than those of white ancestry, but there was a narrow range of variation and the group differences were on the whole minimal.

Heart rate during work was significantly higher in the INDIAN STUDENTS than in the WHITE STUDENTS, and many of the INDIAN STUDENTS reached or exceeded "maximal heart rate" during this prolonged exercise. Both TRAINED groups and the RURAL INDIANS had heart rates intermediate to those of the two STUDENT groups. However, there were only minor group differences of oxygen pulse. The 2 U.S. WHITES tested showed a heart rate markedly lower than the other subjects, together with a very high oxygen pulse. These circulatory responses of the U.S. WHITES did not reflect any greater physical fitness since they had the lowest aerobic capacity.

Ventilation volume, and the ventilation equivalent, were both higher in the WHITE STUDENTS than in the INDIAN STUDENTS. Similarly the LOWLAND TRAINED had elevated values compared to the HIGHLAND TRAINED. The RURAL INDIANS, as in the case of maximal exercise, had a ventilation equivalent at least as high as that of the other groups of permanent residents. These differences were small, however, compared to the much greater ventilatory responses of the U.S. WHITES.

Heart rates during this prolonged heavy work did not appear to reflect the level of fitness with clarity since the less fit subjects in many cases had lower heart rates than subjects with a greater capacity. The relative workload ($\dot{V}_{O_2}$ as a percent of $\dot{V}_{O_{2max}}$) was used as an index of the severity of work for the individual and heart rate correlated poorly

($r = 0.4$) with this measure. In contrast ventilation was more closely associated with relative workload ($r = 0.76$) and the correlation was higher in the permanent residents. Group differences in ventilatory responses therefore reflected in part group differences of work capacity. Even considering relative workload, however, the LOWLAND TRAINED and U.S. WHITES tended to have ventilatory values above those of the residents.

DISCUSSION

Maximal exercise: One major group difference was the relatively low aerobic capacity, low maximal heart rate, and high maximal ventilation of the U.S. WHITES. Partially acclimatized altitude newcomers, both trained and untrained, frequently show a depressed maximal heart rate which progresses in severity over several weeks of exposure (2-12, 21,22, 27,32). Acute hypoxia does not produce heart rate depression in maximal exercises(30) and long-term acclimatization appears to eliminate all evidence of this depression since both permanent altitude residents, and persons sojourning for more than a few months, have maximal heart rates entirely comparable to those at sea level (13, 22-24, 31). Individual subjects in the four groups of permanent altitude residents included in this report had maximal heart rates of from 175 to 215 b/min. Kollias et al (22), using identical procedures, also found high heart rates in native Indians at 4000 meters, while lowland athletes and non-athletes had maximal heart rates of 165 and 161 b/min respectively after one to two months exposure. The aerobic capacities of the latter groups were very similar to those reported here for the comparable RURAL INDIANS, LOWLAND TRAINED, and U.S. WHITES. The relatively low aerobic capacity of altitude newcomers may be related to this lower maximal heart rate, and to consequent reduction of maximal cardiac output (21,27). Longer exposure and/or physical conditioning may eliminate some of this effect; for example the maximal heart rate and aerobic capacity of the LOWLAND TRAINED group after 8 months at altitude, were very similar to those of the HIGHLAND TRAINED. Failure to note improvement in the capacity of altitude newcomers over a month or two of exposure may not accurately indicate the potential improvements following longer periods of exposure.

It was unusual that the TRAINED groups had an aerobic capacity only 10% greater than that of the STUDENTS (47 vs 44 ml/kg/min) since at sea level the difference is more on the order of 20%. The small difference of inspired oxygen tension between the two testing locations (2 to 3 mm Hg) probably was not a significant factor. These university students had an aerobic capacity about 10% below that of comparable groups at low altitude, while the TRAINED groups had a capacity some 15 to 20% below expected sea level values. The relatively small difference in aerobic capacity between these physically conditioned and relatively untrained subjects suggests a disproportionately greater reduction of capacity in the trained subjects at altitude. Several studies have indicated that athletes and highly conditioned subjects have a greater reduction of aerobic capccity, and of endurance, in hypoxia than do sedentary persons (6-8, 17, 19,28). At an altitude of about 4000 meters the percent reduction of work capacity is about 25 to 30% in athletes, but only about 20% in sedentary subjects (3,6-12, 18, unpublished observations). However, Faulkner et al (14) found little evidence of a strong association between sea level capacity and the reduction of capacity at altitude in trained subjects. Findings of a greater performance reduction in athletic newcomers to altitude have usually been ascribed to a conditioning effect in the untrained "controls", but a tendency for a disproportionate effect of altitude on the more highly conditioned subject should not be discounted.

All groups of altitude residents tested had relatively high work capacities compared to newcomers at similar altitudes. For example trained athletes, having an aerobic capacity of 64 ml/kg/min during two months at 4000 meters, while sedentary newcomers in the same situation had a capacity of 38 ml/kg/min (7,8,22). Most notable, however, was the high aerobic capacity of Andean Indians is at least equal to, but usually greater than, that of white newcomers to altitude (4, 13,22,31). The fact that Andean Indians have a capacity equivalent to that of trained residents and athletic newcomers need not be construed as evidence for a significant "racial adaptation" of these Indians. For example there appeared to be only minimal differences in responses to maximal exercise which could be ascribed to "race" in the comparison of WHITE and INDIAN STUDENTS. The rural peasants of Indian ancestry in Peru probably derive their high degree of fitness from full acclimatization to altitude through lifetime residence and from extensive conditioning through a lifetime of hard physical activity. The full acclimatization of these Indians, and other altitude residents, is evident not only from their performance at altitude but from the small increases of performance capacity which they show on going to sea level. Velasquez (31) has demonstrated that natives at 4500 meters can perform at 95% of their sea level capacity.

Submaximal exercise: One major finding in prolonged work at about 850 to 900 kpm/min was the virtual identity of mechanical efficiency in all six groups tested. The average value of 21.2% was similar to values usually found for bicycle ergometer exercise at sea level. In addition groups of whites and Indians have been measured at sea level and during one month at 4000 meters, and the efficiency of both groups at both altitudes was

identical to that reported here (Baker and Mazess: unpublished observations). It has been widely observed that the mechanical efficiency of bicycle work is not significantly affected by workload, physical training, sex, race, or altitude exposure (1,6,27). The present results are entirely in accord with such findings. Some investigators (20,29), however, have observed that Andean Indians had a lower oxygen consumption than either sea level dwellers or altitude newcomers, apparently as the result of a higher mechanical efficiency in the Andean Indians. Kollias et al (22), in better controlled studies, gave evidence that Andean Indians have a lower mechanical efficiency than either athletic or untrained newcomers. Observations of group differences in oxygen intake can be artifacts and it seems unlikely, in view of both the present results and the results of numerous other studies, that permanent altitude residents have an enhanced mechanical efficiency. Further there did not appear to be any significant differences among the altitude resident groups as a consequence of either physical conditioning or racial background.

Heart rates during this test did not reflect either acclimatizational state or physical fitness clearly. For example, the much higher heart rate of the INDIAN STUDENTS compared to the WHITE STUDENTS ran counter to the group difference of physical fitness. On the whole, however, there was a similarity of heart rates and oxygen pulse in both trained and untrained altitude dwellers. Others also have observed similarity of heart rates in both athletes and untrained newcomers at 4000 meters, and as in the present case, the values for the newcomers were below those of high altitude Indians (22). Apparently high altitude residents, including U.S. whites, Sherpas, and Andean natives, do not have heart rates during submaximal work below those of newcomers and heart rates in these residents acutally seem to be

elevated (4,17,22-24,27). In newcomers the increase of submaximal heart rate is usually most marked during mild and moderate work and becomes obscured at more intense workloads (27,32). Heart rates in heavy or prolonged work at altitude therefore may not reflect physical fitness or physiological strain as reliably as at sea level.

Permanent altitude residents have been observed to have lower exercise ventilation than newcomers (4,22-24, 27) although there are some contrary findings (16,28). Ventilation differences among groups of divergent fitness may be difficult to interpret since, as in the present case of INDIAN and WHITE STUDENTS, a significant ventilatory difference can be completely accounted for by the group difference in aerobic capacity and relative workload. Ventilatory response was in fact well-correlated with relative workload, and the data for the altitude residents were distributed about a single regression line. The LOWLAND TRAINED and U.S. WHITES fell above this regression indicating a relative hyperventilation in these subjects. This was confirmed by data on whites and Indians from a comparable study at 4000 meters (22). Consideration of relative workload reduced the ventilatory differences between less fit newcomers and more fit residents, but the differences are not completely eliminated. Grover and Reeves (16,28) have suggested that ventilation is closely related to relative workload, and that increased ventilation with increasing altitude is a function of the decrease in aerobic capacity and consequent elevation of relative workload. The present data not only lie close to their regression line, but confirmed a functional association between ventilation and relative workload.

CONCLUSIONS

Both physically conditioned and untrained altitude residents have higher aerobic capacities than altitude newcomers, and the residents even compare well with partially acclimatized athletes. Rural Andean Indians have a higher capacity than sedentary residents, and equal to that of conditioned residents; this relatively high degree of fitness probably derives from both lifetime conditioning and acclimatization. The relatively high maximal capacity of the altitude residents in general occurred together with an absence of the depressed maximal heart rate common in newcomers; this heart rate depression may disappear within a year of exposure.

There were no group differences of mechanical efficiency in heavy submaximal work, and the valves of efficiency observed were identical to those for bicycle ergometer exercise at sea level. Heart rates in this heavy work did not clearly reflect group or individual levels of fitness. In contrast ventilatory response was related to level of fitness, and the correlation of ventilation with relative workload was 0.76. Consideration of relative workload reduced but did not eliminate ventilatory differences between partially acclimatized newcomers and residents.

Long-term acclimatization was associated with several responses different than those of newcomers: higher aerobic capacity, higher maximal and submaximal heart rates, and somewhat lower ventilation. Acclimatization and training appear to be the major factors influencing exercise

performance at altitude; racial or genetic factors seemed to have little significant direct effect. More extensive studies of altitude residents, and of lowlanders throughout longer sojourns at altitude, seem necessary to define the course and limits which acclimatization can achieve in modifying exercise performance at altitude.

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APPENDIX G

Summary of Total Results Available on Testing Metabolic and Temperature Responses of Various Groups at 10°C

(All Results Obtained in the Nuñoa Laboratory)

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Nuñoans N = 26 Mean	S.D.	All Whites N = 19 Mean	S.D.	df = 43 Sig. Level	2nd Exposure Nuñoans N = 26 Mean	S.D.	All Whites N = 19 Mean	S.D.	df = 43 Sig. Level
Mean Weighted Skin Temperature										
(0)	33.53	0.88	32.67	1.16	≤ .01	33.17	1.04	32.84	1.15	Not Sig.
(0- 20)	29.80	0.76	28.98	0.69	≤ .001	29.36	0.74	28.93	0.85	Not Sig.
(20- 40)	28.40	0.81	27.66	0.56	≤ .001	28.10	0.65	27.55	0.78	≤ .05
(40- 60)	27.60	0.80	26.92	0.61	≤ .01	27.35	0.69	26.85	0.80	≤ .05
(60- 80)	27.17	0.80	26.44	0.77	≤ .01	26.95	0.72	26.45	0.73	≤ .05
(80-100)	26.90	0.86	26.16	0.81	≤ .01	26.63	0.68	26.07	0.78	≤ .05
(100-120)	26.74	0.79	26.08	0.83	≤ .05	26.44	0.64	25.98	0.71	≤ .05
(0- 60)	28.60	0.77	27.85	0.58	≤ .001	28.27	0.67	27.78	0.77	≤ .05
(60-120)	26.94	0.81	26.22	0.79	≤ .01	26.67	0.67	26.16	0.72	≤ .05
Mean Body Temperature										
(0)	33.9	0.53	35.6	0.82	Not Sig.	35.7	0.53	35.6	0.88	Not Sig.
(0- 20)	34.8	0.42	34.3	0.47	≤ .01	34.5	0.38	34.3	0.52	Not Sig.
(20- 40)	34.4	0.44	33.9	0.38	≤ .001	34.1	0.38	33.9	0.48	Not Sig.
(40- 60)	34.1	0.44	33.6	0.34	≤ .001	33.8	0.41	33.6	0.47	Not Sig.
(60- 80)	33.8	0.46	33.4	0.40	≤ .001	33.6	0.41	33.4	0.47	Not Sig.
(80-100)	33.7	0.47	33.2	0.44	≤ .001	33.4	0.42	33.2	0.47	Not Sig.
(100-120)	33.6	0.43	33.1	0.47	≤ .01	33.2	0.42	33.2	0.43	Not Sig.
(0- 60)	34.4	0.43	33.9	0.39	≤ .001	34.1	0.38	33.9	0.48	Not Sig.
(60-120)	33.7	0.45	33.2	0.43	≤ .001	33.4	0.41	33.3	0.45	Not Sig.
Heat Loss Rate										
(0)										
(0- 20)	-11.58	3.40	-18.16	7.88	≤ .01	-13.05	3.66	-17.38	7.99	≤ .05
(20- 40)	- 3.53	1.01	- 4.50	1.62	≤ .05	- 3.26	1.16	- 4.57	2.12	≤ .05
(40- 60)	- 2.27	1.13	- 3.17	1.32	≤ .05	- 2.58	0.65	- 2.80	2.18	Not Sig.
(60- 80)	- 2.01	1.30	- 2.85	1.68	Not Sig.	- 1.57	1.06	- 2.54	1.54	≤ .05
(80-100)	- 1.21	1.19	- 1.57	1.22	Not Sig.	-].80	1.16	- 1.47	1.57	Not Sig.
(100-120)	- 0.66	1.39	- 0.45	1.66	Not Sig	- 0.76	1.33	0.03	2.78	Not Sig.
(0- 60)	- 5.79	1.26	- 8.60	2.96	≤ .001	- 6.30	1.38	- 8.25	2.69	≤ .01
(60-120)	- 1.29	0.69	- 1.62	1.12	Not Sig.	- 1.37	0.74	- 1.33	1.23	Not Sig.

Two Hour Exposure Nude 10°C (continued)
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Nuñoans N = 26 Mean	S.D.	All Whites N = 19 Mean	S.D.	df = 43 Sig. Level	2nd Exposure Nuñoans N = 26 Mean	S.D.	All Whites N = 19 Mean	S.D.	df = 43 Sig. Level
Rectal Temperature										
(0)	37.05	0.48	37.11	0.78	Not Sig.	37.00	0.47	36.95	0.82	Not Sig.
(0- 20)	37.21	0.37	36.92	0.46	$\leq .05$	36.99	0.34	36.99	0.45	Not Sig.
(20- 40)	37.32	0.40	36.95	0.45	$\leq .01$	37.04	0.38	37.02	0.48	Not Sig.
(40- 60)	37.25	0.41	36.87	0.43	$\leq .01$	36.95	0.40	36.93	0.54	Non Sig.
(60- 80)	37.14	0.44	36.78	0.45	$\leq .05$	36.82	0.42	36.84	0.59	Not Sig.
(80-100)	37.03	0.42	36.64	0.48	$\leq .01$	36.72	0.45	36.77	0.61	Not Sig.
(100-120)	36.93	0.41	36.57	0.48	$\leq .05$	36.60	0.49	36.74	0.53	Not Sig.
(0- 60)	37.26	0.39	36.91	0.44	$\leq .01$	36.99	0.37	36.98	0.48	Not Sig.
(60-120)	37.03	0.42	36.66	0.46	$\leq .01$	36.71	0.44	36.78	0.57	Not Sig.

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure: Mollendo Indians N = 9 Mean	S.D.	U.S. Whites N = 19 Mean	S.D.	df = 26 Sig. Level	2nd Exposure: Mollendo Indians N = 10 Mean	S.D.	U.S. Whites N = 19 Mean	S.D.	df = 27 Sig. Level
Mean Weighted Skin Temperature										
(0)	34.48	0.79	32.67	1.16	Not Sig.	33.91	0.72	32.84	1.15	.01
(0- 20)	29.40	0.47	28.98	0.69	Not Sig.	29.16	0.58	28.93	0.85	Not Sig.
(20- 40)	27.70	0.47	27.66	0.56	Not Sig.	27.83	0.53	27.55	0.78	Not Sig.
(40- 60)	26.72	0.52	26.92	0.61	Not Sig.	26.92	0.66	26.85	0.80	Not Sig.
(60- 80)	26.27	0.59	26.44	0.77	Not Sig.	26.43	0.65	26.45	0.73	Not Sig.
(80-100)	25.91	0.50	26.16	0.81	Not Sig.	26.08	0.66	26.07	0.78	Not Sig.
(100-120)	25.75	0.60	26.08	0.83	Not Sig.	25.91	0.55	26.98	0.71	Not Sig.
(0- 60)	27.95	0.48	27.85	0.58	Not Sig.	27.97	0.56	27.78	0.77	Not Sig.
(60-120)	25.97	0.55	26.22	0.79	Not Sig.	26.13	0.61	26.16	0.72	Not Sig.
Mean Body Temperature										
(0)	36.8	0.42	35.6	0.82	$< .05$	36.6	0.53	35.6	0.88	$< .001$
(0- 20)	34.7	0.41	34.3	0.47	$< .05$	34.8	0.38	34.3	0.52	$< .05$
(20- 40)	34.2	0.36	33.9	0.38	$< .05$	34.4	0.33	33.9	0.48	$< .01$
(40- 60)	33.9	0.36	33.6	0.34	$< .05$	34.1	0.38	33.6	0.47	$< .01$
(60- 80)	33.6	0.39	33.4	0.40	$< .05$	33.9	0.37	33.4	0.47	$< .01$
(80-100)	33.4	0.40	33.2	0.44	$< .05$	33.7	0.35	33.2	0.47	$< .01$
(100-120)	33.3	0.44	33.1	0.47	$< .05$	33.6	0.33	33.2	0.43	$< .01$
(0- 60)	34.3	0.37	33.9	0.39	$< .05$	34.4	0.35	33.9	0.48	$< .01$
(60-120)	33.4	0.41	33.2	0.43	$< .05$	33.7	0.34	33.3	0.45	$< .01$
Heat Loss Rate										
(0)										
(0- 20)	-21.73	3.55	-18.16	7.88	$< .05$	-20.20	4.37	-17.38	7.99	Not Sig.
(20- 40)	- 4.64	1.10	- 4.50	1.62	$< .05$	- 3.48	1.32	- 4.57	2.12	Not Sig.
(40- 60)	- 2.39	0.78	- 3.17	1.32	$< .05$	- 2.69	0.66	- 2.80	2.18	Not Sig.
(60- 80)	- 2.64	1.69	- 2.85	1.68	$< .05$	- 2.28	1.08	- 2.54	1.54	Not Sig.
(80-100)	- 1.51	1.25	- 1.57	1.22	$< .05$	- 1.59	0.90	- 1.47	1.57	Not Sig.
(100-120)	- 1.81	0.62	- 0.45	1.66	$< .05$	- 0.27	1.37	0.03	2.78	Not Sig.
(0- 60)	- 9.59	1.35	- 8.60	2.96	$< .05$	- 8.79	1.72	- 8.25	2.69	Not Sig.
(60-120)	- 1.77	0.68	- 1.62	1.12	$< .05$	- 1.38	0.74	- 1.33	1.23	Not Sig.

Two Hour Exposure Nude 10°C (continued)
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Mollendo Indians N = 9 Mean	S.D.	U.S. Whites N = 19 Mean	S.D.	df = 26 Sig. Level	2nd Exposure Mollendo Indians N = 10 Mean	S.D.	U.S. Whites N = 19 Mean	S.D.	df = 27 Sig. Level
Rectal Temperatures										
(0)	37.92	0.48	37.11	0.78	$\leq .01$	37.92	0.54	36.95	0.82	$\leq .001$
(0- 20)	37.34	0.40	36.92	0.46	$\leq .01$	37.55	0.35	36.99	0.45	$\leq .01$
(20- 40)	37.44	0.35	37.95	0.45	$\leq .01$	37.66	0.29	37.02	0.48	$\leq .001$
(40- 60)	37.38	0.36	36.87	0.43	$\leq .01$	37.62	0.33	36.93	0.54	$\leq .001$
(60- 80)	37.26	0.39	36.78	0.45	$\leq .01$	37.53	0.36	36.84	0.59	$\leq .001$
(80-100)	37.11	0.42	36.64	0.48	$\leq .01$	37.42	0.34	36.77	0.61	$\leq .01$
(100-120)	37.00	0.42	36.57	0.48	$\leq .01$	37.38	0.38	36.74	0.53	$\leq .001$
(0- 60)	37.38	0.36	36.91	0.44	$\leq .01$	37.60	0.32	37.98	0.48	$\leq .001$
(60-120)	37.12	0.41	36.66	0.46	$\leq .01$	37.44	0.35	36.78	0.57	$\leq .001$

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure: Nuñoa Indians N = 26 Mean	S.D.	Mollendo Indians N = 9 Mean	S.D.	df = 33 Sig. Level	2nd Exposure: Nuñoa Indians N = 26 Mean	S.D.	Mollendo Indians N = 10 Mean	S.D.	df = 34 Sig. Level
Mean Weighted Skin Temperature										
(0)	33.53	0.88	34.48	0.79	≤ .01	33.17	1.04	33.91	0.72	< .05
(0- 20)	29.80	0.76	29.40	0.55	Not Sig.	29.36	0.74	29.16	0.58	Not Sig.
(20- 40)	28.40	0.81	27.70	0.47	≤ .01	28.10	0.65	27.83	0.53	Not Sig.
(40- 60)	27.60	0.80	26.72	0.52	≤ .001	27.35	0.69	26.92	0.66	Not Sig.
(60- 80)	27.17	0.80	26.27	0.59	≤ .01	26,95	0.72	26.43	0.65	< .05
(80-100)	26.90	0.86	25.91	0.50	≤ .001	26.63	0.68	26.08	0.66	≤ .05
(100-120)	26.74	0.79	25.75	0.60	≤ .001	26.44	0.64	25.91	0.55	≤ .05
(0- 60)	28.60	0.77	27.94	0.48	≤ .01	28.27	0.67	27.97	0.56	Not Sig.
(60-120)	29.94	0.81	25.97	0.55	≤ .001	26.67	0.67	26.14	0.61	≤ .05
Mean Body Temperature										
(0)	35.9	0.53	36.8	0.42	≤ .001	35.7	0.53	36.6	0.53	≤ .001
(0- 20)	34.8	0.42	34.7	0.41	Not Sig.	34.5	0.38	34.8	0.38	≤ .05
(20- 40)	34.4	0.44	34.2	0.36	Not Sig.	34.1	0.38	34.4	0.33	≤ .05
(40- 60)	34.1	0.44	33.9	0.36	Not Sig.	33.8	0.41	34.1	0.38	≤ .05
(60- 80)	33.8	0.46	33.6	0.39	Not Sig.	33.6	0.41	33.9	0.37	≤ .05
(80-100)	33.7	0.47	33.4	0.40	Not Sig.	33.4	0.42	33.7	0.35	≤ .05
(100-120)	33.6	0.43	33.3	0.44	Not Sig.	33.2	0.42	33.6	0.33	≤ .05
(0- 60)	34.4	0.43	34.3	0.37	Not Sig.	34.1	0.38	34.4	0.35	≤ .05
(60-120)	33.7	0.45	33.4	0.41	Not Sig.	33.4	0.41	33.7	0.34	≤ .05
Heat Loss Rate										
(0)										
(0- 20)	-11.58	3.40	-21.73	3.55	≤ .001	-13.05	3.66	-20.20	4.37	< .001
(20- 40)	- 3.53	1.01	- 4.64	1.10	≤ .05	- 3.26	1.16	- 3.48	1.32	Not Sig.
(40- 60)	- 2.27	1.13	- 2.39	0.79	Not Sig.	- 2.58	0.65	- 2.69	0.66	Not Sig.
(60- 80)	- 2.01	1.30	-2.64	1.69	Not Sig.	- 1.57	1.06	- 2.28	1.08	Not Sig.
(80-100)	- 1.21	1.19	- 1.51	1.25	Not Sig.	- 1.80	1.16	- 1.59	0.90	Not Sig.
(100-120)	- 0.66	1.39	- 1.18	0.62	Not Sig.	- 0.76	1.33	- 0.27	1.37	Not Sig.
(0- 60)	- 5.79	1.26	- 9.59	1.35	≤ .001	- 6.30	1.38	- 8.79	1.72	< .001
(60-120)	- 1.29	0.69	- 1.77	0.68	Not Sig.	- 1.37	0.74	- 1.38	0.74	Not Sig.

Two Hour Exposure Nude 10°C (continued)
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure: Nuñoa Indians N = 26 Mean	S.D.	Mollendo Indians N = 9 Mean	S.D.	df = 33 Sig. Level	2nd Exposure: Nuñoa Indians N = 26 Mean	S.D.	Mollendo Indians N = 10 Mean	S.D.	df = 34 Sig. Level
Rectal Temperature										
(0)	37.05	0.48	37.92	0.48	≤ .001	37.00	0.47	37.92	0.54	≤ .001
(0- 20)	37.21	0.37	37.34	0.40	Not Sig.	36.99	0.34	37.55	0.35	≤ .001
(20- 40)	37.32	0.40	37.44	0.35	Not Sig.	37.04	0.38	37.66	0.29	≤ .001
(40- 60)	37.25	0.41	37.38	0.36	Not Sig.	36.95	0.40	37.62	0.33	≤ .001
(60- 80)	37.14	0.44	37.26	0.39	Not Sig.	36.82	0.42	37.53	0.36	≤ .001
(80-100)	37.03	0.42	37.11	0.42	Not Sig.	36.72	0.45	37.42	0.34	≤ .001
(100-120)	36.93	0.41	37.00	0.42	Not Sig.	36.60	0.49	37.38	0.38	≤ .001
(0- 60)	37.26	0.39	37.38	0.36	Not Sig.	36.99	0.37	37.60	0.32	≤ .001
(60-120)	37.03	0.42	37.12	0.41	Not Sig.	36.71	0.45	37.44	0.35	≤ .001

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Nuñoans N = 26 Mean	1st Exposure Whites N = 19 Mean	df = 43 Sig. Level	2nd Exposure Nuñoans N = 26 Mean	2nd Exposure Whites N = 19 Mean	df = 43 Sig. Level
Oxygen Consumption (V_{O_2}/min.)						
(0)	0.314	0.358	≤ .01	0.331	0.357	Not Sig.
(0- 20)	0.313	0.326	Not Sig.	0.317	0.337	Not Sig.
(20- 40)	0.303	0.318	Not Sig.	0.291	0.326	≤ .05
(40- 60)	0.315	0.362	≤ .05	0.305	0.346	≤ .05
(60- 80)	0.344	0.373	Not Sig.	0.326	0.387	≤ .01
(80-100)	0.347	0.416	≤ .01	0.337	0.415	≤ .001
(100-120)	0.374	0.432	≤ .01	0.350	0.436	≤ .001
(0- 60)	0.310	0.335	Not Sig.	0.304	0.337	≤ .05
(60-120)	0.355	0.407	≤ .05	0.337	0.413	≤ .001
Heat Production (K cal/min.)						
(0)	91.5	104.3	≤ .01	96.4	103.9	Not Sig.
(0- 20)	91.1	95.0	Not Sig.	92.4	98.3	Not Sig.
(20- 40)	88.4	92.7	Not Sig.	84.8	95.0	≤ .05
(40- 60)	91.7	105.5	≤ .05	88.8	100.9	≤ .05
(60- 80)	100.4	108.6	Not Sig.	94.9	112.9	≤ .01
(80-100)	101.0	121.3	≤ .01	98.1	120.8	≤ .001
(100-120)	109.0	125.8	≤ .01	101.8	126.9	≤ .001
(0- 60)	90.4	97.7	Not Sig.	88.7	98.0	Not Sig.
(60-120)	103.4	118.5	≤ .05	98.2	120.2	≤ .001
Heat Production per Meter of Surface Area (K cal/min./m^2)						
(0)	59.5	58.4	Not Sig.	62.6	54.6	≤ .05
(0- 20)	59.1	49.9	≤ .001	60.0	51.6	≤ .01
(20- 40)	57.4	48.7	≤ .01	55.1	50.0	≤ .05
(40- 60)	59.4	55.6	Not Sig.	57.6	53.1	Not Sig.
(60- 80)	65.1	57.1	≤ .05	61.6	59.4	Not Sig.
(60-100)	65.5	63.7	Not Sig.	63.7	63.6	Not Sig.
(100-120)	70.8	66.0	Not Sig.	66.1	66.8	Not Sig.
(0- 60)	58.6	51.4	≤ .05	57.6	51.6	≤ .05
(60-120)	67.1	62.3	Not Sig.	63.8	63.2	Not Sig.
Heat Production per Kilogram Body Weight (K cal/min./kg)						
(0)	1.82	1.61	≤ .05	1.90	1.61	≤ .05
(0- 20)	1.80	1.47	≤ .001	1.83	1.52	≤ .01
(20- 40)	1.75	1.43	≤ .01	1.68	1.47	≤ .05
(40- 60)	1.81	1.64	Not Sig.	1.76	1.57	Not Sig.
(60- 80)	1.98	1.68	≤ .05	1.88	1.75	Not Sig.
(80-100)	2.00	1.87	Not Sig.	1.94	1.87	Not Sig.
(100-120)	2.16	1.94	≤ .05	2.01	1.96	Not Sig.
(0- 60)	1.79	1.51	≤ .01	1.75	1.52	≤ .01
(60-120)	2.04	1.83	≤ .05	1.93	1.86	Not Sig.

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Mollendo Indians N = 9 Mean	1st Exposure U.S. Whites N = 19 Mean	df = 26 Sig. Level	2nd Exposure Mollendo Indians N = 10 Mean	2nd Exposure U.S. Whites N = 19 Mean	df = 27 Sig. Level
Oxygen Consumption (V_{O_2}/ min.)						
(0)	0.337	0.358	Not Sig.	0.308	0.357	Not Sig.
(0- 20)	0.318	0.326	Not Sig.	0.294	0.337	$\leq$ .05
(20- 40)	0.300	0.318	Not Sig.	0.283	0.326	$\leq$ .05
(40- 60)	0.325	0.362	Not Sig.	0.301	0.346	Not Sig.
(60- 80)	0.353	0.373	Not Sig.	0.341	0.387	$\leq$ .05
(80-100)	0.349	0.416	$\leq$ .01	0.365	0.415	Not Sig.
(100-120)	0.395	0.432	Not Sig.	0.380	0.436	$\leq$ .05
(0- 60)	0.314	0.335	Not Sig.	0.293	0.337	$\leq$ .05
(60-120)	0.366	0.407	Not Sig.	0.362	0.413	$\leq$ .05
Heat Production (K cal/min.)						
(0)	98.1	104.3	Not Sig.	89.7	103.9	Not Sig.
(0- 20)	92.6	95.0	Not Sig.	85.7	98.3	$\leq$ .05
(20- 40)	87.4	92.7	Not Sig.	82.5	95.0	$\leq$ .05
(40- 60)	94.6	105.5	Not Sig.	87.7	100.9	Not Sig.
(60- 80)	102.9	108.6	Not Sig.	99.3	112.9	$\leq$ .05
(80-100)	101.6	121.3	$\leq$ .01	106.3	120.8	Not Sig.
(100-120)	115.0	125.8	Not Sig.	110.5	126.9	$\leq$ .05
(0- 60)	91.5	97.7	Not Sig.	85.3	98.0	$\leq$ .05
(60-120)	106.5	118.5	Not Sig.	105.4	120.2	$\leq$ .05
Heat Production per Meter of Surface Area (K cal/min./m^2)						
(0)	62.0	54.8	Not Sig.	54.7	54.6	Not Sig.
(0- 20)	58.2	49.9	$\leq$ .05	52.3	51.6	Not Sig.
(20- 40)	54.8	48.7	Not Sig.	50.3	50.0	Not Sig.
(40- 60)	59.2	55.6	Not Sig.	53.5	53.1	Not Sig.
(60- 80)	64.6	57.1	Not Sig.	60.7	59.4	Not Sig.
(80-100)	63.8	63.7	Not Sig.	65.0	63.6	Not Sig.
(100-120)	72.1	66.0	Not Sig.	67.7	66.8	Not Sig.
(0- 60)	57.4	51.4	Not Sig.	52.0	51.6	Not Sig.
(60-120)	66.8	62.3	Not Sig.	64.5	63.2	Not Sig.
Heat Production per Kilogram Body Weight (K cal/min./kg)						
(0)	1.92	1.61	Not Sig.	1.70	1.61	Not Sig.
(0- 20)	1.80	1.47	$\leq$ .01	1.62	1.52	Not Sig.
(20- 40)	1.69	1.43	$\leq$ .05	1.56	1.47	Not Sig.
(40- 60)	1.83	1.64	Not Sig.	1.66	1.57	Not Sig.
(60- 80)	2.00	1.68	$\leq$ .05	1.88	1.75	Not Sig.
(80-100)	1.97	1.87	Not Sig.	2.02	1.87	Not Sig.
(100-120)	2.23	1.94	$\leq$ .05	2.10	1.96	Not Sig.
(0- 60)	1.77	1.51	$\leq$ .05	1.61	1.52	Not Sig.
(60-120)	2.06	1.83	Not Sig.	2.00	1.86	Not Sig.

Two Hour Exposure Nude 10°C
Data Recorded on 4 min. Intervals

Time Span Covered in min.	1st Exposure Mollendo Indians N = 9 Mean	1st Exposure Nuñoa Indians N = 26 Mean	df = 33 Sig. Level	2nd Exposure Mollendo Indians N = 10 Mean	2nd Exposure Nuñoa Indians N = 26 Mean	df = 34 Sig. Level
Oxygen Consumption (V_{O_2}/min.)						
(0)	0.337	0.314	Not Sig.	0.308	0.331	Not Sig.
(0- 20)	0.318	0.313	Not Sig.	0.294	0.317	Not Sig.
(20- 40)	0.300	0.303	Not Sig.	0.283	0.291	Not Sig.
(40- 60)	0.325	0.315	Not Sig.	0.301	0.305	Not Sig.
(60- 80)	0.353	0.344	Not Sig.	0.341	0.326	Not Sig.
(80-100)	0.349	0.347	Not Sig.	0.365	0.337	Not Sig.
(100-120)	0.395	0.374	Not Sig.	0.380	0.350	Not Sig.
(0- 60)	0.314	0.310	Not Sig.	0.293	0.304	Not Sig.
(60-120)	0.366	0.355	Not Sig.	0.362	0.337	Not Sig.
Heat Production (K cal/min.)						
(0)	98.1	91.5	Not Sig.	89.7	96.4	Not Sig.
(0- 20)	92.6	91.1	Not Sig.	85.7	92.4	Not Sig.
(20- 40)	87.4	88.4	Not Sig.	82.5	84.8	Not Sig.
(40- 60)	94.6	91.7	Not Sig.	87.7	88.8	Not Sig.
(60- 80)	102.9	100.4	Not Sig.	99.3	94.9	Not Sig.
(80-100)	101.6	101.0	Not Sig.	106.3	98.1	Not Sig.
(100-120)	115.0	109.0	Not Sig.	110.5	101.8	Not Sig.
(0- 60)	91.5	90.4	Not Sig.	85.3	88.7	Not Sig.
(60-120)	106.5	103.4	Not Sig.	105.4	98.2	Not Sig.
Heat Production per Meter of Surface Area (K cal/min./m^2)						
(0)	62.0	59.5	Not Sig.	54.7	62.6	$\leq$ .05
(0- 20)	58.2	59.1	Not Sig.	52.3	60.0	$\leq$ .001
(20- 40)	54.8	57.4	Not Sig.	50.3	55.1	$\leq$ .05
(40- 60)	59.2	59.4	Not Sig.	53.5	57.6	Not Sig.
(60- 80)	64.6	65.1	Not Sig.	60.7	61.6	Not Sig.
(80-100)	63.8	65.5	Not Sig.	65.0	63.7	Not Sig.
(100-120)	72.1	70.8	Not Sig.	67.7	66.1	Not Sig.
(0- 60)	57.4	58.6	Not Sig.	52.0	57.6	$\leq$ .01
(60-120)	66.8	67.1	Not Sig.	64.5	63.8	Not Sig.
Heat Production per Kilogram Body Weight (K cal/min./kg)						
(0)	1.92	1.82	Not Sig.	1.70	1.90	$\leq$ .05
(0- 20)	1.80	1.80	Not Sig.	1.62	1.83	$\leq$ .01
(20- 40)	1.69	1.75	Not Sig.	1.56	1.68	Not Sig.
(40- 60)	1.83	1.81	Not Sig.	1.66	1.76	Not Sig.
(60- 80)	2.00	1.98	Not Sig.	1.88	1.88	Not Sig.
(80-100)	1.97	2.00	Not Sig.	2.02	1.94	Not Sig.
(100-120)	2.23	2.16	Not Sig.	2.10	2.01	Not Sig.
(0- 60)	1.77	1.79	Not Sig.	1.61	1.75	$\leq$ .05
(60-120)	2.06	2.04	Not Sig.	2.00	1.94	Not Sig.

APPENDIX H

Cold Stress and Microclimate in the Quechua Indians of Southern Peru

Joel M. Hanna

COLD STRESS AND MICROCLIMATE IN THE QUECHUA INDIANS OF SOUTHERN PERU

Joel M. Hanna, Ph.D.

The University of Arizona, 1968

Cold, as a stressful agent, has influenced human evolution and has produced considerable variation in living populations. Many studies on males of European ancestry have illuminated some aspects of this variation. Studies of peoples of non-European ancestry have shown that there is also variation between populations. Most of these investigations have been concerned with the responses of adult males as representative of entire populations, thus they really represent an individual level of study.

This dissertation deals with responses to cold at the population level. The population considered lives in a cold climate which is inhospitable to unprotected humans. The group is the Quechua Indians living in the Nuñoa region of southern Peru and is especially suited to population analysis because numerous parameters have already been defined. Studies were undertaken in controlled laboratory conditions and under natural conditions of everyday life.

The variations in response to cold stress encountered within the population are considered from three viewpoints. The first is related to the physical environment and arises from altitude, the salient geographic feature in this Andean region. Altitude influences the response of the population to cold chiefly through decreasing air temperature at

higher elevations. Thus, those population segments living at higher elevations regularly experience colder microclimates. Altitude also produces variation in a less direct manner through its influence on economy. By prohibiting farming at higher elevations it influences daily activities related to cold exposure. It also affects nutrition.

The second viewpoint emphasizes biological variation. Combinations of laboratory and field studies illustrate variation which is related to age and sex. Younger members of the population live in colder microclimates and are more frequently exposed to cold as they go about their daily activities. Males and females respond differently in the laboratory, but the differences diminish in the field. The male-female differences in the Quechua are distinct from those reported for other populations in that Quechua women maintain warmer surface temperatures than men.

The final viewpoint is that of human culture. Clothing is examined in detail to determine its effectiveness and evaluate its design. The addition of clothing to the unclothed subject increases microclimate temperature to a significant degree but has no apparent influence upon internal (core) temperature. Clothing is then examined from the viewpoint of design and suitability for cold climates. It is found to comply with standards prescribed for cold weather clothing by the U. S. Army.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support and assistance of a number of people during all phases of the preparation of this paper. Mrs. Gaby A. Hanna, Mr. Victor Berreda and Mr. Juan Bravo assisted in collection of the data. Dr. Hermann K. Bleibtreu provided for numberous improvements and presented invaluable criticism during its writing. Dr. Allan Humphrey and Mr. Lawrence Manire assisted with and suggested improvements in numerical analysis. Dr. Raymond H. Thompson, Head of the Department of Anthropology of The University of Arizona, made numerous useful suggestions and provided support through the University Computer Center.

Dr. Frederick S. Hulse, Professor of Anthropology at the University of Arizona, accepted the responsibility of directing the analysis and writing of the final draft. His useful suggestions and carful editing made the preparation of the paper proceed with unusual speed.

Finally, Dr. Paul T. Baker, Professor of Anthropology at The Pennsylvania State University, provided the opportunity for data collection in Peru through Contract DA-49-193-MD-2260 for which he is Principal Investigator. During the time which the author spent in Peru, Dr. Baker provided constant support and motivation.

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CHAPTER 1

INTRODUCTION

The evolution of man has been characterized by considerable subspecific variation. The degree of this variation has been so pronounced that man has become a most polytypic species (Haldane 1949) and the fossil evidence suggests that he has been so for some time (Coon 1962). Observed variation has taken the form of obvious morphological features such as skin color and body size; and it has taken the form of less obvious features which can be studied only under specific laboratory conditions (Hulse 1963).

Some of this variation may originate from non-adaptive, random forces (genetic drift), but it is most likely that the major portion results from genetic adaptation and plasticity reactions to environmental factors (Hulse 1960; Baker 1966a). Some traits, such as sickle cell anemia, seem well correlated to specific environmental factors, but most human variation is seen as geographical gradients of unknown origin (Garn 1961). Full understanding of the problem is further complicated by our inability to differentiate between genetic adaptations and phenotypic plasticity resulting from exposure to specific environments (acclimatization). For example, it has not been possible to determine if the large chest size of high altitude dwellers is the result of genetic adaptations or simply acclimatization to the uniformly low oxygen tension to which all such people are exposed (Monge 1954).

Partitioning of observed variation into its component parts is extremely difficult in the case of populations and almost impossible at the individual level. Since most studies of environmentally induced variation have been made at the individual level, such separation of components must await future methodological innovations. Despite these limitations on our ability to assign specific causes for specific types of variation, a meaningful analysis can be undertaken in a broad framework which emphasizes environmental control over variation. This framework may be called Human Ecology and is defined as, "Human ecology seeks to understand man and his problems by studying individuals and populations as biological entities profoundly modified by human society and culture and by studying the effects of physical, biological, and cultural environments upon man and those of man upon his environment" (Shargeant and Shimkin 1965:512). Utilizing this approach, the basic unit of study, the dependent variable, is biological man. The independent variables, the physical (natural), biological and cultural environments may be studied under a variety of conditions and their effects estimated.

Choosing biological man as the basic unit of study provides for a considerable simplification of methodology. Biological man is readily defined and many of the parameters of his biological variation are easily studied. Further, it is possible to lump genetic adaptations and phenotypic plasticity for some aspects of study. This is not the most desirable framework for studying human variation, but it provides a suitable approach in the absence of more detailed knowledge of genetics.

One of the most pervasive forces in promoting human variation has been cold. It has been a force in human evolution for thousands of generations, first limiting human expansion as it limits the range of other great primates today, then favoring certain classes in variation. So evident is the effect of cold on human variation that it has occupied an important place in many early and recent theories of human race (Count 1950; Coon, Garn and Birdsell 1950). Recently Hammel (1964) has tried to envision an evolutionary sequence based upon response to cold. He argues that cold has been a limiting factor in the human population of the globe and that expansion into non-tropical areas had to await technological progress. According to this argument, man probably originated in the tropic savanna and, lacking any protective technology, suffered cold stress during the nights. Present day temperatures in these areas fall to 20°C, a temperature which is uncomfortable but not dangerous. The naked hominoid could have met this stress by limiting blood flow to the extremities much as the Australian Aborigines do today. Fire enabled expansion into cooler climates and with the discovery of clothing the entire globe could be populated. When housing became widespread, the chronic aspects of cold were reduced and other forms of cold response were promoted.

Just as cold must have influenced peoples in the past, it influences current human populations. This may be illustrated in the variation in body size which has been found between various groups. Bergmenn's Rule, derived from observed effects of cold on animal populations, states that in any homeothermic species the individuals living in the colder parts of the range will be larger than those forms living

in the warmer parts (Allee and others 1949). This seems related to the dynamics of heat exchange in solids. As the size of a solid increases, the mass increases at a greater rate than does the surface area. In biological terms this suggests that a larger animal will have a greater heat producing mass in relation to surface area than will a smaller one. This is desirable in a cold climate.

Several investigators have attempted to establish the validity of this rule for humans. A typical example is provided by Roberts (1953) who compared the reported mean weights for various indigenous peoples with mean annual temperature of the areas in which they live. These were found to correlate -.600. The significant, negative correlation suggests that people living in colder areas are heavier. A partitioning of the sample showed similar relations existed within ethnic groups and over continental land masses. Other studies have yielded similar results (Schreider 1951; Newman 1953). These have been challenged (Scholander 1955; Wilber 1957), but their general validity seems to remain (Mayr 1956; Garn 1958).

Cold also influences human culture, such artifacts as houses, fires and clothing usually function to deal with it, but there may also be more subtle influences. Whiting (1964) has recently reported that such cultural phenomena as post partum taboo, length of nursing period and sleeping behavior may be adjustments to temperature.

This paper will deal with the responses to cold of a human population. In accordance with the ecological approach already discussed, three aspects of cold interactions will be examined--those related to

the physical environment, to the biological environment and to the cultural environment.

The next two chapters will be devoted to the dependent variable, biological man, and to his responses to cold. Chapter 2 will deal with the generality of human responses to cold, and Chapter 3 will examine the specific responses of a variety of human groups.

CHAPTER 2

THE PHYSIOLOGY OF COLD STRESS

The Dynamics of Heat Exchange

The effects of low environmental temperature on the human body are most easily understood in terms of physical laws which govern heat exchange in all objects (Bazett 1949; Carlson and Hseih 1965). There are four forces which operate in living and inanimate objects.

Evaporation

Evaporation results in the loss of 0.58 Calories of heat per gram of water changed from liquid to gas. Thus, evaporation of water from the surface of living things serves as a cooling agent. In the human body, evaporation takes place on the surface of the skin, lungs and the linings of the respiratory tract. It is obvious that under cold conditions the evaporation of large amounts of water is not desirable because of the quantities of heat which it may remove.

Conduction

Conduction is heat transfer from molecule to molecule. In the study of human heat exchange body to environment conduction is frequently neglected because of the insulative properties of clothing. Conduction also takes place within the body and is of extreme importance in the study of temperature regulation. This internal conduction is

carried from tissue to tissue, especially by the blood and represents a major force in the distribution of body heat.

Convection

Heat transfer resulting from the movement of fluids (air and water) is convection. In cold environments this represents a constant source of cooling as the homeothermic body attempts to maintain a shell of warm air between itself and the environment. Wind activity represents the most frequently encountered convective force in cold climates.

Radiation

Radiation is heat transfer through electromagnetic waves which all warm objects direct towards all colder objects in their environment. Thus, even a fully clothed man is constantly radiating heat to other objects such as houses, rocks, bodies of water, and even the sky.

These forces may act individually or in concert to remove heat. In a common situation, the man in a cold environment will lose heat to the rock upon which he is sitting by conduction, by evaporation from the skin and respiratory tract surfaces, by radiation to the sky and surrounding objects and finally convective wind activity will remove still more. The heat lost through these avenues must be produced by the body if homeostasis is to be maintained. These relations may be summarized in equation form.

Equation 1

$$M = E + Cd + Cv + R$$

where, M is metabolic heat production,
E is evaporative heat loss,
Cd is conductive heat loss,
Cv is convective heat loss, and
R is radiation heat loss.

Since there is only one means of heat production and four avenues of heat loss, it should be possible to define a point of equilibrium such that production is exactly equal to heat loss. Experimental evidence based upon European adult males suggests that the following is typical of neutral conditions:

Equation 2

$$72 \text{ Cal/hr} = 63 \text{ Cal/hr} + 0 \text{ Cal/hr} + 5 \text{ Cal/hr} + 4 \text{ Cal/hr}$$

$$M \qquad E \qquad Cd \qquad Cv \qquad R$$

Windslow and Harrington 1949: 55). The metabolic heat production is at the basal metabolic level which may be defined as "the energy expenditure of a subject resting quietly after at least eight hours of sleep and at least 12 hours after the last meal" (Consolazio, Johnson and Pecora 1963: 22).

The Physiology of Temperature Regulation

Most of the detailed knowledge of human temperature regulation in the cold has been gained from studies of adult males of European ancestry. In this chapter all data, except that specifically labeled as distinct, may be assumed as derived from adult males of European ancestry.

The physiology of temperature regulation in man is best understood by dividing the body into two parts, the core and the shell (Bazett (1949). The core is the internal part which consists of the brain, lungs, heart, liver and the viscera, all of which must function at a constant temperature. Normally core temperature is measured in the rectum and is observed to average about 38°C (98.6°F). The lower limit of the core temperature seems to be between 24 and 26°C (75.5 and 78.8°F). Surrounding the core is the shell which consists of the skin, muscles, subcutaneous fat and other peripheral tissues. The temperature of the shell may be varied in accordance with the heat demands of the body. Under cold conditions the shell may be pictured as an overcoat in that it is of considerable depth and acts as an insulative body (Carlson and others 1953). The lower limit of the shell is about freezing or 0°C (32°F).

The relationship between the temperatures of the core and the shell may be defined in terms of an equation which weighs the contri-= bution of each:

Equation 3

$$\text{Body Temperature} = 0.33\ (\text{Mean Skin Temperature}) + 0.67\ (\text{Rectal Temperature})$$

(Consolazio, Johnson and Pecora 1963: 420). Body temperature is the total heat content of the body, mean skin temperature is an estimate of the average surface temperature and rectal temperature is an estimate of core temperature.

Response to Cold Stress: Insulation

At an environmental temperature of about 34 to 35.5°C (93.2 to 95.9°F), the human body is in thermal equilibrium with none of its defense mechanisms in operation (Burton and Bazett 1936; Craig and Dvorak 1966). This "neutral" point has been defined in stirred water baths where temperature could be carefully controlled. In terms of Equation 1 most heat would be lost through convection and respiratory tract evaporation. In air there must be a similar point with different avenues of heat loss. At such a point Rubner (Windslow and Harrington 1949: 27), expected the exchange to be 44 percent loss through radiation, 32 percent through convection, 21 percent through evaporation, and 3 percent through work and food ingestion.

More meaningful than this neutral point is the "critical temperature" defined as "the ambient temperature below which the metabolic rate begins to rise for the maintenance of the body temperature" (Consolazio, Johnson and Pecora 1963: 434). Above this point there is no need to increase energy expenditure in order to maintain a favorable internal temperature. The critical temperature has been empirically established at 27 to 28°C (80.6 to 82.4°F) for nude adult males in still air. It was first established by Hardy and Sonderstrom (1938) and later confirmed by Scholander and others (1950). Craig and Dvorak (1966) found metabolic heat production to increast at 30°C (86°F) during water immersion. This difference between air and water test mediums suggests the caution with which studies of critical temperatures must be undertaken.

Between the neutral point and the critical temperature some of the basic mechanisms of temperature regulation in the human body are seen to begin operation. Their chief orientation seems to be taking advantage of the insulative qualities of the shell. At some point below 35°C (95°F) vasomotor responses begin to reduce the outward flow of heat from the core to the surface. Most probably the first mechanism to be used is vasoconstriction, closing off some blood vessels and thereby limiting the flow of warm blood to the tissues which they serve. Hardy and Sonderstrom (1938) suggest this is "vasoregulation" for it is temperature regulation based upon blood vessel physiology. The immediate result of this lower blood flow is a decreased core to shell conductance which is measured in terms of Calories /square meter of surface area/degree C. Conductance changes due to cooling have been reported by Windslow and Harrington (1949: 76) who provide the following information. Above the point of vasoregulation, conductance was observed to be 20.3 Cal/m^2/C while below that point the conductance fell to 12.6 Cal/m^2/C. This decreased heat flow (or increased insulation) is the result of reduced heat carried from the core by the blood and increased insulation of the overlying tissues. The effects of reduced blood flow in preventing heat loss without great changes in the insulative ability of the tissue may be estimated from the study of Forrester, Ferris and Day (1946). At an environmental temperature of 15°C blood flow to the hand was only 0.15 ml/100 ml hand/min. while at 38°C it was 32 ml/100 ml hand/min. Translated into actual heat loss, practically all of which was the result of blood flow, the result was 6 Cal/hand/min. at 15°C and 32 Cal/hand/min. at

38°C. Because the tissue insulative ability of the hand is limited, this 26 Cal/min. difference is largely the result of changes in blood flow.

Heat conservation is further enhanced by the insulative value of overlying tissues after blood flow is decreased. Subcutaneous fat seems to be of special importance in this respect (Buskirk, Thompson and Whedon 1963). The direct insulative value of subcutaneous fat was demonstrated by Baker and Daniels (1956) who found significant correlations between surface temperatures of specific areas and the amount of underlying subcutaneous fat. Pugh and others (1960) have shown that in long-distance swimmers, subcutaneous fat, as estimated by skinfolds, slows the rate of heat flow from the core to the surface to the extent that each mm. of fat is equivalent to increasing the water temperature almost 1.5°C. When blood vessels are constricted, subcutaneous fat is of considerable value in reducing heat flow from the core. This ability of fat is not uniformly found all over the body surface for Steegman (1965) found no significant relation between subcutaneous fat and surface temperature in the face.

Thus, one of the initial mechanisms in protection against cooling is a combination of reduced blood flow and increased tissue insulation. Subcutaneous fat is of special value in providing insulation.

In addition to these mechanisms, vasoregulation has recourse to a countercurrent heat exchange system. This mechanism, well developed in sloths and aquatic mammals, is of considerable value to man (Schmidt-Neilsen 1963). Heat conservation is accomplished by

shifting returning venous blood flow from the surface veins to the deeper venae comitantes which are closely associated with the arteries (Bullard 1963: 585). This close association of arteries and veins favors a heat exchange which warms the blood bound for the core and precools the outgoing blood. The effectiveness of this mechanism was demonstrated by Bazett and associates (1948) who report a 3°C/decimeter change along the radial and brachial arteries during cold exposure. The combination of vasoregulation mechanisms are so effective that upon their employment an increase in rectal temperature of 0/5°C may result (Bullard 1963).

Response to Cold Stress: Increased Heat Production

When environmental temperature falls below the critical temperature, these vasoregulative mechanisms are inadequate and the human body must respond through greater heat production. The resting and fasting male may be expected to produce about 1.0 to 1.2 Cal/min. (Lucas and Ridout 1961). As previously noted, this is the "basal state" and "basal heat production." The most rapid and effective way for production of more heat is by voluntary exercise, the heat producing qualities of which are well known and need not be discussed here. Let it suffice to note that violent exercise may increase the metabolic rate by a factor of 32, resulting in a heat production increase from 1.17 Cal/min. at the basal level to 37.94 while running (Consolazio, Johnson and Pecora 1963: 330). This is adequate heat production for any cold environment in which man is likely to find himself.

Such voluntary activity cannot go on for long periods of time and when it becomes restricted, shivering will be mobilized to make up the heat deficit. Shivering is a regular muscular tremor normally varying from 7 to 13 cycles/sec. with a mode of 10 cycles/sec. It is preceeded by a tonic contraction which prepares the muscle for heat production (Stuart and others 1963). The contractions remain constant and are synchronous in antagonistic muscle pairs so that there is limited movement. Shivering may lead to a four to five fold increase in oxygen consumption, which suggests an appreciable increase in heat production (Horvath and others 1956; Impietro and others 1960). This increase in heat production is progressive for Glickman and others (1967) report beginning with a basal heat production of 35.4 $Cal/m^2/hr$ which increased in the following sequence throughout a severe exposure to cold: end of one hour 54 $Cal/m^2/hr$; end of two hours 72 $Cal/m^2/hr$; end of three hours 92 $Cal/m^2/hr$ and end of four hours 96 $Cal/m^2/hr$. Despite such great increases in heat production, shivering does not significantly increase the heat content of the body, and its warming capacity is limited. Horvath and others (1956) balanced extra heat produced by shivering against post-exposure heat depth and estimate shivering to be only 11 percent efficient. This may be the result of increased blood flow to the muscles and the resulting rise in conductive heat loss)Burton and Bazett 1936).

A second, but less well defined source of heat production is non-shivering thermogenesis. Hemmingway and Stuart (1963: 408) have defined non-shivering thermogenesis as "an increase in cellular metabolism without muscular movement," which suggests some adjustment at

the cellular level (Barbashova 1964). This mechanism, which homeotherms probably inherited from reptilian ancestors (Smith and Hoijer 1962), is well established in rats and has only recently been seriously studied in man (Cottle and Carlson 1956). Davis (1963) has summarized a series of studies in his laboratory and offers two kinds of evidence for its existence: (1) of 36 individuals who were exposed to severe cold, 21 showed no signs of shivering but maintained a metabolic rate above the resting level; (2) numerous other studies have indicated a systematic decrease in the level of shivering with increasing amounts of exposure. This evidence is interpreted to show that with increasing exposure, a non-shivering mechanism gradually takes up more of the heat production. Hemmingway and Stuart (1963) question the existence of such a non-shivering mechanism on the basis of a literature survey. They report that the shivering mechanism may increase metabolic heat production more than 400 percent, while the non-shivering mechanism is always reported to increase it less than 100 percent. Therefore, even if the non-shivering mechanism exists it is not of much importance when compared to shivering. The forces of their argument is diminished when it is recalled that shivering is only 11 percent effective in warming the body. This would credit shivering with an increase of 44 percent, about the same level typically reported for non-shivering mechanisms.

The locus of non-shivering thermogenesis is not precisely known, but it is most certainly located in the core (Smith and Hoijer 1962) where its effectiveness is maximal. It has frequently been noted that

various organs of the viscera increase in size and oxygen consumption when the animal is cold stressed for long periods of time (Kleiber 1963; Smith and Hoijer 1962). This suggests greater heat production. Organs involved seem to be the heart, kidneys, muscles, and endocrine glands; the contribution of the liver being questionable (Depocas 1960). Fat tissue and fatty acids are also suspected (Masoro 1965).

Responses to Long-Term Cold Exposure

Extended exposure or residence in cold climates may lead to "acclimatization" which may be defined as "The physiological response of the organism associated with repeated exposures to environmental stress" (Consolazio, Johnson and Pecora 1963: 432). Despite this clear definition and a host of studies, it is impossible to give a clear picture of acclimatization in any human population (Carlson and Hseih 1965; Buskirk 1966). This is the result of the myriad of test procedures utilized and of the frequent failure to control a number of important variables (Buskirk 1966).

One aspect of cold acclimatization has already been discussed under the name of non-shivering thermogenesis. This mechanism is seen only in animals and men who have been exposed to cold temperatures for considerable periods of time. Davis (1963) reports significant mobilization of the non-shivering mechanism after 31 days of cold exposure in man. Other studies have included rats whose exposure has been life long (Cottle and Carlson 1956). Its central role in cold acclimatization has been stated as "The basic difference between the

acclimatized and the non-acclimatized mammal is an improved capacity of the former to increase his non-shivering heat production before he has to resort to physical thermogenesis" (Hannon 1963: 470).

The most easily demonstrated physiological change which results from long-term cold exposure is in peripheral blood flow to the extremities. Acclimatization in the hands has been demonstrated in Americans, both White and Colored (Impietro and others 1959), in Eskimos (Egan 1963) and in Japanese (Yoshimura and Iida 1952). The standardized test has been for the acclimatized and unacclimatized subjects to immerse their hands in some cold environment (usually ice water) and to measure the changes in temperature of their fingers. The unacclimatized subject will undergo a severe vasoconstriction and the temperature of his finger will approach that of the water, while the finger of the acclimatized subject will show an initial constriction. This fluctuation in blood flow maintains the average temperature of the acclimatized hand far above that of the water (Lewis 1930). Figure 1 illustrates this reaction in a group of English fish filleters who dip their hands into ice water each day. They are compared to a group of students who never do. Both groups immersed their hands in ice water for 10 minutes. It is easily seen that the hands of the filleters remain much warmer than those of the students (Nelms and Soper 1962). This local acclimatization of the hand seems to have a three fold function: (1) to prevent cold injury, (2) to limit heat loss through the hand, (3) to retain a more normal hand function in cold environments (Hanna 1965). Surveys of peoples native to cold

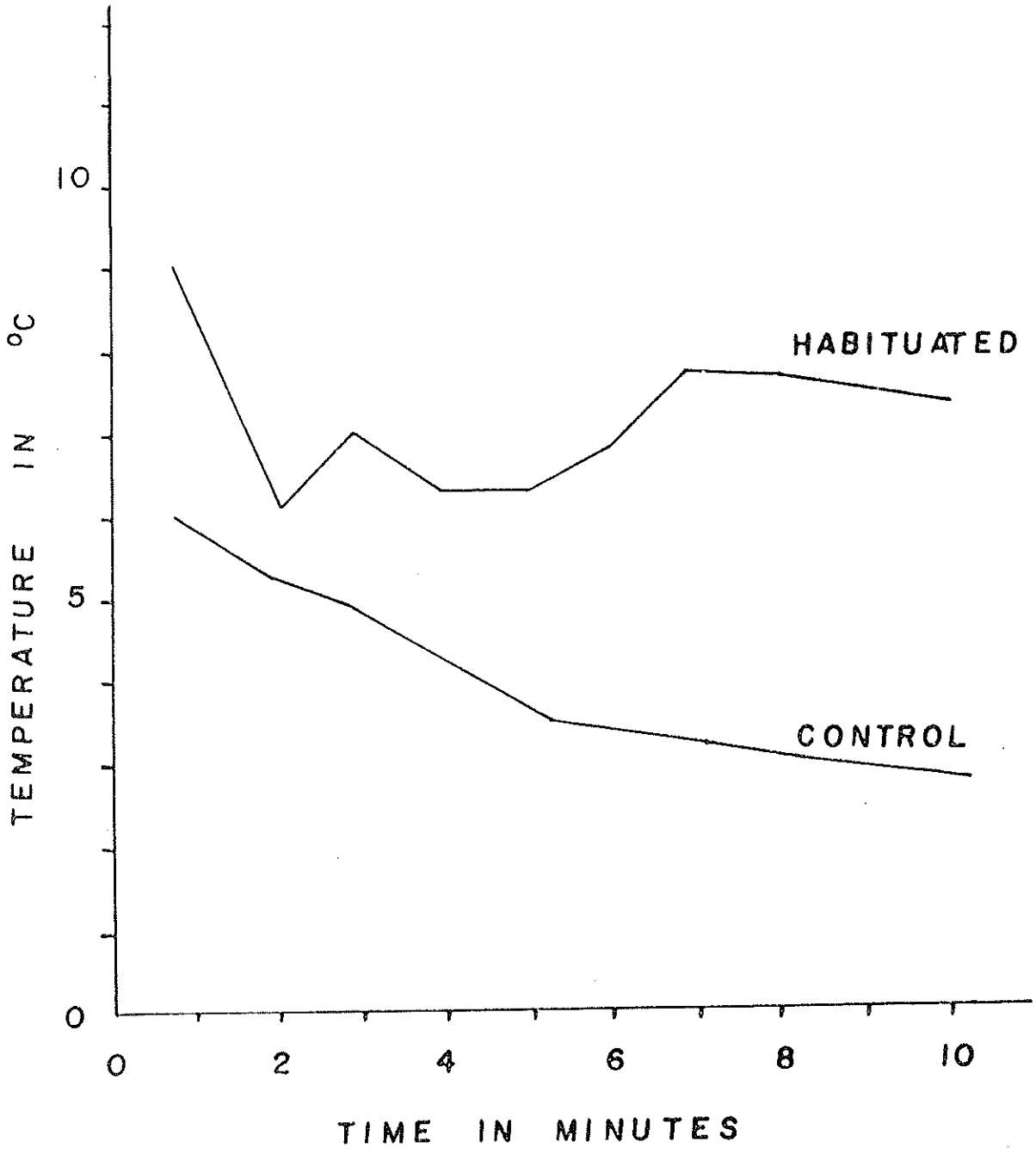

Figure 1. Finger temperatures during ice water immersion in habituated and control subjects.

climates show that they are more likely to react as filleters than are students (Carlson and Hsieh 1965).

Although such local acclimatization is well established, there is no clear picutre of the effects of chronic cold exposure over the entire surface of the body. This is the result of dissimilar testing siuuations and unequal amounts of exposure as has already been noted.

From what is known of acclimatization to heat it appears that there are two variables which may influence acclimatization. They are extremity of temperature and duration of exposure (Leithead and Lind 1964). Failure to control both can lead to incomplete acclimatization and erroneous conclusions (Lind and Bass 1963). It would follow that a similar phenomenon could exist in cold acclimatization. Failure to induce full acclimatization could account for the variety of results seen in the literature.

At this point, it will be helpful to define several terms which are frequently used in studies of cold exposure. Burton and Edholm (1955) have classified changes in physiology which lower the amount of stress experienced by the organism living in a cold environment as: (1) habituation-behavioral responses to short-term exposure, (2) acclimatization-responses to short-term exposure, (3) acclimation-responses to long-term exposure, and (4) adaptation-changes resulting from exposure over many generations. These are expected to be genetic in nature. It will be helpful to add another definition to this list. (5) Full acclimation-maximal changes possible after long-term exposure to severe cold.

With this in mind, a final term may be defined as (6) natural level of acclimation--the state of acclimation produced by the amount of cold stress encountered by members of a population as they go about their daily activities.

This term has been used in a similar manner by Strydon and Wyndham (1963) in a discussion of heat acclimatization.

If cold acclimation can be thought of in terms of the above continuum, then it is evident that all humans will fall somewhere between the two extremes. The point at which they fall will be their natural level of acclimation. The concept may be applied to individuals or to populations. In terms of populations the natural level of acclimation would be the arithmetic mean of the responses of the entire group. A population may be defined as all of the members of a particular town, all of the male children from 1 to 5 years of age or simply all of the men engaged in Army exercises in Alaska during Operation Muskox.

Definition of the Extremes of the Continuum

With the premise of a continuum in mind, it becomes necessary to survey the literature for examples of the two end points. If severe exposure for long periods of time produces full acclimation, the study of Wyndham, Plotkin and Munro (1964) seems to fulfill these criteria. Five South Africans were tested before and after six and twelve months in Antarctica. During their stay they were observed to wear progressively less clothing and on occasions "to frolic naked" in the snow on windless days. In terms of the above criteria, one

year seems adequate for acclimation inasmuch as exposure was considerable. The statistical treatment of the authors is somewhat inadequate; however, their graphic manner of presentation allows the following interpretation. After six and twelve months residence, when tested at low temperatures (5°C.), they showed a lower metabolic response to cold, lower rectal temperature, and a lower skin temperature (except for the temperature of the toe, which was higher). The group showed the same pattern of change when compared to their own pre-exposure reactions and when compared to a group of unexposed Whites from South Africa. They were tested at a number of temperatures ranging from 28 to 5°C, but these exposure-induced changes in physiology were observed only at the coldest temperatures. Therefore, it seems that full acclimation to cold will be evident only under cold temperatures and studies should be evaluated in terms of the levels of cold stress which they impose on their subjects.

There are some other investigations which seem to support the results of Wyndham, Plotkin and Munro. LeBlanc (1956) also found similar changes in metabolism and temperatures of soldiers after a winter in the arctic regions of Canada. The exposure of LeBlanc's subjects seems unique in that they were required to remain stationary for long periods of time (while on guard duty) and suffered from considerable cooling. Davis (1963) also reports similar changes with long term, intensive cold exposure.

At the other end of the continuum, the reactions of unacclimatized European males are well known (Scholander, Hammel, Lange-Andersen

and Loyning 1958). He suffers from a falling skin temperature (especially toe temperature), no great change in rectal temperature and a considerable increase in metabolic rate. If these represent the acclimated and unacclimated poles of the cold stress spectrum, it might be possible to use this model to explain some of the variety found in supposedly well acclimated groups. For example, Rennie (1958) compared a group of soldiers on arctic bivouac with a group of non-exposed controls. The two groups were almost identical in reaction except for the significantly higher hand and arm temperatures of the cold exposed group. An interpretation in terms of the model proposed above would be as follows. Soldiers on bivouac reacting in the same manner as nonexposed soldiers suggests that they had not become acclimated. This might be expected because soldiers in the arctic wear full arctic gear and engage in vigorous activity while outdoors. They would not normally suffer total body cold exposure but more likely, they would experience some local cooling of the extremities -- the hands and feet. They would appear unacclimated except when extremity cooling had been severe enough to occasion local adjustment. This is what Rinne reported.

Another study of cold acclimation by Iampietro, Bass and Buskirk (1957), five subjects were placed in a 15°C cold room for two weeks. They were exposed nude for 24 hours per day. The subjects showed no significant change in rectal or skin temperatures; however, they did show a typical unacclimated pattern of a high metabolic rate which began to decline after one week of exposure. It was still slowly declining at the end of the two-week period when the test

terminated. This could represent an intermediate stage of acclimation where heat production decreases to be followed by falling skin and rectal temperatures.

Utilizing the continuum model proposed above, it might be possible to organize the mass of acclimation data which is currently available. Unfortunately, it is not possible to do so here.

Summary and Conclusions

This chapter has attempted to outline some of the dynamics of heat exchange and certain aspects of temperature regulation as they apply to man. It has been proposed that analysis of reactions to cold stress can be undertaken by conceptualizing the human body as consisting of an inner, heat producing core and an outer, insulative shell. It has been shown that, as temperature falls from a neutral point of about 34°C (93.2°F), various mechanism are invoked to prevent excessive cooling of the core. The first of these are a reduction of blood flow into the shell and the mobilization of a countercurrent heat exchanger system. As the temperature drops to lower levels and the critical temperature is passed, other heat producing mechanisms are called upon. In the absence of voluntary exercise, which serves to increase metabolism, shivering and perhaps nonshivering thermogenesis are utilized. Some aspects of long-term reactions to cold stress have been discussed, and it has been proposed that a continuum may be constructed. At one end of the continuum is the completely unacclimated man and at the other end is the fully acclimated man. All living humans must fall somewhere between these two

points. Finally, some of the acclimatization studies reported in the literature were analyzed in terms of this model and their results explained in terms of it.

All of the material discussed has been collected on what is essentially the same population-Whites of European ancestry. It will be most helpful to examine some of the information which has been collected as non-Europeans.

CHAPTER 3

COLD RESPONSES OF PEOPLES OF NON-EUROPEAN ANCESTRY

Milan (1964) has summarized the physiological responses of various peoples to the cold. The following discussion is a basic re-examination of the data which he compiled.

Eskimos

Because Eskimos inhabit one of the coldest regions of the earth, they have attracted much attention and are well known in terms of cold physiology. Eskimos survive with the aid of a complex material culture system ranging from artificially heated, wind-tight houses to the best cold weather clothing in the world. Stefansson (1953) found the microclimate in which they live to be relatively warm and subsequent studies have confirmed his observations. Rodahl (1958) measured various types of dwellings commonly used by the Eskimo and reports about 21°C mean interior daytime temperatures and about 10°C mean interior nighttime temperatures. Indoor temperatures do not frequently appear below freezing. Milan (1964) reports that in the course of daily exposure, Eskimos carry a tropic microclimate and are not cold stressed. In spite of this effective protection, it is unlikely that the Eskimo can escape cold completely, especially during winter seal hunting and ice fishing (Jenness 1928).

Eskimos are chiefly hunters of arctic game and provide themselves with considerable quantities of fat and meat. In unacculturated conditions it is estimated that the Eskimo derived about 50 percent of his daily calories from fat and most of the rest from protein (Rodahl 1958: 209). There seem to be no deficiencies in his diet, and he consumes about 2,800 to 3,000 Calories per day, about the daily recommended allowances by the F.A.O. The high fat and protein intake might be expected to increase heat production (Mitchell and Edman 1952). This adequate diet has not always been the rule for starvation has been a constant spector in the Eskimo culture (Jenness 1928).

The reactions of Eskimos to cold stress at their natural levels of acclimatization are well documented. The most outstanding feature of these physiological responses seems to be a 20 to 40 percent increase in basal metabolic rate (BMR) over American White standards (Milan 1964). The locus of this extra heat production is most likely the protein rich diet; however, other factors may also be important (Rodahl 1952). In addition to maintaining a high metabolic rate, the Eskimo also responds more rapidly and more vigorously when exposed to cold (Adams and Covino 1958). As a complement to this high heat production, the Eskimo exhibits a high core to shell conductance which may be 60 percent greater than that of the unacclimatized White (Rennie and others 1962; Milan 1964). This may also be manifested in a high rate of blood flow to the extremities (Brown, Hatcher, and Page 1953).

Eskimos show very high finger temperatures when they are subjected to the ice water immersion test. They maintain higher hand and finger temperatures than White controls before and during immersion (Meehan 1955). This pattern persists after several months residence in a milder climate (Egan 1963). The result of these warmer hand temperatures is an increased resistance to cold injury and a greater manipulative ability in the cold (Coffee 1955). The Eskimo may also possess a more effective heat exchanger system (Brown and others 1963).

The results of this series of adjustments is seen when Eskimos and Whites are compared under standardized conditions of cold stress. Adams and Covino (1958) compared nude Eskimo and White subjects in a 17°C cold room. For 30 minutes the subjects were covered with two blankets and were comfortable, then the blankets were removed and they were exposed to the ambient temperature for two hours. The Eskimos were observed to maintain higher rectal temperatures during both the control (comfortable) and test periods. They also showed a significantly higher metabolic rate which increased heat production long before the Whites. The essential points of these differences have been confirmed in a controlled temperature water immersion bath by Milan (1964).

The particular responses of the Eskimo to cold stress seem ideal in terms of the environment in which he lives (Milan 1964). The high heat production and high conductivity enable him to expose various body members to the extreme cold of the arctic winter and not

risk their loss due to frostbite. He is also able to remain immobile for long periods of time without suffering from falling extremity temperatures. This series of adjustments is energy consuming, but this seems to present no real problem.

In none of the studies of Eskimos is there any attempt to acclimate him beyond his natural state of acclimation. Because of an effective material culture it is doubtful that he is fully acclimated under natural conditions. A severe, long duration cold stress might induce other types of reactions.

Alacaluf Indians

At the other end of the Americas is Tierra del Fuego, the home of numerous bands of hunters and gatherers. These Indians are rapidly disappearing through contact with the Western world and the problems this brings. European diseases have decimated their number and those who remain are rapidly assimilating European culture (Santiana 1962). Fortunately, most of this process has occurred only recently, and many of the surviving Alacaluf are still engaged in traditional activitees.

Before intensive contact the Alaclauf inhabited numerous islands and inlets along the west coast of southern Chile. Fifty year records suggest that "all stations report mean daily temperatures at least 4°F (2.3°C) above the freezing point during over half of the days of each of the winter months. During the same winter months the minimum temperature falls below freezing on less than half of the days although it is below 36°F (2.5°C) nearly every day" (Mather 1954:

311). These low temperatures are accompanied by considerable rainfall and the climate is comparable to the Northwest Coast of Canada. While this is a mild climate in relation to the Arctic, it presents a problem to a people with a primitive technology.

Before Western contact the Alacaluf were hunters and collectors of sea foods. Foods consisted of "Sea food, seals, stranded whales, otters, sea birds, fish and shellfish such as mussels, limpets, and sea urchins (Hammel 1960: 1). For clothing they used small capes of seal, otter or fox skin which covered on the shoulders and chest. Foot coverings were infrequent and head coverings were never used. Children frequently ran about naked (Mather 1954: 310). Their yearly migrations in open canoes gave them the name of "nomads of the sea" (Santiana 1962).

Houses were made of wooden ribs covered with branches of trees and bushes, topped with seal skins. The base of the house was usually a circular pit about one and one-half meters deep. The floor was lined with branches, covered with seal skins and a fire was constructed in the middle (Panyella 1961).

The physiology of temperature regulation under cold stress of the Alacaluf has been studied by Hammel (1960). When compared to the unacclimatized White man, the Alacaluf initially showed a 50 to 100 percent greater metabolic rate which gradually declined, a lower average skin temperature, a higher foot temperature and a similar rectal temperature. Elsner (Hammel 1960: 32-33) reports that hand and foot immersion in cold water indicated a similar heat output for the Alacaluf and Whites; however, the former admitted less pain.

Another experiment immersed an Indian in sea water (8.2°C) and according to the author "He was active all of the time, swimming and diving but revealed no apparent discomfort caused by the exposure. His rectal temperature was hardly affected by the immersion and his skin temperatures (foot, leg, and thigh) immediately after the end of the exposed period were remarkable high, all more than 7°C above the water temperature. Unfortunately, no White man volunteered to compare himself with the Indian in this test" (Hammel 1960: 32). This apparently represents a common activity for pre-contact Alacaluf.

The Alacaluf were also studied under conditions of daily life. In one case, skin temperatures were measured during a night's sleep. Skin temperatures were somewhat below those considered comfortable for sleeping Europeans but not below those acceptable during daily activity. House temperatures frequently fell near freezing. In another study the skin temperatures of children were measured as they engaged in daily activities. Again, their skin temperatures were below those expected for Europeans but not so low as to be uncomfortable.

Athapaskan Indians

In northern Canada contiguous with the Eskimos and extending into the interior regions of the continent live the Athapaskan Indians. During the winter temperatures of -40°C are not uncommon and snowfall if frequent and heavy (Honigmann 1954: 14), but there are periods of windlessness to ameliorate the intense cold. The aboriginal peoples are chiefly hunters and gatherers. A very large portion of their winter diet came from animal foods ranging from moose and rabbit to

fish. They made pemmican of meat, grease and berries as a hedge against periods of scarcity. Clothing was similar to that of the Eskimo with several layers of leather topped with a parka as winter dress for both sexes. Aboriginal housing consists of excavated caves or "inverted V" shaped houses of which the sides and roof were covered with moss and sod to retain heat. A fire was maintained in the center of the dwelling. Unfortunately, there is no way of estimating the amount of actual cold stress experienced by the Athapaskans, but it would appear that clothing and housing were sufficient. It might also be supposed that they would suffer stresses similar to those felt by the Eskimo during hunting or traveling.

The BMR of these arctic Indians has been observed to be 10 to 14 percent higher than a comparable group of Whites (Milan 1964; Egan 1963; Andersen 1963), however this difference disappears if lean body mass rather than surface area is chosen as the reference standard (Elsner, Andersen and Hermansen 1960). When compared to unacclimatized Whites during 8 hours of cold stress, arctic Indians showed similar (but slightly lower) rectal temperatures; similar average skin temperatures, except for the foot which was higher; and similar core-shell conductance (Andersen 1963; Milan 1964). When Indians and Whites place their hands in ice water, the former show higher blood flow, even if the Whites are well habituated (Egan 1963). The cold reactions of the Athapaskan Indians have been studied in the fall when acclimatization is lowest (Irving and others 1960) and in the spring when it is the greatest (Elsner, Andersen and Hermansen 1960).

There was a tendency toward greater heat production in the spring but no significant seasonal differences were noted. Nor were there seasonal changes in rectal temperature. Only in maintaining a higher foot temperature did the Indians tested in the spring differ from those tested in the fall. These seasonal differences are similar to those found in Whites (Davis and Johnson 1961).

Lapps

The Lapps live in the isolated northern portions of Norway, Sweden, Finland and western Russia. Many of them are nomadic reindeer herders and follow the herds during their yearly migrations (Itkonen 1951). The climate is severe during the winter and represents a constant threat to the unprotected human. Clothing is heavy and adequate, made mostly of reindeer hides, although woven cloth and wool are used. During the winter the entire body is encased so that only the face is exposed. The nomadic family's dwelling is a conical shaped skin tent which may be warmed by a log fire. There is no information as to the effectiveness of this dwelling as protection against the cold. In some cases more permanent dwellings of logs and spruce branches are constructed. Diet consists largely of reindeer products augmented with wild game, gathered plant materials and bartered rye flour.

Temperature regulation in the Lapps has been reported by Andersen (1963). A group of nine nomadic Lapps was compared to a group of city dwelling students who volunteered as controls. The results were: Lapps slept better and produced slightly less metabolic

heat than did the controls. Skin temperatures were similar except for foot temperature which was higher in the Lapps. The Lapp rectal temperatures declined more than did that of the controls. A group of village Lapps, who were presumably less cold exposed, were intermediate in reactions. Little difference was reported in blood flow to the hands when Lapps were compared to controls. It is noteworthy that the responses of the Lapps seem similar to those of fully acclimated Whites already discussed.

Australian Aborigines

Australian Aborigines have attracted investigators because of their primitive technology and archaic morphology (Coon 1962). Decades of study have provided considerable detail on their physiological reactions to cold.

The Aborigines are of interest in the present discussion because the groups which inhabit the central deserts endure near freezing nighttime temperatures without very much cultural protection (Hicks 1964). Even during the colder night of the year they sleep nude, under the open sky with only small fires and a windbreak for protection. There is considerable potential for cooling, especially from convection and radiation.

The diet of the precontact Australians is not well known. Ethnographic accounts dating from the early part of this century show that they were typical hunters and gatherers, deriving a large amount of their daily calories from plant foods (Spencer and Gillen 1912;

Mountford 1951). In spite of this in a recent survey, Macpherson (1966) states "The pre-European Australian aboriginal neither tilled the soil nor husbanded any domestic animals, but lived by the chase. His diet, in consequence, was essentially meat (and fish in littoral communities), supplemented by what fruits or roots the women folk could gather" (1966: 444). At this time there is not adequate information available to support either viewpoint.

Studies conducted early in this century of Aborigines living under aboriginal conditions have recently been summarized by Hicks (1964). The experiments were undertaken during the late evening or early morning, before or after the period of maximal nighttime cold stress, but they give ample evidence on the abilities of the aborigine in the cold. In one case it is reported that the Australians were able to sleep comfortably with skin temperatures below those considered cold by Whites. They also moved less and did not increase metabolic heat production through shivering. In another study when placed in tents, sheltered from wind and radiation heat loss, Aborigines and Whites responded to cold in the same manner. The only measurable difference was a lower pulse amplitude in the radial artery of the Aborigines.

A second and more recent series of studies undertaken by P. F. Scholander and others (1958b) has illuminated the responses of Australians to cold stress even more. Under controlled conditions, they compared Aborigines and Whites. Both groups were placed in thin sleeping bags in intense cold. The Whites showed the expected reaction of unacclimatized Europeans-increased heat production,

falling skin and rectal temperatures. The Aborigines showed declining heat production accompanied by declining skin and rectal temperatures. The Whites complained and thrashed about during the eight hours of cold exposure, while the natives slept soundly. Clearly the two patterns are distinct. The Whites attempt to keep warm by increasing heat production while the Australians allow themselves to cool slowly. This second type has been called insulative acclimatization (Hammel 1961) and is supposed to illustrate the reliance of the Aborigines upon lowering heat loss through restriction of blood flow. Hammel (1964) thinks that this might be the pattern of cold response developed while our ancestors still lived in tropic habitats and suffered only nighttime cooling.

This study also investigated the relation of material culture to cold stress (Scholander and others 1958). Natives and White controls slept nude between fires in typical aborigine fashion. While the Australians snored and slept soundly most of the time, the Whites were always uncomfortable and had difficulty sleeping. The controls found that frequent stoking of the fires was necessary for sleep.

The unique Australian pattern depending upon tissue insulation and vasoconstriction rather than upon heat production stimulated further investigation. The second series of studies were undertaken to determine whether the greater body cooling without metabolic compensation was seasonal and whether this condition would be found in the tribes living in more tropical areas (Hammel 1961).

Tests conducted during the summer disclosed that the winter pattern was not seasonal. Low skin temperatures in the absence of

a metabolic response was almost identical. The investigators then went to the Northern Australian coast where tropical climate and housing preclude chronic cold exposure. The tropic Aborgines did not differ from the White controls in either rectal temperature or in body temperature. They did show the same central Aborigine pattern in terms of metabolic decline and lower conductance. The particular Australian pattern was concluded to be racial in origin.

Bushmen

Like the Australians, the Bushmen have excited speculation as to their abilities to withstand the cool nights of the Kalahari Desert which is their home. The diminutive Bushmen represent the remnants of an earlier population which is supposed to have ranged over the entire area of South Africa. They retain various distinctive characters such as yellow-brown skin color, short stature, peppercorn hair, medial epicanthic folds and steatopygia (Tobias 1966). They are so distinct from surrounding populations that they are frequently given separate racial status (Coon 1962; Garn 1961). About 50,000 Bushmen live in the desert and river areas of southwestern Africa and about half of them are still nomadic hunters and gatherers.

During some periods of the year the temperature of the Kalahari Desert drops to levels which will freeze water, but the Bushmen have only minimal protection against this. In some cases crude huts may be constructed but frequently they are content with a small fire and a skin cloak to cover the torso. The effectiveness of these cultural mechansism has been studied by Wyndham and Morrison (1958).

Environmental temperatures were observed to vary between 10 and 15°C, but with the use of a small fire and a leather cloak, the Bushmen create a microclimate of 25 to 26°C over the surface of the torso. The Bushmen responded to cold with a metabolic increase similar to that of a pair of European controls, and rectal temperatures were observed to decline in both groups. The skin temperatures of the Bushmen tended to be somewhat lower. They were also observed to conduct heat from the core to the shell at a more rapid rate than the controls. It was concluded that "the Bushman has not adapted himself physiologically to the climatic conditions to which he is exposed but has made satisfactory and intelligent use of the meager materials available to him to create a comfortable local climate around his body during the Kalahari nights" (Wyndham and Morrison 1958: 670).

Hammel (1964) reports another study comparing Bushmen and European controls for 8 hours of cold exposure. Both groups showed similar skin temperatures and falling rectal temperatures, but the Bushmen conducted heat from core to shell more rapidly. Average metabolism increases were greater in Europeans than in Bushmen, but the latter slept better. A lack of subcutaneous fat was supposed to be a major factor in the high conductance of the Bushmen. In the most recent study of the Bushmen, Wyndham (1966) reports reactions in agreement with those discussed above except that Bushmen were observed to have higher metabolic heat production per unit of surface area than would be expected for European subjects.

In summation, when compared to unacclimatized European control subjects, Bushmen show falling skin and rectal temperatures

accompanied by an increase in heat production. They show a rapid core to shell heat transfer which may be due to lack of subcutaneous fat.

Bantu

Wyndham (1966) has also studied the Bantu of South Africa. Unfortunately, the individuals studied were recruits for work in the gold mines so the amounts of cold stress they encountered in their native cultures cannot be accurately estimated.

When compared to a group of Europeans over temperatures ranging from 5 to 27°C, the Bantu showed the following reactions: similar toe, finger and skin temperatures; a significantly lower rectal temperature; and increased metabolic heat production above 17°C and below 6°C. This has been supposed to be a similar reaction to the unacclimatized European except for the higher metabolic rate and lower rectal temperature. These differences are probably the result of limited subcutaneous fat deposits.

American Colored

The American Colored cannot be directly compared to the African because of the considerable cultural differences between them (Wyndham 1966). Not only are the Colored well protected in terms of clothing and shelter, but there has been considerable admixture with the European population. Roberts and Hiorns (1962) estimate that the American Colored population may have 23 to 26 percent European ancestry.

The classical study comparing Colored and Europeans was reported by Adams and Covino (1958). Soldiers were selected at random from the population of an Alaskan army base during the summer. Several from each race were selected. They were first placed nude in a 17°C room and covered with blankets for 30 minutes to establish non-stress reactions. They were then uncovered for 120 minutes. Both groups were identical in rectal and skin temperature. Metabolic heat production was equal for the first 35 minutes of cold exposure whereupon the Whites increased and the Colored did not. Only after 85 minutes of cold did the Colored begin to increase heat production and then it was inadequate. It was concluded that Colored allow skin temperatures to fall to lower levels before increasing heat production. This makes it more difficult to make up the heat deficit. These results have been confirmed by Iampietro and others (1959) who exposed Whites and Colored to 10°C for 2 hours. They found no differences in rectal or skin temperatures. They exercised careful selection of subjects so that the groups were identical in terms of body composition factors (especially fat). This resulted in both Colored and Whites maintaining the same level of metabolic heat production.

Meehan (1955) and Iampietro and others (1959) demonstrated that the American Colored are less likely to show the hunting response when their hands are placed in ice water than American Whites.

Plan of Study

This summary of the physiology of cold stress and of the responses of peoples of non-European ancestry shows that there is a considerable amount of variation within the human species. The peoples

studied seem to represent different populations of men living in most types of cold climates. Groups living in severe and mile climates; in humid and dry climates have been examined. Some groups show great differences from others and all seem to respond in individual manners. In viewing these responses it should be remembered that the locus of the differences is not known. Thus, it cannot be assumed that similar responses show an underlying genetic similarity nor that distinct reactions represent different genetic mechanisms. This will not be possible until the relationships between cold response and some genetic mechanism are more clearly defined.

In the first chapter it was suggested that an ecological approach to human variation might prove fruitful. Each variant would be defined in terms of the situation in which it is observed. Returning to that definition, it was stated "Human ecology seeks to understand man and his problems by studying individuals and populations..." The data summarized in the two preceeding chapters shows ample information on the responses of individuals but almost none on the responses of populations. This concentration on individual variation is understandable because population analysis is costly and time consuming; however, the complete neglect of population parameters could lead to erroneous conclusions. Thus, Hammel's (1964) evolutionary sequence is based upon supposed types of responses. These types have empirically established through studying adult males living in various parts of the world. Aside from the obvious problems associated with typological thinking (Schreider 1966), there are other, equally objectionable, assumptions inherent in this method of sampling.

First, it must be assumed that adult males represent the entire population in their responses to cold. There is considerable evidence that they do not. Any human population consists of biological seg-ment ments, biologically based subpopulations. The most salient of these, age and sex groups. are biological phenomena which are known to produce distinct physiological reactions to cold (Buskirk 1966). These also represent divi .ions of labor in human societies and, as such, could produce distinct activity patterns. A combination of biological variety and culturally prescribed differences in activity patterns might lead to different microclimates in different segments. Thus, different segments may well live in diverse microclimates and experi- distinct life histories of cold exposure. They would, therefore, respond to cold in distinct ways.

A second assumption is that males collected in one area live in the same microclimate as do peoples from other areas. They are assumed to be "typical." This might be the case in a uniform environment, but if the habit is extensive or the environment is variable, segmentation into subpopulations might take place. This has been seen above where Australian Aborigines from different parts of the continent responded in distinct manners. Aside from climate, economic and ecological factors produce variation. Thus, as was seen in the Lapps, groups which differ in economy may respond in different manners even if they are from the same population. Such climatic or ecological variation could not be detected from either small size random samples (which has characterized most studies) or from sampling from one local population segment.

The present study will try to examine these two assumptions and try to determine the amount of variation which may characterize a human population as it is exposed to cold stress. The study will inquire into the responses of some of the major segments of the population. These segments will be studied in natural conditions so that the underlying ecological relationships are exposed. To provide greater control of some variables, laboratory studies will also be utilized. In accordance with the ecological concepts presented in the first chapter, three aspects of variation will be investigated. They arise from the physical, biological and cultural environments. Through the study of these influences it should be possible to estimate the amount of population homogeneity and illustrate some of the factors promoting variety.

CHAPTER 4

THE BIOLOGY AND CULTURE OF NUÑOA

Introduction

The present study was undertaken during 1967 when the author was in the Highland regions of Peru. During that period I served as Field Director for a long-term research project on the Quechua. The project was undertaken by Dr. Paul Baker of the Pennsylvania State University under Contract Number DA-49-193-MD-2260, which was supported by the U. S. Army Medical Research and Development Command.

Investigations were carried out from a laboratory situated in the town of Nuñoa, Melgar Province in the Department of Puno, Peru. There are several factors which make this area and this population of interest to anthropologists. The climate is inhospitable for humans in the absence of some technological protection. There is no natural source of fuel so that some means other than heating of houses must be utilized. Baker (1966b) has shown that during certain seasons the technological protection is inadequate and some segments of the population experience cold stress. Yet, despite the cool climate and the inability of culture to fully protect the population, it remains stable which suggests that some form of adjustments have been made. This chapter will discuss the various aspects of cold in Nuñoa and will outline some of the biological and cultural parameters of the population which seem relevant.

Geography and Climate

Nuñoa consists of two broad valleys and the surrounding mountains. The base of the valley is at 13,150 feet above sea level and the peaks of some mountains rise above 19,000 feet. The area has been intensively studied by Baker and others (1965) whose report provides most of the available information. The district is composed of a central town and the surrounding rural area. The total area is 158,183 hectares with 340 under cultivation, 157,535 for pasturage, and 308 unused.

The district is part of the Altiplano, a broad high plateau which drains into the Lake Titicaca basin on the south. The plateau is a series of broad valleys cut by streams and marshes and surrounded by rounded hills and high mountains on the flanks. These elevations provide rain traps for the moisture-laden Amazon winds and there is a heavy run-off to the valley floor. The area is called puna after a short grass which is the dominant vegetation. Mosses and lichens abound, together with a few herbaceous plants and diminutive native trees. There is no marked seasonal change in plant life. Fauna include deer, vicuna (a cameloid), various small rodents and a few other species of small mammals. There are numerous birds, and trout abound in the streams.

Climatic data is constantly being collected, but as of this writing no significant information has been published beyond an incomplete four month survey undertaken in 1964. Baker (1966b: 68) refers to a more complete unpublished study. (included as an appendix in this report).

> Based on a one year record, the mean annual temperature at 4,000 meters was 7.8°C with a 6.1 degree average for July and 8.0 degree for January. Diurnal variation is greatest during the dry season which begins in May and lasts until early December. During July the mean maximum was 15°C while the mean minimum was -3.1°C. The January mean maximum was slightly lower at about 14°C, but the mean minimum rose to nearly 2°C. There is little day to day change with an absolute maximum during the year of only 20°C and an absolute minimum of -8°C. Precipitation is frequent during the rainy season, falling mostly as rain during the day and snow at night.

Thus, it appears that the climate is cool and could be dangerous to the unprotected human. The periods of greatest potential cold stress are during the nights of the dry season when the temperature falls below freezing and in the wet season when rain and snow are accompanied by cool temperatures.

Demography

The only demographic information on the Nuñoa region is presented by Baker and others (1965); the following discussion is based upon that monograph. The district has 7,750 inhabitants, the majority of whom are Quechua Indians. The central town of Nuñoa is typically Spanish in design, being laid out in a grid system with a central plaza. This plaza is surrounded by small stores, administrative offices and a church. It is, therefore, a cultural focus for the district. Its 2,137 inhabitants are mestizo and Quechua, but predominantly Quechua. The rest of the population of the district numbers 5,613 people and is scattered in various rural areas.

The population has a high birth rate and death rate. Thus, 47 percent of the population is under 15 years of age and less than

5 percent is over 50. In a sample of 276 individuals, the mean age was 25 or partitioned by sex, 21 years for males and 29 years for females. The overall sex ratio is 97 males per 100 females, but there are age specific variations. Thus, between 0 and 15 years of age there are 121 males per 100 females, but during reproductive years of 16 to 50 the ratio reverses with only 78 males per 100 females. This reversal in sex ratio is attributed to higher rate of male migration, male activities which take them from home, or higher male mortality.

The population is clustered along the numerous streams which drain the valley floor. These valley residents are sedentary and practice a limited amount of agriculture. The most important crops are potatoes and native grains such an canihua and quinua. In addition to farming the valley residents engage in herding sheep, llamas and alpacas. Most families have at least one horse. Above 14,000 feet agriculture cannot be practiced and the economy is based entirely upon herding. The same animals found in the valley are used here but in greater numbers. Much of this high altitude land is owned by large haciendas who require the pastors to care for hacienda herds along with their own. Such large herds of animals occasion frequent moving due to depletion of grass so the population remains somewhat mobile. No estimate can be made at this time as to the amount of altitude change involved in moving the herds to new pastures.

This natural line at 14,000 feet divides economies but does not divide the population. One surprising aspect of Nuñoan life is

the mobility of the natives. Most families have horses and the adult males are frequently seen riding to town, the rest of their families walking behind. The ubiquitous trucks which serve mines in the most remote regions are always loaded with human as well as mineral cargo. Indeed, one of the greatest problems in the field studies was finding space for theiinvestigators after their truck had been filled with Indian travelers and their copious bundles. This frequent traveling has a long history as is evidenced by the well worn foot paths which pass through every valley and climb every hill. Isolated populations probably do not exist.

Biology

Despite the efforts of Baker and others for over five years, there is no morphological description of the Nuñoa population which has yet been published. Some anthropometric information is available from the reports of Baker and others (1967) and Frisancho (1966) but these are limited in size and scope. To compound the problem there is no adequate comparative material. Steggerda (1950) lists only stature and cephalic index for less than 500 Quechua.

More information is available on growth. Baker and others (1965) report a growth study on a limited number of children from the Nuñoa region. The first part of the report compares the height and weight of Nuñoa children with a Quechua group from lower altitudes and with U. S. standards. Until mid-teens the Nuñoa Indians are lighter and shorter than the other two groups, but a longer growth

period brings them to the level of the Indians of lower altitudes. In neither Quechua group is there a significant dimorphism in secondary sex characters until about 16 years of age, a date somewhat later than is expected for American youth. Another interesting phenomenon is the extension of the growth period into the early twenties in both Indian populations.

A second part of the paper deals with the radiographic analysis of the brachium of 78 boys and 68 girls. The pattern of late maturity and late dimorphism in secondary sex characters is also observed in bone, muscle and subcutaneous fat development. Frisancho (1966) increased the sample somewhat and found similar results.

Studies of other highland communities have suggested that the Indians may be suffering from nutritional deficiencies as well as from altitude and cold stress. At Vicos and Chacan, rural highland communities in northern Peru, the typical diet was below United Nations world-wide standards in total calories, protein, calcium and Vitamin A (Collazos and others 1954). If this were the case in Nuñoa, dietary deficiencies might explain the growth retardation. In 1963 Baker and Mazess showed that there were certain sources of calcium not included in dietary studies. Then in a comprehensive survey of 39 families in the Nuñoa region they determined that the quantity and quality of the diet was adequate by world standards and that it was better than any other reported for the highland areas of Peru (Mazess and Baker 1964). The adequacy of the Nuñoa diet is apparently the result of the number of exploited ecological zones which exist in proximity.

Laboratory Studies of Cold Stress

The responses of Nuñoa Indians to cold stress under laboratory conditions have recently been reported by Baker and others (1967). Twenty-six Indian men were compared to 15 unacclimatized American men for 2 hours at 10°C. The White Americans were transients to high altitudes. The two groups were first brought into thermal equilibrium and then placed in the cold environment. Rectal temperatures, skin temperatures and oxygen uptake were measured every 4 minutes. The study was repeated on two different days and the results compared in order to estimate the reliability of the measurements. Indians showed significantly higher foot and toe temperatures which were reflected in higher skin temperature. During the 2 hourscold period the Whites showed an increase in oxygen uptake greater than that of the Indians but when converted to metabolism, in terms of surface area, the Indians produced more heat. The Indians exhibited significantly higher rectal temperatures during first exposure but were similar to the Whites during the second exposure. This could have been an artifact of their being unaccustomed to the apparatus during the first test. It was concluded that the Indians produce more heat (higher metabolic rate) and lose more to the environment through the extremities.

Another study of cold stress in Quechua Indians is reported by Elsner (1963). In this study an 8 hour exposure in a thin sleeping bag procedure was followed. No White control group was used but Elsner projected reactions of Whites under similar conditions.

In average skin temperatures and metabolic rates, the Quechua and theoretical Whites were identical. The Quechua showed higher foot temperatures and much lower rectal temperatures. In the Cuzco area Baker (1966c) compared the reactions of male Quechua Indians to those of a small White control group. The subjects were exposed nude to 14°C for 2 hours while skin and rectal temperatures were measured. The Indians were observed to have higher skin temperatures and slightly lower rectal temperatures. The foot and toe temperatures of the Indians were considerably above those of the Whites. Metabolic data was not collected.

These three studies suggest that when the Quechua Indian is exposed to cold stress, he maintains higher extremity temperatures than does an unacclimatized White. No conclusions may be drawn from rectal temperatures or metabolic rates because these are contradictory.

The effects of cold temperatures on the hands and feet are of considerable interest because traditional Quechua clothing offers no protection to these organs. Yet the Indians show no discomfort and are frequently observed walking barefoot in the snow or washing clothes in an icy mountain stream. Under these conditions the high rate of heat flow to the feet observed in studies of total body cold stress seems especially useful. Thomas (Baker, Thomas and Little 1967) has studied the responses of the Nuñoa residents as they exposed their hands to 0°C air for one hour. They were compared to American Whites and to sea level Quechua of Andean ancestry. The latter group was assumed to have escaped cold exposure for most of their lives. Subjects were tested once in the morning and again in

the afternoon. When morning and afternoon responses were compared, there was considerable variation in the Indian groups; the coastal Indians had the highest hand temperatures in the morning and the Nuñoa residents were highest in the afternoon. The White group, on the other hand, maintained the lowest temperatures in both the morning and afternoon. It was observed that the reactions of the Whites to cooling tended to be more vigorous than did those of either Indian group. Thomas concludes that Indians tend to maintain higher hand temperatures regardless of residence. This is somewhat different from results reported by Hanna (1965) who found no difference in hand temperature between rural Indians, urban Indians, Whites who lived permanently at high altitudes and White transients at high altitudes. The difference is probably the result of Hanna's use of ice water which is considerably more stressful than air.

Little (Baker, Thomas and Little 1967) studied the relation of age to foot tempterature in Indians from Nuñoa. Again, there were morning and afternoon runs of one hour each at 0°C. The Indians were divided into two age groups on the basis of growth information. The younger group ranged from 7 to 19 years of age and the older from 20 to 62 years. As in the case of hand temperature, there was considerable variation between runs, nevertheless the older Indians always maintained statistically significantly higher foot and toe temperatures than did the younger ones. This was assumed to be related to growth. Currently a White control group is being tested by the same techniques, but the results are not yet available.

Cultural Mechanisms

The Quechua of Nuñoa conform to the general Andean cultural pattern as described by Mishkin (1947), LaBarre (1948) and Adams (1959).

Houses are a most conspicuous cultural mechanism of utlity in withstanding cold stress. In technologically advanced countries the ability to control house temperature assures a tropic microclimate, but in Nuñoa where there is no fuel and the houses are much less elaborately constructed their effectiveness in this respect is of interest.

One of the two dominant forms of houses in Nuñoa is constructed of adobe. They are rectangular in floor plan, about 15 feet wide and about 30 feet long with a gabled roof peak about 15 feet above the floor. The walls are usually plastered with mud and there are no large openings other than the door. The roof is made of grass and straw. In many cases a wooden door is hung so the house is more air tight. The effectiveness of adobe houses as protection against cold has been studied by Baker (1966c). Under climatic conditions similar to those found in Nuñoa, native houses were observed to maintain interior temperatures more than 10°C above the outdoors. During the coldest part of the year when temperatures fell below 0°C, the average minimum of these houses was 7°C. The sleeping Indians covered themselves with sheepskins and blankets and seemed little effected by the cold. The major effect of the house seems to be reduction of heat loss through radiation and convection.

The second house form is a small temporary house with piled stone walls, sometimes sealed with mud, and topped with a straw roof. These are usually circular in floor plan and may be from five to eight feet in height. They are constructed with native materials and may be abandoned with no great economic loss each time the family moves. The effectivenss of these stone houses in the Nuñoa region has been studied by Baker (1966b). After all night studies of 21 houses, it was reported that the average indoor-outdoor temperature difference was only 3.7°C. Thus, temperature of the houses must approach freezing during the cold nights of the dry season. Heating from the cooking fires may partially warm the house, but there is nothing in Baker's data to show that this has any appreciable effect upon the inhabitants. The chief protectiveness of these stone houses would seem to be reduced radiation heat loss and somewhat reduced conductive heat loss.

It is noteworthy that adobe houses would be associated with agriculture and stone houses with pastoralism. This might result in a differential cultural protection dependent upon economy.

As with most other cold exposed populations the Quechua rely upon clothing as a primary cultural barrier between themselves and the hostile environment. Its primacy would seem to lie in production of a warm and portable microclimate.

All native clothing is made of homespun materials produced from alpaca or sheep wool. When worn in layers this should be quite warm. The Nuñoa residents wear a traditional dress which dates from

the middle of the last century and represents a mixture of native and Spanish influences (Adams 1959: 150). Dale (1946: 111-2) has described the basic Andean pattern which is faithfully reproduced by the Indians of Nuñoa.

> The color and design of the dress of both Indian men and women distinguish them from other communities or regions. The man wears woolen homemade pants, a shirt, homemade or bought in a store, a faja of colored design to serve as a belt, a colored poncho over his shoulder and a homemade black or grey felt hat.... The women wear several woolen skirts of black or various bright colors, a blouse of wool of one color and over their shoulders a cape which is fastened in front with a large pin. On their heads they wear hats like the men.... Indian children dress according to the same pattern as their parents.

As noted, clothing is worn in layers. In Nuñoa the men are frequently observed wearing rubber tire sandals but women almost never are.

Very young children, those less than about three, wear a special type of clothing. This is a single woolen tunic which covers the torso but leaves most of the legs and arms bare. In addition, most babies wear the typical Andean stocking cap also made of wool. Since the extremities are exposed and because the garment is of only one layer, considerable cold stress must be encountered by the young.

In addition to these items of material culture, behavioral adjustments to the cold have been observed (Baker 1966c). The sun is of paramount importance in regulation of the life of the people. In ancient Indian cultures, such as the Inca or Tiahuanaco periods, the sun was venerated and worshipped. The contemporary Quechua have abandoned such institutionalized adoration, but nevertheless regulate their lives in relation to the sun. They arise in the morning just

after sunrise and go to bed at sunset. If the day is clear, they spend considerable time outdoors away from the house or they may undertake non-vigorous sedentary activities such as weaving or sewing.

Typical Quechua outdoor activities are vigorous, favoring a greater production of heat so that in combination with insulative value of the clothing, cold stress may be lessened. During the rainy season when the sky is overcast (and there is no agricultural work to do) men may work on public projects such as building roads or schools. Most house construction is also undertaken at this time.

Field Studies

The relation of cultural and biological mechanisms to cold stress has been studied in Nuñoa during the nights of the dry season (Baker 1966b). Rectal temperature and skin temperature were recorded hourly for about 18 men, 10 women and 28 children as they slept under natural conditions in their homes. Average indoor temperatures were about 3.6°C. The families slept in groups of two to four, beneath blankets and sheepskins and wore varying amounts of clothing. All slept in a fetal position. Rectal temperatures of the women were highest, men were slightly lower, and children were lowest. The rectal temperatures of the children were not only lower than those of the adults but they showed an entirely different pattern. During the first hour the children fell to equilibrium and maintained it thereafter, while the adults' temperatures fell very slowly during the night. Skin temperatures were not different except for the toe

temperature which was highest in children and similar in male and female adults. There was a definite reaction between age of child and rectal temperature: older children maintained higher temperatures for longer periods of time. Baker thinks that the particular pattern of the child is the result of greater cold stress during the night. It must therefore be concluded that the technological modification of microclimate of the Quechua is not completely adequate in terms of the degree of cold which he encounteres. Such exposure, especially among children would favor acclimatization to cold at an early age and could provide an opportunity for natural selection to produce genetic adaptations.

A second period of cold stress is encountered during the rainy season when cloudiness and precipitation produce rapidly falling temperatures. These should create considerable cold stress for the human population. Precipitation falls daily in the form of sleet, rain, hail and snow and is accompanied by high wind. It is during this time that the Indians are engaged in outdoor activities, frequently far from home so that they must endure the storms without protection. Cold stress might be expected to appear in the forms of extremity cooling from mud and water immersion and in the form of total body cooling as the wind chills the soaked Indian. This period was not studied by Baker.

CHAPTER 5

EXPERIMENTAL PROCEDURES AND RESULTS

General Methodology

As outlined, the aims of this paper are to examine the effects of cold on various segments of the population of the Nuñoa region. The time selected was the rainy season when large numbers of Indians are exposed to an inhospitable environment. During this time the established biological and cultural protective mechanisms should become most evident.

The problem is to estimate the microclimate within which the segments of the population live. This microclimate may be estimated through measurement of skin temperature as the individual goes about his daily activities (Davis 1963). In this context, the microclimate represents the combined effects of the climate, any local geographic features which might modify it, and the sum of the biological and cultural responses which the population utilizes. Thus, skin temperatures were measured in a number of individuals of both sexes representing different age groups and living in diverse parts of the environment. These measurements were taken in the course of a normal day's activities so that the results should represent the real climatic forces and the population's responses rather than an approximation of them.

To study some aspects of this variation more clearly, laboratory studies were undertaken. The effects of a number of variables

could be isolated in the laboratory by controlling the subjects' activity and the environmental temperature. Laboratory studies included the effects of sex and clothing upon response to cold. Thus, ti becomes possible to differentiate between actual sex differences and any masking or modifying effects which the field conditions might impose. The clothing of the Quechua Indian provides his major technological buffer against the cold environment. Its protective ability is therefore of interest. This, too, is best studied in the laboratory where the number of complicating variables can be controlled.

Skin temperatures were generally measured at the same sites in the laboratory and in the field so that valid comparisons could be made.

One further methodological note is in order. The present study should present fewer psychological artifacts than have been present in earlier studies through a reduction in anxiety.

The effects of anxiety on the circulatory system are well documented (Best and Taylor 1961: Ch. 28) and since this system is closely related to temperature regulation, similar effects might be expected here. Meehan (1957) has studied this phenomenon in response of hand temperature to ice water cooling. In a subject whose hand temperature response to ice water was known, he induced anxiety by upbrading him. This resulted in a marked decline in hand temperature due to vasoconstriction. Such effects may result from expectation rather than from experiencing an unpleasant situation (Plutchik

1966), so the primitive anticipating an uncomfortable period in the presence of unknown men and strange machines could become anxious. This may have been the case in a recent study reported by Baker and others (1967) in which Quechua Indians exposed to cold temperatures showed higher rectal temperatures during the first exposure than during its replication. Increased rectal temperature could have resulted from anxiety produced vasoconstriction, which retained heat in the core.

Such psychological variables are difficult to control. They may be somewhat controlled through familiarzation with the testing situation. This is a long and laborious process which is largely impractical. This study will try to reduce such psychological variables in a unique manner. In the region where the studies were undertaken there has been a laboratory staffed by anthropologists for several years. The subjects utilized were familiar with the laboratory and generally accepted that they would not be harmed by such study. Some of the people had participated in earlier studies and were familiar with procedures. They were usually enthusiastic and were thus given preference as subjects. This general familiarity with the laboratory, anthropologists, and previous experience should reduce anxiety somewhat.

Field Studies

Procedure

Skin temperature was measured at the following sites so that the data would be comparable with those collected in the laboratory.

The two lists of sites are similar except in the present series forearm is substituted upper arm and thigh temperature is dropped. These changes were made because of the difficulty of measuring upper arm and thigh temperature in fully clothed and active individuals.

1. Forehead: at a point midway between the hairline and glabella.
2. Chest: on a vertical line about three inches above the left nipple.
3. Forearm: one inch below the elbow on the midline of the ventral surface.
4. Hand: the approximate geometrical center of the back.
5. Finger: on the pad of the third finger.
6. Leg: midway between the knee and ankle on the midline of the dorsal surface.
7. Foot: on the upper surface midway between the third toe and the ankle.
8. Toe: on the pad of the great toe.
9. Rectal or Oral: sensor inserted 5 to 7 cm. into the rectum or placed under the tongue.

Temperature was measured on clothed subjects while standing. A Yellow Springs Instrument Company Tele-Thermometer and a skin surface probe were utilized. These probes were not permanently attached to the skin, but were placed on the predetermined spot for each reading. Temperatures were recorded 20 seconds after equilibrium was reached. The entire cycle, excluding rectal or oral temperatures, usually required about eight minutes. Since subjects were reluctant to retain the rectal probe, when not in use, it was inserted before the cycle of observations was begun and had always reached equilibrium by the time that final surface temperature measurements were

taken. Rectal temperature was preferred but if it was not possible the oral temperature was taken. The same period for equilibrium was required.

Testing was carried out on a day-long basis between February 1 and March 31, 1967. One family was studied each day. Three investigators divided themselves among the family members. One remained at the house to collect weather data while the other two followed any subject who might leave. More than three investigators were seldom required.

Initial measurements were taken immediately after the morning meal. Earlier measurements were difficult because the subjects remained in bed or in the house before eating. After the initial observations, measurements were taken every two hours throughout the course of the day. This usually resulted in six observations per subject. An observer accompanied the subjects and noted hourly activities taking measurements at the end of each two hour cycle. In some cases subjects went in different directions or tried to hide so that some of the observations are missing.

Climatic information was collected every hour at the house and may be taken as characteristic of the area. Information collected included temperature, humidity, cloudiness, and precipitation. Table 1 illustrates climatic data.

Food consumption was measured for each individual utilizing the methods of Mazess and Baker (1964). A comparison with their data from the same area in the dry season is presented in Chapter 6. Since detailed analyses of the nutritional characteristics of the native tubers

Table 1. Climatic data from field studies.

Day	Temperature (°C) Max.[1]	Min.[2]	Mean[3]	Mean Humidity %	Precipitation
	(Altitude 14,000 feet or more ("High Altitude")				
1	15	2.2	8.3	84.5	none
2	12.8	1.4	8.1	86.4	frost
3	15.6	1.7	9.8	81.9	sleet
4	13.4	1.1	9.0	84.7	frost
	(Altitude 13,100 feet ("Lower Altitude")				
5	14.5	5.0	9.9	89.6	none
6	18.3	5.0	12.7	85.5	frost
7	18.3	5.6	10.1	89.9	frost
8	14.5	3.4	11.1	85.9	rain
9	18.9	2.9	11.2	85.6	rain

[1] Maximum temperature recorded during day

[2] Minimum temperature recorded during day

[3] Mean of all temperatures recorded during day

and grains is not available to the author at present, the comparison is only in terms of bulk consumed per family. The significance of the nutritional differences in the table will be discussed in Chapter 6.

Results

Biological Variation (age and sex). A total of 355 observations were made on 62 subjects during the course of field studies. This represents an average of six observations per subject or about the number expected if taken every two hours during a 10 hour day. The 62 subjects are of both sexes, range in age from three to 80 years and live at high (14,000 feet or more) and lower (13,100 feet) elevations. The latter altitude corresponds to the valley floor and the former to the surrounding mountains. The biological characteristics of these groups is presented in Table 2. Age estimates for older groups are difficult to check so subjects' own estimates were uncritically accepted.

Due to observer error and equipment failure, some observations are incomplete. The statistical techniques selected for analysis were such that incomplete observations had to be discarded. As will be shown, this resulted in only a slight reduction in the number of subjects.

One constant source of such incompleteness was children who refused the rectal Thermister probe. In these cases, oral temperature was taken and converted to rectal temperature through the use of the following equation:

Rectal Temperature (°C) = Oral Temperature (°C) + 0.3°C

Table 2. Biological data from field studies. Means and standard deviations (S. D.) by age, sex and altitude.

Group		No.	Height (cm)	Weight (Kg)	Average Skinfold (mm)	Age (years)
(13,100 foot altitude ("Lower Altitude")						
Young Male	Mean	7	1198.4	27.5	6.4	10.9
	S.D.		172	7.3	2.4	3.9
Young Female	Mean	10	936.1	17.1	6.9	5.7
	S.D.		211.0	7.5	1.4	3.1
Old Male	Mean	10	1593.9	55.9	5.3	28.6
	S.D.		67.9	4.7	1.0	11.9
Old Female	Mean	6	1471.0	49.3	7.9	45.0
	S.D.		59.8	6.5	1.1	18.6
(14,100 feet or more altitude ("Higher Altitude")						
Young Male	Mean	6	1071.0	20.9	n.d.[1]	8.8
	S.D.		246.0	12.8		5.3
Young Female	Mean	8	1073.0	21.2	n.d.	7.7
	S.D.		237	10.3		4.2
Old Male	Mean	7	1536.0	56.6	5.6[2]	41.0
	S.D.		72.3	5.7	2.3	23.5
Old Female	Mean	8	1434.8	47.9	n.d.	40.8
	S.D.		45.5	5.0		21.4

[1] n.d. - no data available

[2] this estimate is based only upon 3 of the 8 subjects

This equation was derived from simultaneous measurements of rectal and oral temperatures in eight different children.

In very young children it was impossible to take oral temperatures because they could not keep their mouths closed. It was, therefore, impossible to apply the above correction equaltion and they were eliminated from the sample.

With no error or missing observations, six observations per subject would be expected over the ten hour day. Actually, only three observations were available in all 62 subjects. Four observations were available on 58 subjects, and five observations were available on 44 subjects. Analysis was performed on the 58 with four observations because this seems to provide the most information. The group was divided by age and sex. The age division was at 15 years in accordance with the procedure of Baker (1966b). The following categories and number of subjects were thus produced: young males - 13, old males - 17, young females - 14, old females - 14.

The statistical test selected was a multiway analysis of variance. To facilitate calculation it was necessary to produce equal subcells; that is, equal numbers in each group. Because there were only 13 young males, members of other groups were dropped at random to produce symmetry. Therefore, the basic analysis was accomplished with 26 children and 26 adults, equally divided between the sexes. For one variable, rectal temperature, only ten girls provided real or estimated values so that a further reduction was applied. Using the same random procedure, three subjects were dropped from the other three groups. Thus, over the first eight variables 52 subjects entered in

the analysis while in the last one, rectal temperature, only 40 entered.

Table 3 shows the means and the number of subjects in each of the subcells. The results of the analysis of variance for both age and sex groups is presented in Table 4.

Tables 3 and 4 show that there is considerable variation in response to cold which is related to age and sex. Sex differences exist in leg and foot temperatures. In both cases males are warmer than females, the differences being significant at the 1 percent level of confidence. There is also a sex related difference in rectal temperature, significant at the 5 percent level. Again, males are warmer than females.

There are more significant differences due to age than to sex. Children are significantly colder than adults in arm, hand, finger, leg and foot temperatures. In rectal temperatures, children are warmer, the differences being significant at the 1 percent level of confidence. Only in the forehead, chest and toe temperatures are there no significant differences related to age. The complete lack of sex-age interactions indicates that youth acts independently of sex in determining the generally colder microclimate of the children.

Microclimatic temperatures as measured in this study respond to environmental temperatures. Since subjects were measured under slightly different environmental temperatures, analysis was undertaken to determine if this might not explain the observed variation. It might be suggested that children were colder because those children

Table 3. Mean temperatures (°C) during field studies by age and sex.

Site	No. of Subjects	Young Male	Old Male	Young Female	Old Female
Forehead	13	31.6	31.7	31.3	31.7
Chest	13	33.4	33.5	33.5	33.7
Arm	13	30.3	32.7	29.9	31.5
Hand	13	26.4	28.7	24.9	28.3
Finger	13	22.3	24.7	21.5	26.0
Leg	13	29.0	30.9	26.6	28.5
Foot	13	26.4	28.2	23.5	27.3
Toe	13	21.7	22.6	20.2	22.5
Rectal	10	37.4	37.2	37.3	36.8
Environmental temperature	13	11.4	10.8	11.2	11.7

Table 4. F tests of differences between sites in field studies.

Site	Sex	Age	Interaction
Forehead	1.24	0.15	0.32
Chest	0.12	0.20	0.02
Arm	1.31	15.26**	2.26
Hand	2.19	18.49**	0.63
Finger	0.54	11.77**	1.02
Leg	24.43**	14.74**	0.00
Foot	7.50**	17.40**	2.12
Toe	0.91	3.32	0.60
Rectal	4.32*	11.89**	0.74
Environmental temperature	0.63	0.30	0.96

* = 5%

** = 1%

included were simply measured at colder environmental temperatures than the adults. The Environmental Temperature variable in Tables 3 and 4 illustrates environmental temperature and there is no significant difference between the four groups. Thus, environmental temperature would not seem to explain the observed sex-age related variation.

Altitude Related Variation. A most outstanding aspect of the geography of the Nuñoa area is the rapid change in altitude which occurs in relatively short distances. Changes of several thousand feet in less than ten miles are not uncommon. Because such altitude changes also suggest temperature differences, altitude variation could be an important source of intrapopulation microclimate variation.

To determine the effects of altitude in the absence of age and sex controlled variation, the following groups were constructed. From each altitude considered in the field study, six members of each sex and age group were selected on the basis of completeness of data. Thus, there were 24 subjects from each altitude equally divided by age and sex. A one-way analysis of variance was performed, and the results are presented in Table 5. Both F values and means are presented. Rectal temperature is not included because of missing data.

Table 5 shows that there are significant differences between the high and lower altitude groups on all sites except arm and toe. To determine if these differences were not simply due to temperature differences at the two altitudes, a similar one-way analysis of variance was performed on the environmental temperatures corresponding to

Table 5. Means and F tests for altitude related differences.

Site	No. of Subjects	F	Mean Temperature (°C) by Altitude	
			Low	High
Forehead	48	15.64**	31.97	30.34
Chest	48	18.12**	34.06	32.79
Arm	48	3.98	31.42	30.53
Hand	48	4.77*	27.72	26.13
Finger	48	17.70**	25.31	21.55
Leg	48	13.69**	29.59	27.83
Foot	48	1.52	26.65	25.76
Toe	48	8.68**	22.80	20.17
Environment Air	48	18.77**	12.37	10.05

* = 5%

** = 1%

the observations. This is also presented in Table 5. The temperature difference between the two altitudes is significant at the 1 percent level. Since simple ambient air temperature enters into microclimate temperature as measured in this study, it is probably one of the altitude related phenomena. Such phenomena are probably more important than altitude itself in modifying microclimate.

Laboratory Studies

Methods

Because of the number of extraneous factors which could complicate the field situation, laboratory studies were undertaken to supplement them. Thus, under controlled conditions and increased precision of measurement, some aspects of intrapopulation variation could be studied in greater detail. Aspects of variation studied in the laboratory were related to sex and clothing. Time limitations precluded the study of children, so only adults were investigated. There is nothing in the literature to indicate that children have ever been studied so that their responses may not even be estimated.

Clothed and unclothed men and women were studied in the laboratory with the following problems in mind:

a. Are there inherent differences in response to cold if men and women are studied in identical conditions?

b. If sex-related differences in response to cold exist, are they still evident with the cultural mechanism of clothing added?

Techniques utilized were developed by the Human Performance Laboratory of the Pennsylvania State University. This procedure has previously been utilized by Baker and others (1967) to investigate differences between Nuñoa males and transient American males.

Subjects

The individuals who had participated in the field studies lived in rather remote areas and would have required transportation; therefore, they could not be utilized for laboratory work. Instead, subjects were recruited from around the town of Nuñoa where the laboratory is located. They may or may not be representative of the general population, but psychological considerations, noted below, make them an extremely desirable sample. These people from around town were not urban dwellers in the usual sense because all of them had fields in lands surrounding the town. They were, in a sense, farmers living in town. Many subjects were rural farmers who lived within walking distance of the laboratory.

A procedure established for previous studies in Nuñoa were used for recruiting subjects. Town and rural residents were informed that a study was to take place by word of mouth. Detailed information as to the type of study and the duration of cold exposure was circulated. This immediately produced a number of volunteers. Each was to be paid the equivalent of two full days' work, a considerable inducement. Many of the males who volunteered had previously been studied by Baker, Thomas and Little (1967) and by Baker and others

(1967). These men who were familiar with the procedure were given preference because of psychological considerations (Chapter 5). It was decided that reducing such extraneous artifacts is equally important to unbiased sampling for laboratory studies. None of the women had been exposed to the cold chamber previously, but a number of them had served in a study of foot cooling conducted by Little (Baker, Thomas and Little 1967). Of those who volunteered, 18 males and 18 females were selected for analysis. The biological characteristics of the two groups are presented in Table 6.

Procedure

Subjects were tested in pairs on each of two consecutive days. On one day they were unclothed and on the other clothed, the order of exposure determined by odd and even pairs. This provides two observations, one nude and the other clothed for each of the two sexes.

Each pair reported after sunrise having eaten no breakfast. They sat in the patio of the laboratory for about one hour and then were conducted to the preparation room. The preparation room temperature was controlled at about 28°C. Subjects to be tested clothed were then asked to recline on a cot while thermocouples were attached with adhesive plaster. Nude subjects were first asked to disrobe and then to recline covering themselves with a blanket, after which the thermocouples were attached. All subjects reclined for one hour before testing so that they were approximately in thermal equilibrium.

Table 6. Biological characteristics of laboratory subjects.

Characteristic	Mean	S. E.
Male		
Age - years	29.7	3.1
Stature - cm.	1,586.2	14.2
Sitting height - cm.	858.4	5.9
Average skinfold - mm.	6.0	0.3
Weight - kilograms	55.6	1.1
Female		
Age - years	26.3	2.1
Stature - cm.	1,449.5	10.8
Sitting height - cm.	791.0	8.5
Average skinfold - mm.	9.8	0.5
Weight - kilograms	44.5	1.4

Subjects tested while clothed wore ordinary clothing except for ponchos (or carry cloths for the women), sandals and hats. Each was carefully examined to ascertain that he was not wearing more than a normal amount of clothing. This was possible due to the familiarity of the investigator and his assistants with native clothing practices. When subjects were tested unclothed, men wore only athletic shorts and women wore thin, brief smocks.

At the end of one hour in the preparation room, they were conducted about 10 feet into the cold chamber where the temperature was carefully controlled at 10°C (50°F). Exposure continued for two hours, temperatures being measured every four minutes.

Thermocouples were attached to the following sites, established by the Human Performance Laboratory.

1. Forehead: at a point midway between the hairline and glabella.
2. Chest: on a vertical line about three inches above the left nipple.
3. Upper arm: midway between acromion and radiale on the dorsal line.
4. Hand: the approximate geometrical center of the back.
5. Finger: on the volar pad of the third finger.
6. Thigh: on the lateral line midway between trocanterion and tibiale.
7. Calf: on a lateral line approximately 2/3 distally between tibiale and sphyrion.
8. Toe: on the pad of the great toe.
9. Rectal: 7 cm. into the rectum.

These sites were selected because they can be combined into one overall measurement of skin temperature by giving them weights in accordance with their respective contributions. This average skin temperature is called mean Weighted Skin Temperature (MWST) and is calculated from the following equation (after Baker and others 1967).

Equation 4

$$MWST = .30\,(\text{chest}) + .20\,(\text{forehead}) + .175\,(\text{upper arm}) + .05\,(\text{finger}) + .15\,(\text{thigh}) + .075\,(\text{calf}) + .05\,(\text{toe})$$

Room temperature was measured through a thermocouple suspended at chest level midway between the two reclining subjects.

Subjects were placed in the cold chamber at 10°C (50°F) for two hours. During this time they reclined on cots with their heads in metabolic hoods - large plastic bags which serve to collect respiratory gases for metabolic analysis. The hoods were of clear plastic so that they could see outside. This was an open system so fresh air constantly was drawn into the hoods from the room.

During the two hours of exposure an assistant remained in the chamber to prevent movement or crossing of limbs. At the end of the two hours subjects were removed from the chamber and given a meal consisting of soup, bread and coffee. They were then instructed to return for the second trial on the next morning. In some cases two pairs of subjects were tested on a given day, one in the morning and the other in the afternoon. In this case the afternoon group reported at 10:00 a.m., after having eaten breakfast at about 6:00 a.m. All other aspects of the procedure were identical.

Results

Data collected in the laboratory studies was analyzed with a multiway analysis of variance. Analysis included male-female and clothed-unclothed as major effects. The resulting means and F tests are presented in Tables 7 and 8. To facilitate analysis, Mean Weighted Skin Temperature (MWST) was calculated as described in Equation 4 of this chapter. MWST was then used to compute body temperature as outlined in Equation 3 of Chapter 2. Body temperature, MWST and the mean values for each site are plotted in Figures 2 to 11. Graphic representation was selected for purposes of economy. A site-by-site examination of the results suggests the following relations.

Mean Weighted Skin Temperature, Body Temperature and Rectal Temperature. To give an overall view of responses related to sex and clothing, Figures 11 and 12 (MWST and Body Temperature) should be consulted. MWST may be taken as a general estimate of microclimate for it combines all measures of surface temperature into one estimate. As Figure 11 illustrates, clothing has the effect of increasing microclimate temperature in both sexes. Since the curves are generally parallel, it seems that both sexes derive about the same protection from clothing. The overall effect of clothing is to increase the microclimate temperature several degrees.

Women generally have a higher MWST than men when both are clothed or unclothed. Thus, it appears that being a woman provides a slightly warmer microclimate. No statistical analysis was undertaken to determine if these clothing and sex differences in MWST were significant or not.

Table 7. Mean temperatures for sex and clothing differences in laboratory study.

Site	Male (°C)	Female (°C)	Clothed (°C)	Unclothed (°C)
Forehead	32.6	31.8	32.3	32.2
Chest	31.4	33.9	34.6	30.8
Upperarm	28.7	28.4	32.2	24.2
Hand	22.5	25.5	24.6	23.2
Finger	20.7	23.7	23.9	21.0
Thigh	29.3	31.5	33.2	28.0
Calf	26.4	21.9	24.7	23.9
Toe	18.3	15.7	17.6	16.4
Rectal	37.8	38.0	37.9	37.9

Table 8. F values for sex and clothing differences in laboratory study.

Site	Sex	Clothing	Interaction
Forehead	18.27**	0.27	0.16
Chest	46.04**	69.60**	1.22
Upperarms	0.74	229.87**	3.16
Hand	11.32**	9.64**	6.30*
Finger	14.58**	10.91**	7.96*
Thigh	13.79**	93.40**	0.29
Calf	91.58**	6.29*	28.95**
Toe	5.14*	4.83*	0.54
Rectal	4.66**	0.58	0.13

* = 5%

** = 1%

Rectal temperature shows that there is no change due to the addition of clothing, and that women are always warmer than men. The latter is significant at the 5 percent level of confidence. Rectal temperature is an estimate of core temperature, thus the higher rectal temperature of women might indicate a higher metabolic rate. This will be discussed in the following chapter.

Body temperature (Figure 12) provides an overall estimate of the heat content of the body. It combines core temperature as estimated by rectal temperature with microclimate temperature as estimated by MWST (Equation 4, Chapter 5). Body temperatures are presented in Figure 12. Note that the body temperature closely parallels skin temperature and shows the same basic relationship. Again, it is not possible to assign a level of significance to the differences. The addition of clothing seems to influence the body temperature of both sexes about equally; it increases heat content about 3°C. Woemn are generally warmer, with or without the added effect of clothing.

A consideration of these general measures of microclimate and body heat content shows that women are warmer than men. They have more body heat, higher core temperatures, and utilize them to provide a warmer microclimate. The overall effects of clothing are to increase in the microclimate, as estimated by MWST, and to increase in general body heat content. With these general features of sex and clothing in mind, the individual variables will be considered in detail.

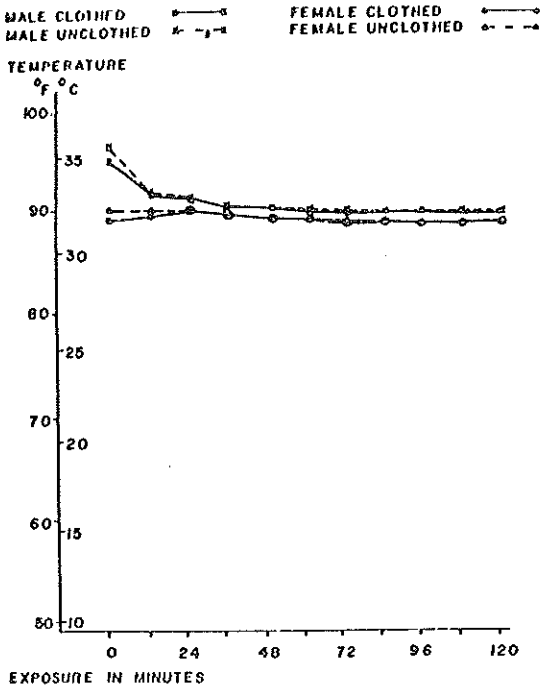

Figure 2. Forehead temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

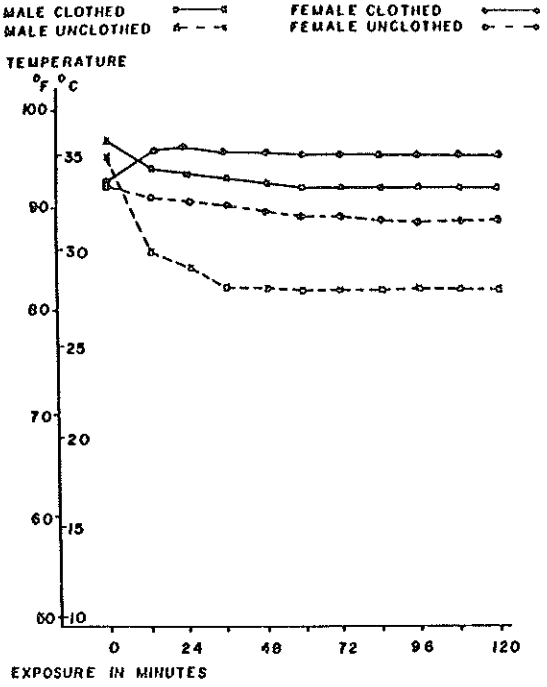

Figure 3. Chest temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

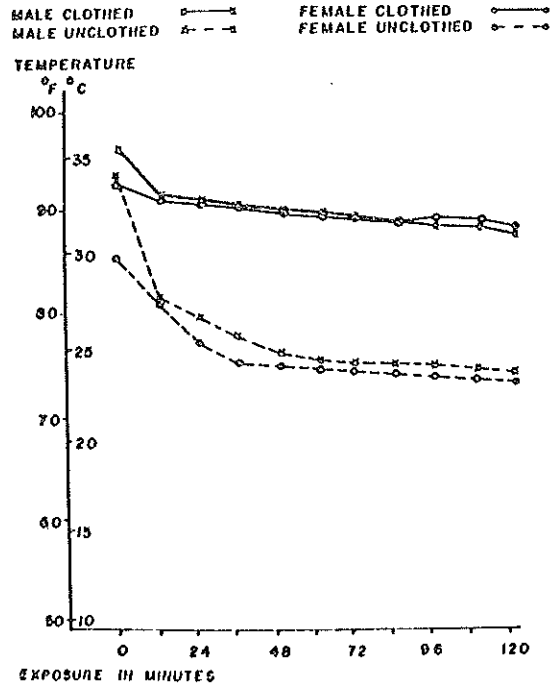

Figure 4. Arm temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

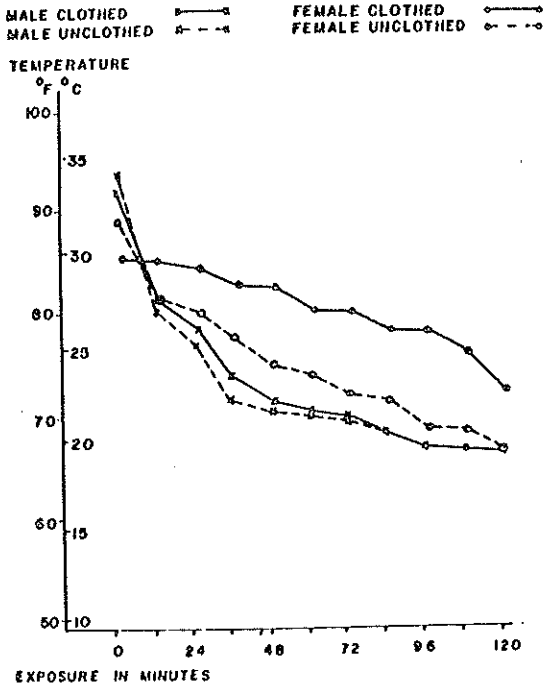

Figure 5. Hand temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

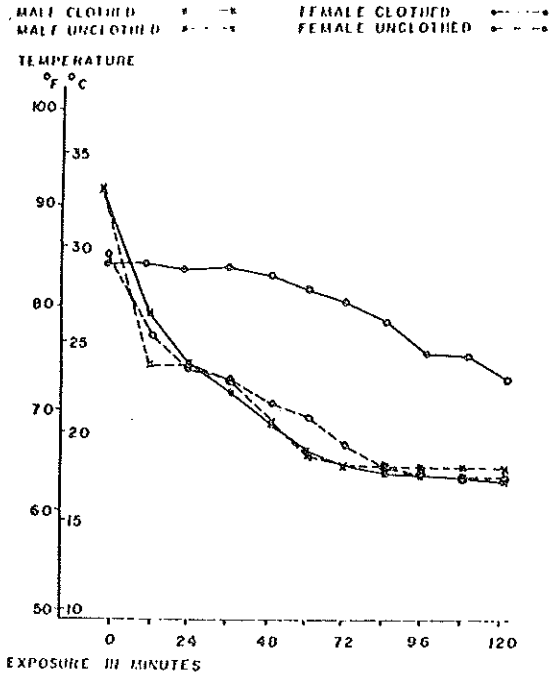

Figure 6. Finger temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

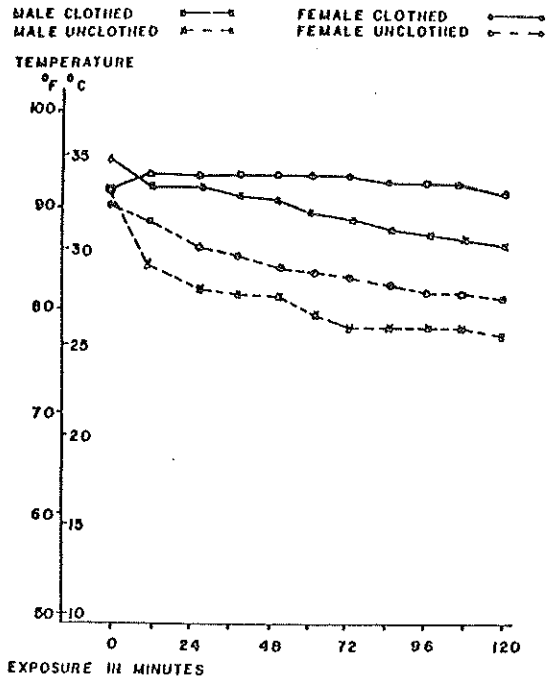

Figure 7. Thigh temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

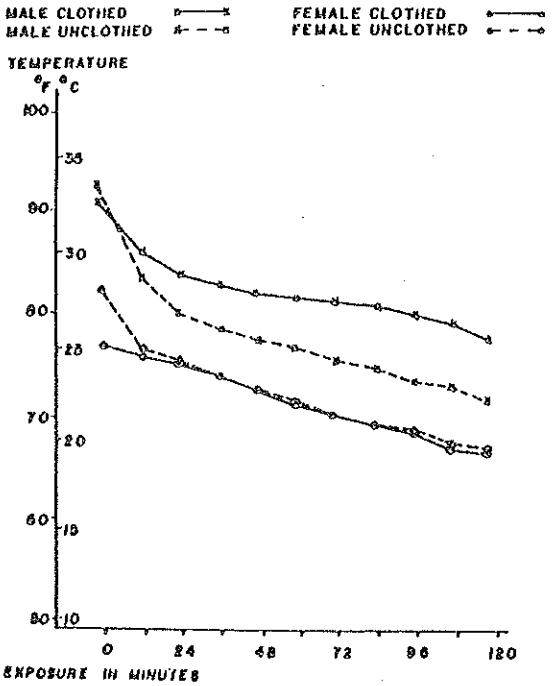

Figure 8. Calf temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

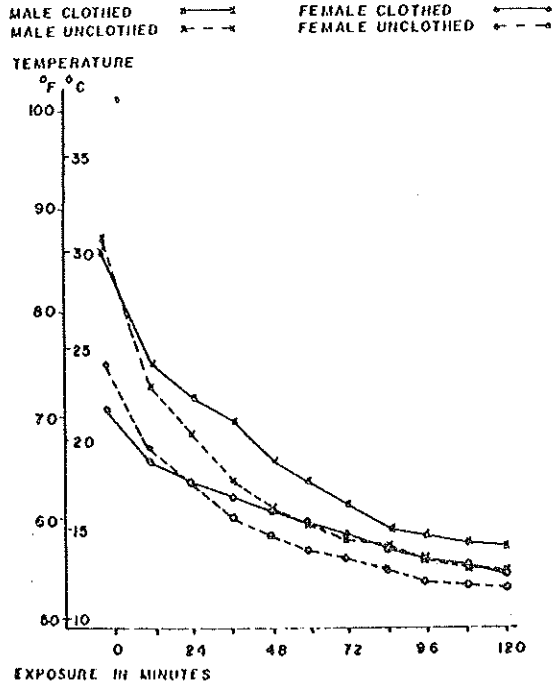

Figure 9. Toe temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

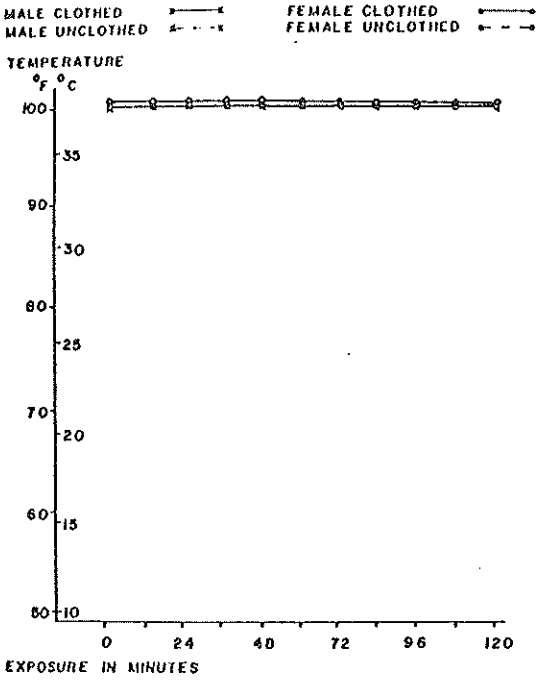

Figure 10. Rectal temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

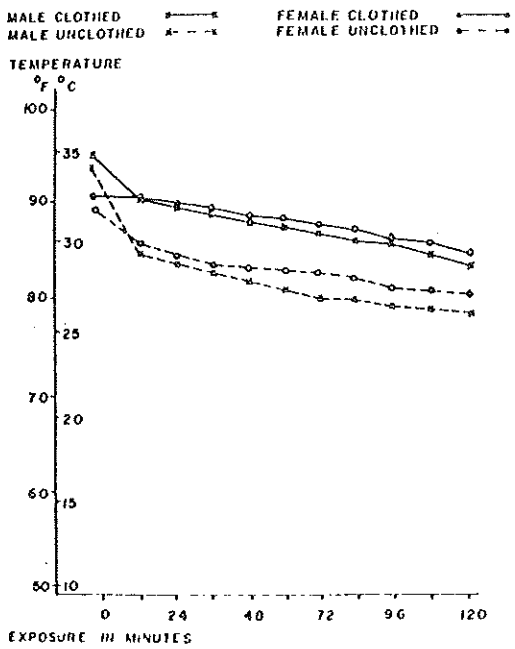

Figure 11. Mean weighted skin temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

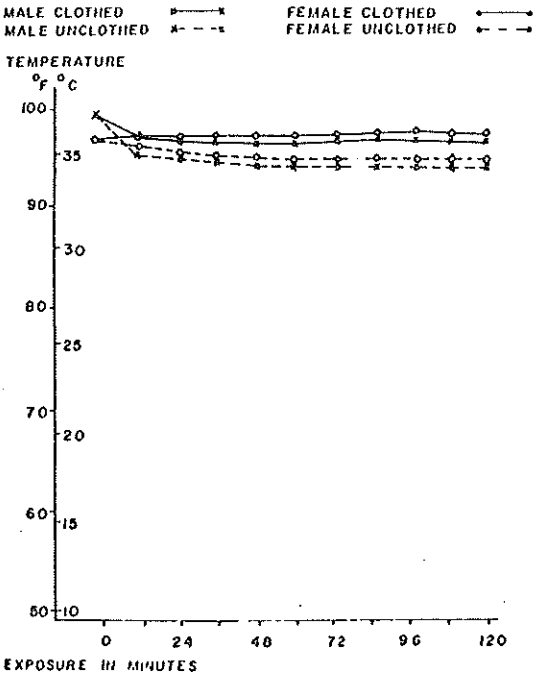

Figure 12. Body temperature of clothed and unclothed males and females during two hours exposure to 10 C air.

Arm. Arm temperature shows an increase, significant at the 1 percent level, which is due to clothing. There is no sex-related difference.

Chest. Females always show higher chest temperatures than males in clothed and unclothed situations (Figure 3). This sex-related difference is significant at the 1 percent level. Clothing increases chest temperature in both sexes, also significant at the 1 percent level.

Hand and Finger. Because hand and finger temperatures are highly correlated (Table 9) and because they respond to cold stress in a similar way (Figures 5 and 6), they will be treated as a unit.

Females are significantly warmer in both the clothed and unclothed states. These sex-related differences are significant at the 1 percent confidence level. The addition of clothing leads to a significant increase in hand-finger temperature. There are also significant sex clothing interactions for both of these variables as is seen in Table 8. Figures 5 and 6 show that these interactions are due to clothed females who are considerably warmer than any of the other groups. This should be interpreted to show that females gain some special temperature advantage from women's clothing. Men wearing women's clothing would be expected to show less of a temperature increase. There is no immediate explanation for this phenomenon.

Thigh. Females also show warmer thigh temperatures in both clothed and unclothed situations (Figure 7). These differences are significant at the 1 percent level of confidence. There are also

increases in thigh temperatures in both sexes with the addition of clothing. These are also significant at the 1 percent level.

In each of these five variables, the addition of clothing has the predictable effect of increasing microclimatic temperature. In the last four cases females show warmer temperatures than males, thus illustrating the general tendency so clearly defined above. In the following variables a somewhat different pattern seems to emerge.

Forehead. Males maintain a significantly (1 percent) higher forehead temperature. This represents a change in the generally observed relationship, but more surprising is that there are no significant increases with the addition of clothing.

Calf and Toe. As with hand-finger, these two variables will be treated as a unit. They behave in a similar manner (Figures 8 and 9), but are not highly correlated (Table 9), especially in the clothed condition.

In both of these variables males are warmer than females, so much so that unclothed males maintain higher extremity temperatures than clothed females. This represents a reversal in the general pattern of women maintaining warmer microclimates.

The addition of clothing produces significant increases in extremity temperatures in both sexes. These increases are at the 1 percent level for calf and at the 5 percent level for toe.

There is a significant interaction between sex and clothing in calf temperature (Table 8). Figure 8 shows males gaining proportionally greater temperature increases from their clothing. This

Table 9. Intercorrelations of temperature in the laboratory study.

Forehead	Chest	Arm	Hand	Finger	Thigh	Calf	Toe	Rectal
Male - Unclothed (above diagonal of the matrix)								
	.02	.28	.52	.40	.16	.42	.38	.08
.03		.38	.33	.04	.22	.31	.26	.35
.04	.41		.77	.61	.55	.72	.81	.64
.49	.07	.21		.75	.43	.72	.80	.08
.19	.21	.13	.65		.40	.51	.68	-.01
.00	.41	.28	.17	.46		.51	.52	.16
.37	.13	.41	.51	.29	-.07		.69	.15
.41	.04	.31	.62	.32	.13	.46		-.08
.11	.21	.15	-.08	.23	.35	.12	-.03	
Clothed (below diagonal of matrix)								
Female - Unclothed (above diagonal of the matrix)								
	.50	.60	.54	.45	.55	.50	.36	.36
.50		.60	.41	.53	.43	.51	.39	.15
.59	.55	.83	.81	.59	.64	.76	.68	.46
.44	.28	.47		.61	.47	.69	.75	.29
.42	.27	.31	.67		.51	.68	.67	.17
.48	.17	.35	.40	.38		.63	.53	.29
.48	.66	.53	.34	.31	.40		.69	.37
.15	.39	.12	.48	.49	.26	.26		.18
.44	.18	.42	.24	.18	.00	.13	.00	
Clothed (below diagonal of matrix)								

is parallel to the sex-clothing interactions in the upper extremity as discussed above. The interaction probably results from a male pattern of higher blood flow (discussed in the next chapter) and tightly fitting pants, which provide greater leg protection than skirts.

In summary, females seem to maintain a warmer microclimate in general. They have warmer cores and a higher overall body temperature. The two exceptions to this are in the forehead and in the lower extremity where males are warmer. Clothing has the general effect of increasing microclimate and body temperature, the only exceptions being in rectal and forehead temperatures where no changes are observed.

Correlations. To determine if there were any patterning effects related to sex or clothing, simple correlations were computed and are seen in Table 9. An inspection of this table shows only one general pattern -- there is a decrease in the magnitude of correlation coefficients when clothing is added. This takes place in both sexes and is probably related to reduced stress. No other sex or clothing related patterns are evident.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

Introduction

As outlined in preceeding chapters, there are three classes of forces which can influence the variation seen at the population level. They are (1) features of the physical environment and climate; (2) inherent biological factors characteristic of any human population; and (3) cultural factors utilized against a specific stress. By examining the responses of the population to a particular kind of stress, it should be possible to observe the effects of these forces. This study has dealt with cold stress.

To illustrate intrapopulation variation in response to cold, it will be necessary to combine both laboratory and field studies, as well as to utilize them independently.

Environment Related Variation

In the Nuñoa region the physical feature of altitude above sea level seems to play an important role in promoting variation in response to cold. These effects might best be called "altitude related" because there is no evidence that altitude alone has been the factor involved. Some phenomena which change as a direct result of increasing elevation are atmospheric pressure, temperature and humidity. Of these, the most important would seem to be temperature. Table 5

demonstrates that temperature was significantly lower in the higher elevations. Since this study deals with a relatively small change in elevation (from 13,000 to 14,000, about 1,000 feet), greater effects would be expected in areas where the altitude differential is greater.

The actual temperature differential in the Nuñoa region is not great. Thus, Baker and others (1965) find that there is no reduction in absolute minimum temperature at higher elevations, but rather a drop in the daily mean. Both high and low residents, mountain and valley dwellers, experience similar minimal temperatures, but those in the mountains are exposed to them more often.

The higher and lower altitude groups utilized here were from 14,000 plus and 13,000 feet, respectively. This is probably representative of the altitude variation in this area of the altiplano. Despite the relatively small difference in absolute altitude, this study shows that it is a major factor in reducing microclimate temperature in the rainy season. In all areas of the body, except the foot, the higher altitude residents are experiencing significantly lower skin temperatures. Thus, living at a higher elevation, be it 14,000 instead of 13,000 feet, leads one to experience more cold.

Altitude does not result in only a reduced microclimate temperature, but promotes a host of ecological differences as well. Because the climate above 14,000 feet is too severe for farming, these residents of higher elevations are entirely herders. Each family typically has more than a hundred animals, including llamas, alpacas, sheep, and perhaps horses. These grazing animals rapidly

deplete the grass and must constantly be moved. This requires a high mobility so that the piled stone houses are universal. These houses have the advantage of minimal economic investment but are also less effective against the cold than are the adobe variety. With the economy based entirely on herds, large numbers of animals are required for each family; and, as a consequence, more family members must be in the field watching the animals. This favors the large-scale employment of children. During the course of these observations in the rainy season, only very small children were observed to be at home. Their older siblings left the house in the early morning and returned with the herds in mid-afternoon. They were, therefore, subject to greater potential cold stress being away from shelter.

Low altitude dwellers are found in a somewhat different ecological situation. In addition to herding, they can practice farming of native grains and potatoes. Although no count was made, fewer animals per family were observed in the valley. Fewer animals require less pasturage; therefore, steep adjacent hillsides, marshes and fallow fields provide adequate food for livestock. Although the same herd animals were observed, there were a few cows and more horses than at higher elevations. In terms of cold stress, with fewer people engaged in herding, more of them could take advantage of shelter offered by houses.

A distinct advantage of the more sedentary, mixed economy of the valley is individual or community ownership of land. In the higher regions, the large herds make individual ownership of pasture

impractical. Ownership at a more personal level provides for a greater economic investment in the land itself. This is most conspicuous in terms of houses. Valley houses are built of adobe and are permanent. As previously noted, this provides a greater protection against cold. In some cases metal roofs were observed, indicating a considerable investment to promote a more comfortable microclimate. This permanence has profound effects on the indigenous community structure. There was additional community development of institutions such as schools and a universal involvement in community projects. The social structure-permanence relation merits further research.

The ecological differences produced by altitude are further evident in the typical diet, presented in Table 10. Here bulk food consumption is compared to Mazess and Baker's (1964) data. There is a definite difference in the two diets, probably related to the season in which they were collected. Mazess and Baker studied the region in the dry season after the harvest when large amounts of potato products were available. The present study illustrates the diet in the wet season shortly before the harvest, a time when yearly stores were presumably at their lowest. In the absence of a detailed analysis, it may be suggested that, since Mazess and Baker found the diet adequate with 80 percent of the bulk derived from tubers, the current diet which is more diversified should also be adequate. It is also noteworthy that there is seasonal variation in bulk food consumption.

Mazess and Baker do not report altitude variation in their study, but Table 10 suggests that it is an important variable. For

Table 10. Comparison of present dietary data with that of Mazess and Baker (1964).

Food	Mazess And Baker	Hanna - present study: Tot. high and lower altitude samples comb.	Hanna - present study: High altitude alone	Hanna - present study: Lower altitude alone
Tubers				
Chuno	30.4	8.64	21.96	2.16
Potatoes	47.9	19.07	0.0	28.37
Other tubers	1.8	0.0	0.0	0.0
Subtotal	80.1	27.71	21.96	30.53
Cereals				
Barley	3.4	3.73	11.36	0.0
Maize	1.6	7.03	21.46	0.0
Wheat	0.9	38.32	21.22	46.65
Subtotal	5.9	49.08	54.04	46.65
Chenopodia*				
Quenua	3.0	1.57	0.0	2.33
Canihua	2.9	6.74	0.0	10.02
Subtotal	5.9	8.31	0.0	12.35
Animal Foods				
Meat	6.0	9.97	19.91	5.13
Fat	0.3	0.0	0.0	0.0
Subtotal	6.3	9.97	19.91	5.13
Others (onions, peppers, sugar, milk)	1.8	4.92	4.07	5.33

All values in percentage of total weight of food consumed.

* = native grains

example, there is an absolute difference in the amount of native grains utilized. The valley floor farmers grow their own native grains (Chenopodia) and use them in considerable amounts, while none were encountered in the higher regions. There is also a difference in the amount of meat eaten. In the lower altitude, about 5 percent of the bulk consumed comes from meat; Mazess and Baker report 6 percent. At higher levels, animal food consumption increased to 20 percent of the total, which is not surprising for a herding economy.

Of further interest is that the valley residents are gaining 46 percent of their bulk from cereals, specifically from wheat flour. Since wheat cannot grow at this altitude, this must come from purchase, trade or gifts. The latter source may be significant because a center for distribution of Alliance for Progress food is in the central town of Nuñoa. The valley dwellers have more easy access to the town. In the higher altitudes, where the town is more remote, there is a reliance upon a greater diversity of cereals. Here maize and barley are utilized as well as flour. Another basic difference is observed in tuber consumption where the farmers are beginning to eat fresh potatoes when the herders are still relying upon chuno, frozen potatoes.

There is also an absolute difference in the bulk consumed each day. The average high altitude resident consumes only 417 grams per day, while the lower altitude resident consumes 729.2 grams per individual.

In summary, the physical variable of altitude results in considerable variation. In the lower region it results in a milder temperature and, as a result, the microclimate is warmer. There is added protection from the cold in the form of more effective adobe houses, which are possible due to the sedentary nature of the economy. The resident's diet includes some plant foods not observed at higher elevations, and almost half of the bulk is derived from wheat flour. Typically, each family member eats more food per day. At the higher elevations the colder temperatures provide a colder microclimate over all parts of the body. The necessity of mobility results in less effective housing, which should increase the amount of cold stress experienced. Although they eat less per day, the diet of these high altitude dwellers is more diverse and more rich in animal protein.

It must be concluded that peoples differ in the amount of cold which they experience in relation to the altitude in which they reside. The amount of altitude change may not be great. The valley floor is at 13,100 feet, and the surrounding areas at 14,000 feet or more. The differences in ecology and economy described may be characteristic of the Nuñoa region alone, so more detailed studies of other regions of Peru and Bolivia are required to determine if such juxtapositioning of ecological zones is common. If it is characteristic of the Andean region, slight differences in altitude are far more important in the evolution of Andean populations than has been expected.

Biological Variation

Age

From the results of the analysis of variance and from an examination of Tables 3 and 4, it appears that age is an important source of intrapopulation variation in response to cold. Specifically, children are colder than adults and therefore must be cold stressed more often. To understand this problem better the mean weighted skin temperature (MWST) and body temperature were computed in accordance with equations 3 and 4. One modification was required. Because thigh temperature was not measured in field studies, leg temperature was inserted in its place. The resulting estimates are seen in Table 11.

The microclimate temperature as estimated from MWST shows children living in a world which is about 1°C colder than that of the adult. They compensate for this by maintaining warmer core temperatures so that overall body temperatures of the children and adults are equal.

The mechanism by which children remain colder in the shell portions but retain a warmer core has two explanations. First, it may result from vasoconstriction which limits peripheral blood flow and takes advantage of the insulation value of the shell. This should produce a rise in core temperature. Second, the increase in core temperature may represent a higher metabolic rate which is mobilized against the massive heat flow from the core into the peripheral tissue. Unfortunately, this problem cannot be resolved in the absence of metabolic information.

Table 11. Estimates of mean weighted skin temperature (MWST) and of body temperature (Body T.) from field studies.

Group	MWST	Body T.
Children	29.95°C	35.01°C
Adults	30.98°C	34.94°C

There are some other complications in the relation of this study to that of Baker (1966b). Baker studied adults and children as they slept and found children to maintain lower core temperatures and higher foot temperatures. This he attributed to a combination of greater preretiring stress and smaller body size. The current study does not support the supposition that children have lower rectal temperatures before retiring. The second explanation, that of body size differences looks somewhat more attractive. Little (Baker, Thomas and Little 1967) adds some important evidence. He demonstrates that the size of the foot, closely related to age, is of extreme importanc in predicting foot temperature. During the 60-minute immersion in 0°C air there was a .486 correlation between volume and temperature of the foot. He found no important age-related temperature change after age 20, lending further credence to simple body size as a major factor in microclimate maintenance.

Even though children are experiencing greater cold exposure than adults, there seems to be no conscious effort to protect them, (except during infancy). Before they learn to walk, children are usually well protected when outdoors. Their mothers carry them wrapped in heavy clothes much as to North American Indians. During this time they are clothed in a short smock which has already been described (Chapter 4). When children begin to walk, they wear the same smock but are no longer wrapped. Thus, I frequently observed inadequately clothed or even nude children playing in the mud after a rain storm. This should occasion considerable cold stress.

Children become an economic asset when they can understand instructions and control animals, for then they may be sent into the fields to tend the herds. This seems to occur between ages three and four, at which time they are dressed in several layers of woolen garments cut in the style of adults. Several children usually go together and can be seen playing as the herds graze. Because they do most of the herding, the children are exposed to greater potential stress in the form of precipitation and wind storms. They are far from home and must watch the animals so that they cannot take shelter. The problem must be most acute in the higher altitudes where more people are required for the larger herds.

If cold operates as a selective agent, it probably operates on children. During the day they live in a colder microclimate and are exposed to greater potential cold stress. During the night they suffer greater core cooling than adults. Thus, the opportunity for selection exists.

Most probably cold itself does not select but paves the way for respiratory infections which are unusually severe because of the high altitude.

Sex

In the laboratory studies the females appear generally warmer than the males. Only in forehead, calf and toe temperatures are men observed to have significantly warmer responses. The exact mechanism for this warmer response on the part of women is not immediately

evident, but the high rectal temperatures accompanied by high skin temperatures suggest an increase in heat production. This supposition will be tested when metabolic data on Nuñoa females becomes available.

These sex-related differences in cold response are distinct from those reported from other populations. Hardy and Dubois (1940) report observations on sex differences in the American White population. Males and females were observed to maintain similar rectal temperatures at various levels of cold exposure. But females showed significantly colder skin temperatures. These sex differences in response were apparently the result of a core to shell conductance differential resulting from thicker deposits of subcutaneous fat in the females. This phenomenon has been demonstrated a number of times, most recently by Wyndham and others (1964). Sex-related differences in cold response which are attributed to subcutaneous fat have been also reported in Koreans (Hong 1963; Lee, Hong and Lee 1965). In each of these cases females were characterized by lower skin temperatures.

It might be suggested that the females tested in the laboratory had less subcutaneous fat than the males, but an examination of Table 6 shows that this is not the case. In the laboratory study the females have almost 50 percent more subcutaneous fat! It is not clear why they responded through heat production instead of taking advantage of the extra insulation provided by the fat. Higher heat production may be an anxiety reaction; but, as will be shown, field studies do not support this.

Although these laboratory studies are different from those reported in other populations, they are similar to data presented by Baker (1966b). During nighttime studies on sleeping Indians, he found women maintained warmer rectal and somewhat warmer chest temperatures than men in the same situation. On the other hand, men showed higher foot temperatures. The close similarity between Baker's data and those obtained in the laboratory is probably the result of the similarity of the two situations. In both cases, ambient temperatures were about the same and activity was restricted. The higher rectal temperature of women while sleeping is in accord with laboratory data and is probably not the result of anxiety reaction.

Studies conducted in the field show a different relation between the sexes in response to cold. Here, there are significant differences in terms of leg, foot and rectal temperatures (Table 4). In each case the men are warmer. The lower rectal temperatures of women in the field is of interest because it represents a reversal of the previously defined relationships. This could be related to activity differences between the sexes, men being more active during the day. Such an explanation gains some support when the higher foot temperatures of men are considered.

Both laboratory and field studies, as well as Baker's (1966b) report on sleeping subjects, indicate that men typically maintain warmer foot temperatures than women. The underlying cause is probably higher peripheral blood flow to the foot in men. This results in warmer foot temperatures, which are somewhat independent of the

status of the core. This phenomenon is probably related to several non-biological factors.

The first of these factors is related to sexual differences in activity. During the field study it was noted that men are generally more activen than women. In the higher elevations they are observed herding or chasing stray animals; in the valleys they herded, farmed and engaged in public works. The women usually remained at home during the day and engaged in such inactive tasks as weaving and cooking. The higher activity level of men should occasion a greater blood flow to working muscles and thus produce warmer extremities (Rohter, Rochelle and Hyman 1963). The higher rectal temperatures of men in the field suggest greater activity. In the laboratory the women showed warmer hand and finger temperatures to a statistically significant degree. An underlying cause of warmer hand temperatures has already been shown to be repeated exposure to a cold stimulus. The women of Nuñoa were frequently seen washing clothing along the banks of the icy mountain stream which cuts through the town. It is possible that this occasioned localized acclimatization of the hands as Nelms and Soper (1962) have demonstrated for fish filleters.

The same feature of differential cold exposure might be related to men's foot temperatures. During the observation period, women were usually at home so that during periods of precipitation they seek the refuge of houses. Men who were working in the fields or chasing strays could not seek such protection, and their feet became soaked. Such differential exposure might result in different patterns of acclimatization.

Finally, simple size differences must be considered. Men presumably have bigger feet, a phenomenon which Little (Baker, Thomas and Little 1967) has shown to be commensurate with higher foot temperatures. Most probably, all of these features contribute in some manner.

Clothing Effects

Perhaps the major cultural mechanism entering into microclimate temperature is clothing, and the advantages of clothing in a cool environment are obvious. Because metabolic data is not available at this writing, the absolute advantages of clothing cannot be assessed; however, some general observations can be made.

In the laboratory, the addition of clothing to the unclothed male and female has the predictable result of increasing overall skin temperature. Figure 11 shows these effects. In males the addition of clothing increases MWST from 25.8 to 30.0°C after two hours' exposure. During the same period, the females increase from 26.6°C to 30.6°C. The overall microclimate temperature is therefore increased about 4°C in each case. This is also evident in body temperature for during the two hours males increase from 33.6°C to 35.1°C, w while females increase from 34.1°C to 35.4°C, or about 1.3°C for each sex. Assuming a body mass equivalent to water that represents a saving of 139.0 Calories for men and 105.8 for women.

There are no significant differences in forehead temperature or in rectal temperature which can be attributed to the addition of clothing. Since most of the organs within the head are in the core,

they are not subject to temperature fluctuation. The rectal temperature is also an estimate of core temperature. Thus, it might be argued that these two temperatures represent the invariable body core temperature. The relatively low correlations between them in Table 9 may be explained in terms of the relatively independent variation of minor fluctuations in internal temperature and overlying skin temperature.

The significant clothing-sex interaction in the hand and finger region (Table 8) implies that some feature of female clothing has additional advantage when coupled with the high hand temperature associated with being a female. This feature is not immediately evident, but its results are readily seen in Figures 5 and 6. Females show a considerable increase in hand and finger temperature due to the addition of clothing.

The extremely high sex-calf temperature interaction seems more easily understood. Men are characterized by higher rates of blood flow to the feet. When they wear clothing, the blood courses through a trouser-protected leg for a considerable distance before being called upon to give up most of its heat. The female's skirts are less effective in insulation in this region.

Table 9, which summarized correlations between temperatures, shows that there is a general decrease in correlations when clothing is added. This might represent a relaxation of a central, integrative control as cold stress is diminished. It is noteworthy that there is no change in the overall pattern of response to cold due to the

addition of clothing as might be predicted from the work of Burton and Edholm (1955: 102-5). They found that the addition of heavy clothing provided for comfort sensations in the skin receptors which lead to massive heat loss due to vasodialation. This was probably avoided in the Quechua by the practice of exposing the feet. The most important surface receptors seem to be located in the feet (Borton 1963) so that there would be no difference in stimulation produced by the addition of clothing.

The form of Indian clothing of both sexes suggests some form of climatic engineering. When Army researchers began to develop arctic clothing, they arrived at two general principles (Kennedy 1961). The first of these was to utilize entrapped air for its insulative value. The Andean Indians seem to utilize this principle, too. The home woven fabrics utilized in the Nuñoa region are made of wool. Wool is a desirable material because the resilience of its fiber maintains the original volume of trapped air for considerable time (Windslow and Harrington 1949: 127). The fiber is especially desirable because it resists crushing and therefore retains its insulative ability. The Nuñoa residents gain further advantage by weaving the wool in a rather course manner to provide more air space between the strands. Clothing which is worn next to the body is frequently knitted to provide for even more air space.

Trapped air is of value only if it is protected from convective heat loss for which wind is the chief agent. The Indians have provided for this by producing outer garments, ponchos and carrying

cloths, which are of a tighter construction. In some cases the weave is so tight as to be water resistant.

The second principle discovered by the Army and by the Indians is that several layers are better than one bulky garment. This is related to heat loss and sweating. The greatest danger to the insulative value of clothing is that the air spaces will be replaced with water. Since water is a more effective conductor of heat than air, massive heat flow into the environment will follow. The most likely source of water is perspiration, thus when activity is required, large quantities of water are released into clothing. If only one porous layer is present, it can rapidly pass through and into the atmosphere. After working, perspiration stops and the remaining water vapor quickly passes to the environment. Dry outer layers which were placed aside before activity was begun are now replaced, and their insulative value remains intact. It might also be added that heavy insulation during work could occasion heat stress if provision were not made for cooling.

The Indians have rejected lower leg and foot covering, utilizing biological protective mechanisms in their stead. This is desirable, for during the rainy season long pants and shoes would become soaked. The resulting massive heat loss could endanger lower extremities and result in cold injury. On the other hand, bare or sandaled feet do not retain water and are rapidly rewarmed.

The Nuñoa Indian has established another principle not emphasized in Army research. He has utilized dark colors for surface

clothing, providing for maximal heat gain. Typical male and female outer garments are black. A black suit will absorb about 95 percent of the ambient radiation, while a white suit will capture only 30 percent (Belding 1949). This extra radiation could reverse the heat flow and increase the heat stores of the Indian. More likely it will remain at the surface and simply reduce the amount of heat lost. Pugh (1964) notes that this surface heat is subject to rapid loss through convection.

The lower air density of higher altitudes also operates to enhance the effects of Indian clothing (Belding 1949). First, it requires less heat to warm an equal volume of air. Second, the insulative value of the air increases as the density decreases. This is related to the fewer molecules per unit volume. Third, the lesser air density also reduced convective heat loss. Convective heat loss is thought to be responsible for about 80 percent of the total heat lost through clothing. A final result is that there is more ambient solar radiation due to the lesser amount of atmospheric screening.

The Nuñoans are thus observed to benefit from clothing in terms of promoting a generally warmer microclimate. He has engineered this clothing for maximal effectiveness against the cold, while taking advantage of the inherent qualities of lower air density at higher altitudes. The antiquity of the present costume is unknown for Nuñoa, but in other regions it dates from the last century (Adams 1959).

Summary and General Implications

This paper deals with the responses of a population to cold stress. It has been shown that certain ecological factors promote variety within the population just as they have been demonstrated to produce variety between populations (Chapter 3). Three sources of this intrapopulation variation have been discussed.

Altitude is one of the principle contributors and has been used to illustrate the influences of the physical environment. As discussed here, it operates directly by reducing the microclimate temperature at higher elevations. The population segments living at higher elevations are therefore subject to colder temperatures on a more regular basis. This is observed in the presence of rather small altitude differences of about 1,000 feet. Altitude may also operate indirectly, in this case through economy, by precluding agriculture about 14,000 feet and thus promoting herding. Large herds require employment of a great number of people in situations where they may frequently become cold stressed. A herding economy requires mobility so that the herders construct a more economical but less effective house. There are also certain dietary consequences which result from remoteness and the inability to farm.

The biological parameters of age and sex also sponsor segmentation of the population. Men and women respond to cold differently even if they are exposed to identical conditions. These differences in response are not greatly modified by clothing. Under natural conditions such sex-related variation is also observed, although in a

somewhat modified form. In field conditions, it is also shown that age-related variation exists. Children under 15 years of age not only live in a colder microclimate but respond to cold in a manner different from adults.

Finally, the cultural mechanism of clothing is examined. It has the effect of increasing the microclimate temperature several degrees, but has notappreciable influence on core temperature. There is some evidence that certain effects of clothing are sex specific, thus men seem to derive greater benefit from wearing pants than would women. This is most probably related to the higher peripheral blood flow to the foot which seems to characterize the Nuñoa men. The clothing designs are of considerable interest, for they employ the same principles utilized by the U. S. Army for designing cold weather clothing. The material from which they are made seems of special utility in that it takes advantage of the increased insulative qualities of air at high altitudes.

The Indian population of the Nuñoa region is the first whose responses to cold are known in detail. The present study, supplemented by those presented in Chapter 4, gives a detailed picture of the variety in response to cold which exists on a yearly basis. To provide information of value in an evolutionary context, these studies should ideally be followed by a demographic survey to determine if cold is operating as a selective agent.

The knowledge gained by examining the responses of these population segments indicates that some qualification must be added to most previous studies. These qualifications spring from the usual procedure of selecting only adult males for subjects. This procedure is

is now known to be inadequate in several respects.

1. In the Nuñoa region, the responses of adult males are not representative of other segments of the population. Thus, extreme caution is in order when populations are to be compared in terms of adult males alone. The hazards in this procedure are illustrated from the work of Baker and others (1967). They report that one of the differences between American Whites and Nuñoa Indians is that the Indians maintain higher toe temperatures in the face of a similar cold stress. From the present study, it is seen that high toe temperature may characterize males but not females. A generalization to the entire populations on the basis of these differences in adult males would be most erroneous. Since there is probably as much variation in other populations (those outlined in Chapter 3, for example), the entire process of comparing populations and their adjustments is questionable. As previously noted, there may be more variation within those populations whose adult males have been tested, than has been demonstrated between them. A major reorientation in cold studies of primitive man is in order. Rather than concentration on "type" responses, investigators should attempt to characterize populations. When they do, Hammal's (1964) evolutionary scheme will undoubtedly need some revision and more concrete evidence on cold stress as a selective agent will become available.

2. Testing in the laboratory may lead to certain difficulty in generalizing to actual living conditions. This problem seems directly related to the approximation of actual living conditions by those imposed in the laboratory. The current laboratory study and that of

Baker (1966b) show similar sex-related differences. This might be expected because in both cases ambient temperature was of a similar magnitude and activity of the subjects was restricted. What is disturbing is the failure of the laboratory studies to predict the daytime cold responses with equal precision. Based upon the controlled laboratory studies, it would have been erroneously concluded that Nuñoa females respond to cold stress through increased heat production and higher skin temperature. It would seem that in the future, the degree, as well as the class of environmental stress, should be investigated. Laboratory studies could then approximate the actual stressful conditions, and more meaningful conclusions could be drawn. The idea that all groups can be tested under uniform conditions and will yield valid data as to their resistance to cold stress must be abandoned.

3. Sampling from one local population can lead to errors in estimating the actual amount of cold stress a population may receive. As seen in this study, altitude and economy produce distinct life histories of cold exposure in different segments of the population. Knowledge of only one segment could lead to a false estimate of some parameters.

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APPENDIX I

Racial and Developmental Factors in Foot Cooling: Quechua Indians and U. S. Whites

Michael A. Little

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CHAPTER I

INTRODUCTION

General Introduction

An important aspect of thermoregulation in man is the maintenance of elevated temperatures in the extremities for adequate neuro-muscular function, to prevent cold injury, and for comfort under cold ambient conditions. Heat regulation in both the hand and the foot is often poor (1) because of the greater surface area in proportion to the volume of tissue, (2) because of the small amount of muscular tissue that is capable of locally increasing heat production, and (3) because of the relatively low amounts of insulative fat. Proper artificial insulation of the extremities is also difficult because of their form. Heat into the extremities can thus be supplied either from an external radiant source or from circulating blood.

Adequate thermoregulation is more of an acute problem in societies where the material culture affords incomplete protection from the cold. This is especially true in the Peruvian highlands where most of the indigenous population wear only sandals or go barefoot. While much of the body is well protected from the cold by wool clothing, the face, hands, and feet are generally exposed. On a number of occasions, visitors to the highlands have noted that Andean Natives from Peru and Bolivia are able to maintain elevated extremity temperatures

under the cold conditions found in these higher ecological zones of the Andes. This phenomenon suggests adaptive or acclimatizational responses by the highland native to the cold stresses of the Andes.

If adjustments to cold stress are present among highland Quechua Indians, then a further problem remains to be investigated. This deals with the mode of adjustment. Alternative modes might be (1) genetic adaptation, (2) developmental acclimatization, (3) short-term acclimatization, or (4) any combination or interaction of these. A productive way to partition out these modes of adjustment is to study a chronically cold-exposed population with subjects sampled from childhood to old age. By this design, developmental changes in responses to cold may be observed. Furthermore, by comparing groups of different racial origins, genetic components of cold adaptation may be uncovered as well.

C. Ladd Prosser (1964) suggests three steps that are required for the systematic analysis of adaptive variation:

1. Description of the variation of natural populations with respect to adaptive capacity.
2. Separation of genetic from environmentally induced variation.
3. Determination of mechanisms of variation.

The present study is concerned with the first two steps in Prosser's analytic sequence. The problem of local cold stress to the foot is considered in the following work by comparing the responses of young and adult Quechua Indians and European derived Americans to standard cold tests.

Literature Review

Terminology

In the past, there has been a great deal of inconsistant usage of terms such as adaptation, acclimatization, acclimation, and others in studies of adjustments to environmental stress. For example, in a recent symposium on temperature acclimation (Smith, 1963), three of the sections or panels included the term "acclimatization" in the title, three used the term "adaptation," and one used the term "habituation." Reviews of the historical and recent use of these terms as well as attempts to standardize terminology are available (Hart, 1957; Eagan, 1963c; Leake, 1964; Prosser, 1964; Folk, 1966). Since there is some general agreement with Eagan's categories (1963c), these will be used, with some additions, in the present work.

1. Adaptation - will be used in a general sense to indicate any beneficial adjustment in an organism in response to environmental stresses, such as cold.

2. Genetic Adaptation - adjustments that are hereditary and favor the survival of a population living under specific environmental conditions.

3. Acclimatization - adjustments that are not hereditary but may be produced by a given period of exposure to specific environmental conditions. The adjustments may be to more than one environmental parameter.

4. Developmental Acclimatization - adjustments that may require a lifetime of exposure, especially during infancy and childhood, for their full expression.

5. Long-term Acclimatization - adjustments that are made over a period of years, but do not require exposure during childhood.

6. Seasonal Acclimatization - adjustments as a result of seasonal changes in exposure to environmental conditions.

7. Short-term Acclimatization - adjustments that may occur in a matter of days, weeks, or months of exposure.

When there is some question as to the source of adjustment, the general term "adaptation" will be used. When the adjustment is clearly not a "genetic adaptation," the term "acclimatization" will be used.

Peripheral Circulation in the Extremities

Blood circulation to all parts of the body serves a number of indispensible functions. Oxygen and nutrients are carried to tissues for metabolic purposes, and carbon dioxide and waste products are removed by the same medium. In addition, the circulatory system is important in the transport of hormones or chemical regulators and immunologic substances. Finally, the circulatory system plays in important role in thermoregulation by distributing heat produced by metabolically-active tissues and organs to all parts of the body, and also by contributing to the regulation of heat balance by circulatory changes in the skin.

The dermal layer of the skin is abundantly supplied with blood as the result of an intricate system of blood vessels. However, the supply of blood to the skin is much greater than is metabolically required, and it is generally agreed that only a small part of this supply is utilized for purposes of metabolism (Greenfield, 1963; Rushmer et al., 1966; Abramson, 1967:130). The remaining blood supply serves to maintain the skin temperature at comfortable levels and to dissipate or conserve heat at the surface (Roddie, 1961).

In the skin, blood flow through dermal capillaries is regulated by the smooth-muscle precapillary resistance and sphincter vessels (Thulesius, 1967). Constriction and dilation of these arteri-

olar vessels changes capillary flow, and as a consequence, skin temperature either increases or decreases. Other vessels called arteriovenous anastomoses (AVA) are found only in certain portions of the dermal layers of the skin of the hands, feet, and some parts of the face and ears. The AVA or shunt vessel directly connects the arteriole and venule and by passes the capillary network. In contrast to capillaries, the AVA contains a layer of smooth muscle and is capable of dilating to provide a blood flow that may be over 1,000 times the flow found during the state of constriction (Nelms, 1963). These vessels were first systematically studied by Grant (Grant, 1930; Grant and Bland, 1931) who recorded AVA's in (1) the nail bed, pad, and palm of the finger, (2) the palm of the hand, (3) the nail bed and pad of the toe, and (4) the sole of the foot. AVA's were most abundant at the distal portions of the hand and foot. In addition, Grant was unable to find any AVA's in the skin of the forearm or lower leg. Lewis (1930), in concurrent experiments, discovered that when the finger is cooled in an ice water bath, the skin temperature rapidly drops nearly to the temperature of the water, but after a few minutes the skin temperature spontaneously increases and continues to rewarm and cool for the remainder of the test. Lewis suggested that this is a protective mechanism to prevent cold injury to especially vulnerable parts of the body. These cyclic rewarming responses (now variously known as Lewis waves, hunting responses, or cold-induced vasodilations) were attributed by Grant and Bland (1931) to the spontaneous dilation and constriction of AVA's. Later work has supported this contention (Mescon et al., 1956), and others have noted a close correspondence

between the presence of AVA's in the skin and the incidence of the cold-induced vasodilatory response (Fox and Wyatt, 1962).

Bazett and his colleagues (1948) discovered another vascular mechanism that contributes to the temperature regulation of the extremities. In tests of arterial blood temperature in the upper limb, they found a temperature gradient between the brachial and radial arteries that changed during cooling of the hand. When the hand is chilled, cool venous blood is shunted from superficial to paired deep veins (venae comitantes) that are directly adjacent to an artery. The temperature gradient is produced by a counter-current heat exchange system that develops between the artery and venae comitantes. The significance of this is that the arterial blood then becomes pre-cooled in passing from the proximal to the distal parts of the limb, and heat loss from the central body core is reduced. An interesting point that may have some bearing on temperature regulation differences between the upper and lower extremities is that the venae comitantes are paired for the full length of the upper extremity; however, in the lower extremity, they extend only from the toes to about the level of the knee(Brash, 1951:1359). Iampietro and Adams (1966) have discussed counter-current heat exchange in detail for man, and Scholander (1955) has surveyed the importance of this mechanism to other animals.

Extremity circulation in man has been studied by a number of indirect methods (Burton, 1954). The majority of qualitative studies have dealt with cutaneous or deeper tissue temperature determination (Nelms and Soper, 1962: Meehan, 1955; Brown, 1954a) and extremity or digit heat flow by bather bath (Elsner et al., 1960) or air (Love,

1948) calorimetry. Quantitative methods have been almost totally restricted to venous-occlusion plethysmography (Abramson, 1967).

The important differences between these techniques is that skin temperatures largely reflect cutaneous blood flow, whereas calorimetry and plethysmography give measures of total blood flow to superficial and deeper tissues. Comparing the results of different methods for the hand and foot (especially the digits) introduces less error than would be expected, since skin and subcutaneous tissue are about twice the volume of muscle in these structures (Abramson and Ferris, 1940; Allwood and Burry, 1954). Successful attempts to determine the relationships among blood flow, heat output and skin temperatures have been made. Catchpole and Jepson (1955) found the relationhsip between hand and finger blood flow and surface temperatures to be quite good, although not linear. Edwards and Burton (1960) confirmed these results but noted a slight lag between the two parameters. Felder and co-workers (1954), in studies of the toe, have shown the same relationship and point out that the correlation between blood flow and skin temperatures is better at skin temperatures below about 28°C.

Excellent reviews of peripheral circulation in the extremities can be found in the works of Richards (1946), Shepherd (1963), Abramson (1967), and Whelan (1967).

Effects of Cold on Extremity Circulation

The circulatory responses of the extremities to local cold exposure are dependent upon a number of important environmental and physiological conditions. Of primary importance is the degree of cold to which the extremity is exposed. For example, cold-induced

vasodilation is seldom elicited at skin temperatures above 15 or 18°C (Lewis, 1930), although the response may be completely suppressed if skin temperatures fall too rapidly to levels that approach tissue freezing (Eagan, 1963b).

Regulation of blood flow to the extremities is strongly influenced by the general thermal state of the body. When the body temperature is maintained at comfortable levels (either by heating or by exercise) and only the extremity is cold-exposed, blood flow and skin temperatures are much higher than when the body is chilled (Spealman, 1945); Rapaport et al., 1949; Bader and Mead, 1951; Greenfield et al., 1951; Wyndham and Wilson-Dickson, 1951; Strömme et al., 1963). General thermal comfort also improves the cold-induced reflex vasodilation response in the hand, while body-chilling tends to inhibit the response (Blaisdell, 1951; Keatinge, 1957). Skin temperatures of the hand and foot during local cooling can be raised by warming other parts of the body, either by radiant sources (Bader and Macht, 1948; Kerslake and Cooper, 1950) or by immersion in warm water (Pickering and Hess, 1933).

Other factors that influence the thermal state of the body, and thus the response to cold, are diet and both long-term and immediate nutritional state. For example, it is likely that at least part of the elevated basal metabolism of the Arctic Eskimo can be attributed to his high intake of protein (Brown, 1954b). Rennie and others (1962) thus suggest that the high values for limb blood flow observed in the Eskimo may result from this elevated metabolism. Iampietro and Bass (1962) tested men under various levels of caloric restriction during continuous cold exposure for 14 days and found decreased heat pro-

duction and core temperatures among the severely restricted subjects. Yoshimura and his colleagues (1952) found that after about a week of an excessive daily intake of protein, the cold-induced vasocilatory response of the finger immersed in ice water was improved. In another study by Yoshimura and Iida (1950), a hot (primarily rice) meal improved cold tolerance in the finger up to 60 minutes subsequent to the meal. Finally, Kreider and Buskirk (1957) noted that when men sleeping in arctic bags at -34.5°C were given a 600 or 1200 kcal food supplement before retiring, they slept more comfortably and with higher rectal and toe temperatures than without the supplement. It can be concluded, then, that skin temperatures can be modified by gross caloric or protein intake during cold exposure, largely through changes in metabolic rate.

Although vasomotor responses to cold in the skin of the hand and foot are primarily under local and sympathetic nervous control (Roddie, 1961; Greenfield et al., 1951), they can be modified by higher brain centers. Pain, fear, general anxiety, hypnosis, and other forms of psychic stimuli can elicit changes in blood flow to the hand and foot (Freeman et al., 1936; Abramson and Ferris, 1940; Meehan, 1957; Glaser et al., 1959; Vanderhoof and Clancy, 1962; Kissen et al., 1964; Teichner, 1965). The typical reaction with anxiety is a decrease in blood flow, although if the anxiety is prolonged (Allwood et al., 1959) or the subject is hypnotized (Kissen et al., 1964), blood flow may increase above normal levels. Anxiety can also suppress or delay the cold-induced vasodilatory response (Meehan, 1957; Teichner, 1965).

Studies of Acclimatization to Cold

A number of animal studies have demonstrated alterations at the cellular and tissue levels of organization that have been attributed to cold exposure. LeBlanc (1963) reported a thickening of the epidermis in the goat ear during winter, and an increase in the number of layers of the stratum corneum in cold-acclimatized rats. Héroux and St. Pierre (1957) demonstrated an increase in capillaries of the ear of cold acclimatized laboratory rats. In a later study (Héroux, 1961), the same increases were shown in the ears of wild rats that were captured in winter when compared with rats captured in the summer. LeBlanc (1963) notes certain characteristics in the skin of cold-acclimatized laboratory rats that are distinctive in cases of what he calls "cold injury" and "cold adaptation." In the former condition, there is blocked mitosis or body cell reproduction, edema, necrosis, and a decrease in skin mast cells. However, in the latter condition, there is an increase in the number of capillaries, an increase in the stratum corneum, a rapid falling off of blocked mitosis, and an increase in the number of mast cells. A greater number of mast cells was also found in the finger skin of cold-acclimatized Gaspé fishermen when compared to unacclimatized controls (LeBlanc et al., 1960). The significance of this finding is obscure, since little is known of the precise function of mast cells at present.

Four general categories of research have been employed in studies of cold adaptation and acclimatization in man. These designs have been utilized in tests of total body or general, as well as local ex-

tremity cold exposure. The first category of studies includes comparisons of racially distinct groups. One of the groups may be chronically cold exposed in the course of normal living or one of the groups may be from a tropical area and never have experienced cold. European derived White subjects are customarily used as standards in this type of study. These and related investigations are discussed in the following section. The second category requires subjects who are chronically cold-exposed, but are members of a population that does not ordinarily suffer chronic cold stress. An example might be a comparison of the hand temperatures of butchers who habitually work with chilled meat and non-butchers. The third category includes seasonal studies of temperature and metabolic responses of subjects from temperate zones where there are marked variations in annual temperatures. Finally, a general category should include studies where attempts have been made to acclimatize subjects to cold by repeated exposure to cold air or water. A summary of investigations of local cold exposure to the hand and foot is given in Table I. The first category given above corresponds to Group Differences in Table I, the second category corresponds to Long-Term Acclimatization, and the third and fourth categories are listed as Short-Term and Seasonal Acclimatization.

Some of the earliest studies of short-term and seasonal changes in extremity temperatures were carried out by Yoshimura and Iida (1950, 1952; Yoshimura, 1960). These authors found higher finger temperatures after a winter of exposure and elicited improvements in the cold-induced vasodilatory responses in the foot after a month of brief daily

TABLE I

OUTLINE OF SOME INVESTIGATIONS OF LOCAL COLD EXPOSURE

INVESTIGATION	SUBJECTS	AGE	PART OF BODY TESTED	EXPOSURE CONDITIONS			RESULTS
				DURATION	TEMP.	COOLING MEDIUM	
GROUP DIFFERENCES							
Brown and Page, 1952	22 Eskimo males 37 White male controls	18 - 40 young adults	Hand	90 to 120 min.	5 to 45°C	water bath plethysmography	Hand blood flow in Eskimo is consistently higher than in controls and differences are more pronounced at lower temperatures.
Coffey, 1954	10 Eskimo and Arctic Indian men raised in mission schools 7 White adult males	------ ------	Hand	20 min.	-25°C	air	Mean finger temperatures were the same for both groups but native subjects' manual dexterity was far superior to that of White subjects.
Elsner, Helms, and Irving, 1960	9 Arctic Indian males 8 White male controls	20 - 39 27 - 63	Hand	30 min.	4 to 5°C	water bath calorimetry	Indians maintained warmer hands and heat loss among Indians was twice as great as among controls. Indians rewarmed more quickly and with less pain than controls.
Hammel, 1960	? Alakaluf Indian men and women 3 White adult males	------ ------	Hand and foot	30 min.	5°C(hand) 10°C(foot)	water bath calorimetry	No difference between Indians and Whites in heat output of hand or foot. But Indians experienced little or no discomfort during the test, while Whites experienced extreme pain.
Hanna, 1965	22 U.S. White male students 22 U.S. White female students 26 Peruvian White male students 23 Peruvian Indian male students 33 Peruvian Indian male farmers	av. 19 av. 21 av. 20 av. 21 av. 35	Fingers	60 min.	0°C	water bath	Indians show better protection against cold than White subjects. No differences between U.S. White and Peruvian White or between Indian Students and Indian farmers. No differences between U.S. males and females.
Hildes et al., 1961	9 Eskimo males 4 White males	19 - 27 30 - 41	Hand	30 min.	5°C	water bath calorimetry	Greater heat loss among Eskimo subjects, but attributed to their smaller hand volumes.
Iampietro et al., 1959	16 U.S. Negro soldiers 17 U.S. White soldiers	18 - 33 19 - 25	Fingers	45 min.	0°C	water bath	Among the White subjects, mean finger temperatures were higher, time to first rewarming was shorter, and temperatures at onset of first rewarming were higher when compared with Negro subjects.
Krog et al., 1960	13 Norwegian Lapp males 12 Northern Norwegian White male fishermen 19 White male controls	18 - 45 16 - 52 21 - 45	Hand	30 min.	0 to 40°C	water bath calorimetry and plethysmography	Lapps maintained greatest blood flow and fishermen were intermediate at temperatures below 20°C. Lapps and fishermen rewarmed earlier than controls, and Lapps reached a higher temperature than the other two groups. Lapps seemed to experience less pain during cooling in ice water and showed less decrement in manual dexterity.
Meehan, 1955	28 Eskimo males 24 Alaskan Indian males 38 U.S. Negro soldiers 168 U.S. White soldiers	All between 18 and 26	Fingers	30 min.	0°C	water bath	Native arctic groups maintained highest temperatures, Whites were intermediate, and Negroes had lowest temperatures.
Miller and Irving, 1962	7 White males unaccustomed to cold 4 White males accustomed to cold 8 Eskimo men 3 Eskimo women 8 Eskimo boys 4 Eskimo girls	23 - 40 20 - 35 26 - 54 25 - 72 11 - 13 11 - 12	Hand and face	30 to 45 min.	-3 to -7°C	Air	Adult Eskimos maintained highest hand temperatures. Unaccustomed Whites and Eskimo children were lowest, while accustomed Whites were intermediate in their temperature responses.
Newman, 1967	17 U.S. Negro males 22 U.S. White males	------ ------	Hand	30 min.	5°C	water bath calorimetry	White subjects lost more heat, maintained higher finger temperatures, and showed greater rewarming responses than Negro subjects.

TABLE I (cont.)

INVESTIGATION	SUBJECTS	AGE	PART OF BODY TESTED	EXPOSURE CONDITIONS: DURATION	TEMP.	COOLING MEDIUM	RESULTS
SHORT-TERM AND SEASONAL ACCLIMATIZATION (cont.)							
Yoshimura and Iida, 1950	7 Adult Japanese males	———	Fingers	30 min.	0°C	water bath	Finger temperatures were higher in August than in February.
Yoshimura and Iida, 1952	30 Japanese boys 30 Japanese men	16 - 17 22 - 23	Foot	15 or 30 min. daily for 1 month	0°C	water bath	Mean skin temperatures were higher and temperatures at onset of first rewarming were higher at the end of one month among the boys. Only slight improvements were noted among the men.
AGE DIFFERENCES							
Spurr et al., 1955	2 Boys 2 Girls 6 Boys 6 Girls 6 Men 2 Women 9 Men	6 - 7 8 - 10 22 - 31 67 - 83	Hand	Variable (10, 20, or 30 min.)	10°C	water bath	Youngest subjects seemed to show most rapid and highest amplitude rewarming responses.
EFFECT OF ANXIETY							
Meehan, 1957	1 White adult male	———	Hand	30 min.	0°C	water bath	Anxious emotional state can inhibit or suppress the rewarming response.
Teichner, 1965	41 Male and female undergraduate students 18 with no shock 13 with weak shock 10 with strong shock	———	Hand	20 min.	1°C	water bath	The time at onset of first rewarming was increased by the threat of shock or by raising the arousal level (anxiety) of the subjects.
EFFECT OF GENERAL BODY THERMAL STATE							
Blaisdell, 1951	4 Young adult males	———	Hand	Variable	0, 5, 10, and 15°C	air	Rewarming tended to occur at lower hand temperatures when the body was cooled. The rewarming curves with highest amplitude tended to occur when the body was warm. Mean hand temperatures were positively related to body thermal state.
Keatinge, 1957	7 Males	18 - 30	Finger	120 min.	0°C	water bath	When subjects were warm (exercise and clothed) the rewarming response was early, rapid, and high. When subjects were cool (room air at 17-18°C and trousers only), the rewarming response was later and the amplitude was lower. When subjects were warm and one foot was immersed in cold water (12°C) a vasoconstriction was induced in the finger followed by a recovery. This response did not occur when subjects were cold.
Rapaport et al., 1949	4 Young adult males	———	Hand (with glove) and foot (with boot)	2 hrs.	-18, -29, and -34°C	air	At low ambient temperatures when the body was warmed (clothing and electric blanket), hand and foot temperatures were maintained at comfortable levels. When hand and foot temperatures were low and the rest of the body was heated, the foot recovered more slowly than the hand.
Spealman, 1945	6 Males	18 - 35	Hand	3 hrs.	2 to 35°C	water bath plethysmography	At warm room temperature (32°C) and cold water temperature (5 and 10°C) finger blood flow and temperatures were higher than at comfortable (24°C) or cool (16°C) room temperatures.
Wyndham and Wilson-Dickson, 1951	2 British sailors	———	Hand and foot	3 hrs.	+9 to -12°C (variable wind speed)	air	Extremity temperatures were maintained at higher levels when rectal temperatures were above normal. Feet showed slower rewarming than did hands.

TABLE I (cont.)

INVESTIGATION	SUBJECTS	AGE	PART OF BODY TESTED	EXPOSURE CONDITIONS: DURATION	EXPOSURE CONDITIONS: TEMP.	EXPOSURE CONDITIONS: COOLING MEDIUM	RESULTS
GROUP DIFFERENCES (cont.)							
Rennie and Adams, 1957	8 U.S. Negro Soldiers 8 U.S. White Soldiers	------ ------	Hand	90 min.	-12°C	Air	Finger temperatures of the White group were higher than those of the Negro group. Whites showed an active rewarming response, while rewarming was rare among the Negroes.
Thomas, 1967	42 Adult Quechua Indian males (highland residents) 10 Adult Quechua Indian males (coastal residents) 8 Adult U.S. and British White males	av. 25 av. 22 av. 27	Hand	60 min.	0°C	air	The two Quechua groups maintained higher hand temperatures than the White group, especially after 30 minutes of exposure. There were no systematic differences between the two Quechua groups.
Yoshimura and Iida, 1952	367 Japanese males 52 Manchurian Chinese males 72 Manchurian Mongol males 19 Orochon males (nomadic Manchurian tribesmen)	8 - 27 8 - 28 8 - 28 10 - 57	Fingers	30 min.	0°C	water bath	Japanese showed least cold protection, Manchurian Chinese and Mongols were intermediate, and Nomadic tribesmen showed greatest protection. Differences were less pronounced in younger age groups (8 - 14 years) and maximal among older groups (20 - 28 years).
LONG-TERM ACCLIMATIZATION							
Egan, 1963	5 Physically fit mountaineers 19 U.S. Air Force sedentary controls	24 - 32 19 - 42	Fingers	10 min. (30 min)	0°C (-22°C)	water bath (air)	No differences between physically fit and sedentary subjects.
Hellström and Andersen, 1960	9 White male Arctic fishermen 9 White male controls	23 - 43 19 - 39	Hand	30 min.	4°C	water bath calorimetry	No differences in heat output between the two groups.
Hellström, 1965	All Norwegians 64 Male students 7 Dairy workers 32 Lumberjacks 29 Fish filleters	 18 - 50 31 - 56 23 - 45 24 - 50	Hand	30 to 40 min.	3 to 5°C	Air and water bath	During a general and a local cold exposure, fish filleters maintained highest finger temperatures. When three subjects were tested daily for from 11 to 15 consecutive working days, there were no increases in heat loss, but pain and the cold pressor response declined at the end of the series.
LeBlanc et al., 1960	14 Male Gaspé fishermen 14 Male controls	av. 35 av. 29	Hand	10 and 30 min.	2.5 and 5°C	water bath calorimetry	Fishermen maintained higher finger temperatures at 2.5°C and showed greater heat output at 5°C. Cold pressor response was greater in controls.
LeBlanc, 1962	6 to 10 Male Gaspé fishermen 7 to 11 Male Controls	------ ------	Hand and foot	5 min.	2.5°C	water bath	Foot temperatures were lower in the fishermen but cold pressor response was also lower. No differences in finger temperatures but cold pressor response was again lower in fishermen. Cold pressor responses always lower in both groups at beginning of summer.
Nelms and Soper, 1962	11 White male fish filleters 9 White male controls	25 - 43 30 - 42	Hand	15 min.	0°C	water bath	Fish filleters had significantly higher hand temperatures, and rewarmed earlier and at higher temperatures than controls.
SHORT-TERM AND SEASONAL ACCLIMATIZATION							
Adams and Smith, 1962	5 White males	------	Finger	20 min., 4 times daily for one month.	0°C	water bath	There were higher finger temperatures and more labile rewarming responses at the end of the month.
Carlson et al., 1953	7 White males	------	Hand (with glove)	16 to 18 hours daily for 14 days.	-5 to -17°C	air	Hand temperatures were warmer at the end of the 14-day period.

TABLE I (cont.)

INVESTIGATION	SUBJECTS	AGE	PART OF BODY TESTED	EXPOSURE CONDITIONS: DURATION	EXPOSURE CONDITIONS: TEMP.	EXPOSURE CONDITIONS: COOLING MEDIUM	RESULTS
GROUP DIFFERENCES (cont.)							
Rennie and Adams, 1957	8 U.S. Negro Soldiers 8 U.S. White Soldiers	------ ------	Hand	90 min.	-12°C	Air	Finger temperatures of the White group were higher than those of the Negro group. Whites showed an active rewarming response, while rewarming was rare among the Negroes.
Thomas, 1967	42 Adult Quechua Indian males (highland residents) 10 Adult Quechua Indian males (coastal residents) 8 Adult U.S. and British White males	av. 25 av. 22 av. 27	Hand	60 min.	0°C	air	The two Quechua groups maintained higher hand temperatures than the White group, especially after 30 minutes of exposure. There were no systematic differences between the two Quechua groups.
Yoshimura and Iida, 1952	367 Japanese males 52 Manchurian Chinese males 72 Manchurian Mongol males 19 Orochon males (nomadic Manchurian tribesmen)	8 - 27 8 - 28 8 - 28 10 - 57	Fingers	30 min.	0°C	water bath	Japanese showed least cold protection, Manchurian Chinese and Mongols were intermediate, and Nomadic tribesmen showed greatest protection. Differences were less pronounced in younger age groups (8 - 14 years) and maximal among older groups (20 - 28 years).
LONG-TERM ACCLIMATIZATION							
Eagan, 1963	5 Physically fit mountaineers 19 U.S. Air Force sedentary controls	24 - 32 19 - 42	Fingers	10 min. (30 min)	0°C (-22°C)	water bath (air)	No differences between physically fit and sedentary subjects.
Hellstrøm and Andersen, 1960	9 White male Arctic fishermen 9 White male controls	23 - 43 19 - 39	Hand	30 min.	4°C	water bath calorimetry	No differences in heat output between the two groups.
Hellstrøm, 1965	All Norwegians 64 Male students 7 Dairy workers 32 Lumberjacks 29 Fish filleters	 18 - 50 31 - 56 23 - 45 24 - 50	Hand	30 to 40 min.	3 to 5°C	Air and water bath	During a general and a local cold exposure, fish filleters maintained highest finger temperatures. When three subjects were tested daily for from 11 to 15 consecutive working days, there were no increases in heat loss, but pain and the cold pressor response declined at the end of the series.
LeBlanc et al., 1960	14 Male Gaspé fishermen 14 Male controls	av. 35 av. 29	Hand	10 and 30 min.	2.5 and 5°C	water bath calorimetry	Fishermen maintained higher finger temperatures at 2.5°C and showed greater heat output at 5°C. Cold pressor response was greater in controls.
LeBlanc, 1962	6 to 10 Male Gaspé fishermen 7 to 11 Male Controls	------ ------	Hand and foot	5 min.	2.5°C	water bath	Foot temperatures were lower in the fishermen but cold pressor response was also lower. No differences in finger temperatures but cold pressor response was again lower in fishermen. Cold pressor responses always lower in both groups at beginning of summer.
Nelms and Soper, 1962	11 White male fish filleters 9 White male controls	25 - 43 30 - 42	Hand	15 min.	0°C	water bath	Fish filleters had significantly higher hand temperatures, and rewarmed earlier and at higher temperatures than controls.
SHORT-TERM AND SEASONAL ACCLIMATIZATION							
Adams and Smith, 1962	5 White males	------	Finger	20 min., 4 times daily for one month.	0°C	water bath	There were higher finger temperatures and more labile rewarming responses at the end of the month.
Carlson et al., 1953	7 White males	------	Hand (with glove)	16 to 18 hours daily for 14 days.	-5 to -17°C	air	Hand temperatures were warmer at the end of the 14-day period.

TABLE I (cont.)

INVESTIGATION	SUBJECTS	AGE	PART OF BODY TESTED	EXPOSURE CONDITIONS: DURATION	TEMP.	COOLING MEDIUM	RESULTS
EFFECT OF WARMING OTHER PARTS OF THE BODY							
Bader and Hacht, 1948	2 White males	18 and	Hand	130 min.	15 and 23.5°C	Air (total body cooling while lightly clothed)	Face warming, using an infra red source, produced significant increases in skin temperature of the hand at both ambient temperatures.
Pickering and Hess, 1933	4 Males	< 30	Hand and foot	Variable	19°C	Air	When one upper extremity and one lower extremity were immersed in water at 43°C the temperatures of the extremities in air showed a rise. There was a considerable lag in the response of the cooled toe when compared with the cooled finger.
DIFFERENCES BETWEEN HAND AND FOOT RESPONSES							
Allwood and Burry, 1954	4 Males	25 - 30	Foot	60 to 120 min.	15 to 44°C	Water bath calorimetry and plethysmography	Foot blood flow was lower than hand blood flow at all local temperatures.
Greenfield et al., 1951	6 White males	24 - 33	Foot and toes	60 min.	0 to 6°C	water bath calorimetry	Less heat loss in toes than in fingers at 0 to 6°C, and less heat loss in forefoot than in hand at same temperature.
Kořranskiĭ, 1947	4 Males	20 - 30	Hand and foot	20 and 30 min.	5 and 10°C	water bath	Rewarming responses were observed during hand cooling but not during foot cooling.

exposures to ice water. In earlier Japanese studies (Takahashi, 1943), it was found that dye workers who wash clothing in the river during winter months show an improved temperature reaction in the toes. Other investigations (Bader et al., 1950; Meehan, 1955) give evidence that individuals who experience a higher incidence of cold injury also have poor rewarming responses during local cold exposure. It is not clear, however, in some of the cases whether or not the cold injury was the result or cause of the poor responses. The work of Glaser et al. (1959) and Eagan (1962) does not support the findings of Yoshimura and Iida (1950). However, Adams and Smith (1962) were able to cold-acclimatize fingers by four 20-minute daily immersions in ice water for a month. Adams and Smith (1962) attributed the lack of positive results in prior studies to an insufficient period of daily exposure. LeBlanc and Potvin (1965) demonstrated reductions in cold-induced pain and the cold pressor response after repeated immersions of the hand in cold water.

In order to test the local effects of long-term acclimatization to cold, comparisons have been made of arctic and sub-arctic fishermen (Hellström and Anderson, 1960; LeBlanc, 1962; LeBlanc et al., 1960), fish filleters (Hellström, 1965), and mountaineers (Eagan, 1963b) with appropriate controls. The results of these studies are somewhat discordant in that no differences were observed in hand temperatures or heat output during standard local cold tests in two of the studies (Eagan, 1963; Hellström and Andersen, 1960). Yet the trend appears to favor either higher extremity temperatures or decreased cold-pressor responses in chronically cold-exposed subjects in the

greater proportion of studies. The most convincing evidence of persistant acclimatization effects after removal of the individual from an occupation of chronic cold exposure was presented by LeBlanc (1966). He found a strong positive correlation between the cold pressor response during hand immersion in cold water and the years of retirement of Gaspé fishermen, and the reduced response persisted for up to 10 years following retirement.

The reports of standardized total body cooling to test for the effects of seasonal and short-term acclimatization in man have presented conflicting results. Joy and others (1962), in tests of soldiers after 43- and 52-day sojourns in Greenland and Alaska, found no changes in skin or rectal temperatures but decreases in shivering responses. The work of Davis and Johnston (1961) in studies carried out from October to February in the United States, and Girling (1967), in tests over a full year in Canada, support these findings. Similarly, Elsner and his co-workers (1961), in a nighttime cooling study of Arctic Indians in the spring and fall, concluded that no metabolic or thermal changes had occurred during the Arctic winter. On the other hand, seasonal changes in the Antarctic were observed by Milan and others (1961) who reported higher foot and average skin temperatures but lower rectal temperatures in IGY scientists at the end of the winter months. In another Antarctic investigation (Wyndham et al., 1964), five subjects tested at 5°C upon arrival and after 6 and 12 months residence, had higher toe temperatures and lower hand and rectal temperatures at the end of their period of residence. In one of the earliest studies of cold acclimatization (Balke et al., 1944)

tests were carried out on subjects who lived for four weeks at an elevation of 1200 m where temperatures averaged about 0°C. The subjects were exposed to a water bath at 20°C before and after the 4-week period, and the final tests showed higher extremity and lower trunk temperatures. Skreslet and Aarefjord (1968) reported the same pattern of skin temperature changes in three scuba divers after 45 days of almost daily exposure in sub-arctic waters.

Perhaps the most striking example of seasonal acclimatization can be found in the basal metabolic changes reported for the female divers (Ama) from Korea (Hong, 1963). The Ama dive regularly for plant and animal foods in ocean waters that may fall as low as 10°C during the winter. As a result of these significant cold exposures, the Ama manifest elevated basal metabolic rates during the winter months that return to normal levels during the summer. Rennie and co-workers (1964) attempted to produce an elevated basal metabolic rate comparable to that found in the Ama by immersing three U. S. college women in water at 20°C. The tests were carried out daily for one hour during a period of over two months, and only one of the three women showed an elevated basal metabolism with continued exposure. Others (Scholander et al., 1958) tested 8 men who lived in Norwegian mountains under cold conditions for 6 weeks, and detected a slight rise in basal metabolism at the end of the period.

Studies of Racial or Population Differences in Local Cold Responses

Studies of population differences in peripheral hand cooling have clearly demonstrated that groups living in cold climates have higher

hand and finger temperatures when compared to control groups living under protective conditions (see Table I). Yoshimura and Iida (1952) found less cold-induced vasodilation and lower hand temperatures in Japanese controls when contrasted with certain Manchurian groups from cold environments. Brown and Page (1952) and Miller and Irving (1962) independently studied the Eskimo and found the same high hand temperatures during exposure to water and air, while the White controls were consistently lower than the Eskimo. Hand calorimetry was investigated by Hildes and others (1961) using Eskimo and White control subjects. It was found that the Eskimo heat loss was greater than that of the control group, although these differences were only noted at room temperatures of 25°C and not at 15°C.

Another investigation (Meehan, 1955) was stimulated by the greater incidence of Negro cold injury to the extremities in proportion to that among White soldiers during the Korean war. Meehan contrasted Negro and White military personnel, Arctic Indians, and Eskimos in studies of finger immersion in ice water. He found that the Arctic groups maintained higher finger temperatures, the Negro group fell almost to the temperature of the water, and the White group maintained finger temperatures midway between the two. Others (Iampietro et al., 1959; Newman, 1967) found that cold-induced vasodilations were conspicuously absent in the responses of American Negroes to local cold exposure of the hand. This pattern of response among American Negroes is usually attributed to their tropical origins and the absence of selection for genetic traits that facilitate cold-induced vasodilation. On the other hand, Eagan (1963d) claims

(no data presented) to have elicited the rewarming response in Negro subjects tested at his laboratory, and thus the problem is far from resolved.

Some studies have been carried out with research designs to test more effectively the influence of hereditary factors. Krog and others (1960) tested the hands of Norwegian Lapplanders, Arctic fishermen, and students in cold water. According to a number of parameters that were tested, their results indicated that Lapps are best protected from local cold, that students show the least protection, and that the responses of Arctic fishermen are intermediate. Hanna (1965) compared rural Quechua Indian farmers, Quechua Indian students, White Peruvian students, and White American students in tests of finger cooling in ice water. Although the differences between these groups were not marked and there was some overlap, the combined results suggested that the racially similar Indian farmers and students are afforded slightly greater cold protection than the racially similar White students from Peru and the United States. Additional evidence for genetic adaptation among Quechua Indians was reported in the work of Thomas (1967). In this study, the hands of naturally cold-exposed highland Indians, coastal Indians, and U. S. and British Whites were tested under conditions of moderate cold (0°C) in air. The coastal Indians and highland Indians were genetically similar, except that the former sample had lived in an area characterized by mild temperatures since early childhood. The results of the tests showed that even though there was a great deal of variation in Indian hand te mperatures, both Indian groups were able to

maintain average skin temperatures at similar levels and higher than those of the White subjects.

Studies of Age Differences in Cold Responses

Few investigations have tested local responses to cold of subjects from the very old or very young age ranges. In cold climates, the aging individual might be more likely to suffer the effects of low temperatures because of characteristic losses in fat insulation or vascular changes concomitant with the aging process.

Studies of the capillary bed in the finger (Segoshi, 1959) indicate a decrease in capillary number, a greater incidence of abnormally shaped capillaries, and a decrease in capillary diameter with increasing age in a sample of 1,934 elderly Japanese. Allwood (1948), in a comparison of young men (age range 18-24 years) and older men (age range 70-82 years) for foot plethysmography at 33°C, found a decreased maximal blood flow and a greater internal vascular bed resistance for the older group. Krag and Kountz (1950) tested young adults and elderly adults during total body cooling at from 5 to 15°C and found that the elderly were less able to maintain core temperatures than the young adults. Horvath and others (1955), on the other hand, in a study of total body cooling found no differences in extremity skin temperatures between two groups of young and older individuals (mean ages were 25.5 and 64.0 years). The results of this study may be atypical, inasmuch as the subjects were not matched for sex and both groups were hospital patients.

Among infants and children, thermoregulation may be less efficient than in the adult for a number of reasons. An increased surface area to volume ratio and a poorly developed musculature in the infant would facilitate heat loss, while at the same time restricting metabolic compensation by shivering (Day, 1953). Yet the high resting metabolism and well-developed fat insulation of the infant should compensate for other disadvantages. The infant or child could, however, be especially vulnerable to cold stress under conditions of poor nutrition. Vascular responses seem to be fairly well-developed at birth, since Yoshimura and Iida (1952) were able to elicit cold-induced vasodilation in a three-day-old infant.

A study by Spurr and others (1955) was carried out in an attempt to define the effects of age on peripheral cooling responses. Observations were made on four groups of mixed males and females with mean ages of 6.5, 9.3, 24.4, and 75.6 years respectively. The test was conducted with the hand immersed in water at 10°C and at a room temperature of 27°C. Vasodilation occurred more frequently, and Lewis waves were more rapid with shorter periods in the younger age groups. The authors attributed the differences in responses to changes in vascular activity with age. Hands of Eskimo children were tested in air temperatures of -3 and -7°C (Miller and Irving, 1962). The minimum finger temperatures were not as high as those of the adult Eskimos, but were as high as or higher than the finger temperatures of the adult White controls in spite of the small hand volumes of the children. The apparently inconsistent results of these two studies may reflect two opposing processes. First, the differences between the young and

adult subjects in the work of Spurr and his colleagues may reflect a decline in vascular flexibility with advanced aging. In the study of Miller and Irving, the young-adult difference could indicate an age-related process of acclimatization that had not been completed by children.

Objectives of the Investigation

The Quechua Indians of Peru have been exposed to the cold conditions of the Andes for generations, and today they have little more protection from the cold than they did a thousand years ago. A part of the body that is constantly exposed in the day-to-day activity of the Indian is the foot. Prior studies have shown that hand temperature responses of chronically cold-exposed native groups tend to be maintained at higher levels during cold exposure when compared with European derived groups. Quechua Indians are also typified by elevated hand temperatures, yet studies have never been designed to explore the problem of cold responses of the lower extremity.

In the present investigation, a comparison is made of the temperature responses of the feet of highland Quechua Indians and U. S. whites during local cold exposures to air and water. The responses of both young and adult subjects are considered in an attempt to uncover any existing patterns of adjustment that may reflect developmental changes. The following questions are examples of problems to be answered.

1. Do highland Indians and U. S. Whites respond in the same manner when the foot is exposed to local cold?

2. If they do not, then are the differences of the same magnitude under various levels of acute and moderate conditions of cold exposure?

3. Do adults and children respond similarly to local cold exposure of the foot?

4. If they do not, then are factors related to their development responsible for the difference or are factors related to their exposure responsible for the difference?

CHAPTER II

ENVIRONMENT AND CULTURE OF NUÑOA

In order to inspect more fully the factors that both contribute to and ameliorate cold stress among highland Quechua Indians, it is first necessary to discuss the way of life of the Indian and the environment within which he lives. Hence, the subsequent material in this chapter will deal with the Nuñoa region of the Andes and its climate, the native residents and their culture, and the conditions of the environment that either contribute to or tend to reduce the effects of cold among these residents.

Background to the Region

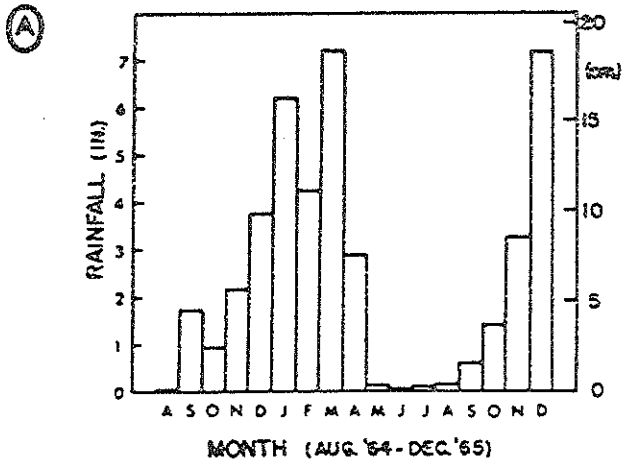
Nuñoa is a political district of approximately 350 square miles in the southern Peruvian Andes. The district capital is a town of the same name. More precisely, the district can be located at about 14° 27' south latitude and 70° 27' west longitude in the northern sector of a region known as the Lake Titicaca Basin or the altiplano. Essentially, the Titicaca Basin is a high plateau with internal drainage, all of which finds its way to the lake. The relief of the altiplano is not as severe as that found in the northern and central Peruvian Andes, but rather it is characterized by broad valleys dissected by meandering streams and flanked by mountains and hills that may rise as much as 1000 m above the valley floors. Few of the valleys of the altiplano are below elevations of 3600 m

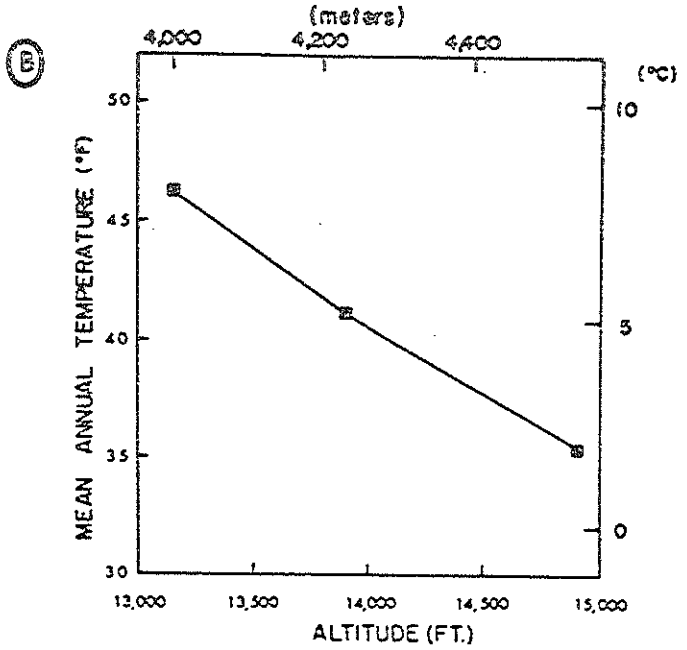
12,000 ft.) which places the region as one of the largest high plateaus in the world.

The District of Nuñoa is situated in the region of Nuñoa and Corahuina Rivers whose broad valleys, narrow tributary valleys, and adjacent mountains ranges comprise the greater part of the district. Within the district, the range in altitude is between 3800 m (12,500 ft.) and 5500 m (17,000 ft.) above sea level, and at this latitude the snow line falls between 4900 and 5200 m. The vegetational zone has been classified by Tosi (1957) as "subalpine humid paramo," while it is more commonly called puna and consists of grasses, herbaceous plants, shrubs, mosses and lichens. Some stunted native trees are found on protected hillsides, but for all practical purposes the district is above the tree-line and the countryside is basically a natural alpine grassland. Wild animals in the district include varieties of small mammals, a few deer, and small herds of free-ranging cameloids (vicuña and guanaco). Hundreds of varieties of birds abound in the area, and Nunoa is well-known for certain rare species.

The Climate

Weather data were collected over a minimum period of 12 months from three weather stations located at different elevations in the district of Nuñoa. The data presented here were recorded between August 1964 and December 1965. The first weather station was located in the town at an elevation of 4000 m, the second weather station was placed at 4250 m on an hacienda about 15 miles from the town, and the third station was located about one mile from the second on





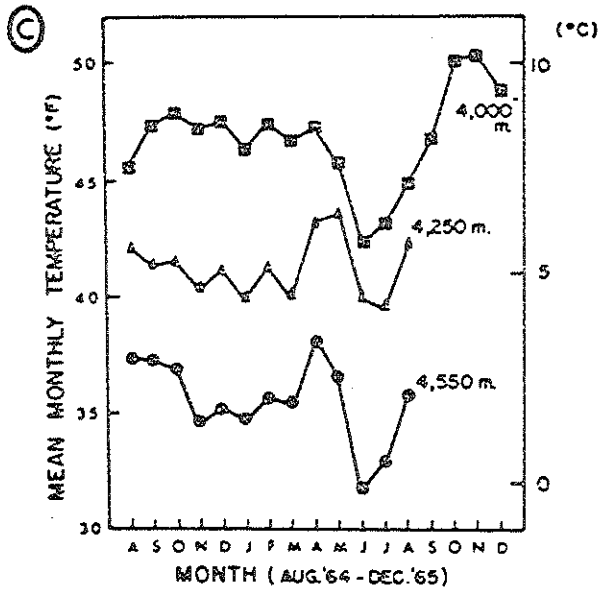


Figure II-1: (A) Monthly rainfall over a 17-month period, (B) The relationship between mean annual temperature and altitude, (C) Mean monthly temperatures at three elevations.

the same hacienda lands at 4550 m. Each station was situated in an area that appeared to be representative for the specific altitude. All of the stations were equipped with mercury maximum-minimum thermometers and 7-day continuous-recording temperature and humidity instruments. In addition, the station in town was equipped with a rain gauge, a pyroheliometer, and a wind direction and velocity indicator.

At high elevations in southern Peru, the climate tends to be uniform throughout the year because of the proximity to the equator. During the daylight hours ambient temperatures are moderate, while at night the temperatures drop off rapidly to levels often well below freezing. As a result, the diurnal temperature variation is great. This pattern is largely produced by high levels of solar radiation at altitude that occur because of the decrease in absorption by atmospheric gases (Platt and Griffith, 1964).

Seasonal temperature variation is primarily the result of the monsoon pattern of wet and dry seasons. In Nuñoa, the rainy season extends from September to April and the dry season from May to August. Onset of the rainy season is usually gradual, and the heaviest precipitation occurs between December and March. During these months, roads may be impassible due to vehicular traffic because of swollen streams. The months from May to August are almost totally dry except for occasional and brief hail or snow storms. Precipitation in the form of hail or snow can fall at any time of the year, but at the elevation of the town it is most common during the months directly preceding and following the dry season. The highest and lowest tem-

peratures of the year are usually recorded during the dry season when the cloud cover increases, incident solar radiation decreases, and slightly lowered daytime temperatures result. However, the nighttime effect of heavy clouds is the reduction of outgoing long-wave radiation (Geiger, 1959) which results in an increase in night temperatures. The overall pattern of ambient temperatures, then, is one in which the diurnal variation is greater during the dry months because of the temperature extremes, whereas the mean daily temperatures are higher during the wet months largely because of the increase in nighttime temperatures.

The weather data for the three stations in the district of Nuñoa are given in Figure II-1 and in Tables II-1, II-2, and II-3. The annual precipitation from August 1964 to July 1965 (Figure II-1 (A)) totaled close to 76 centimeters. It is not known, however, how much of the precipitation fell as snow and hail, but it is estimated that this would probably have contributed less than ten percent to the total. At the elevation of the town, snowfalls would occur occasionally at night, in the early morning, or in the late afternoon, but would seldom reach accumulations of over one inch or persist beyond midday.

Figure II-1 (B) shows the relationship between altitude and the mean annual temperature for the three weather stations. Within this altitude range, there is a drop of approximately 2.2°C for the mean annual temperature with each altitude increase of 500 m. Values for the mean monthly temperatures (Figure II-1 (C)) illustrate the

Table II-1

TEMPERATURE DATA (° C.)

TOWN OF NUÑOA AT 4,000 METERS

	1964					1965											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Av. daily max.	17.1	17.1	17.4	16.3	15.3	14.1	15.4	14.7	15.7	16.6	15.4	15.4	16.9	17.1	18.9	18.1	15.4
Av. daily min.	-1.9	0.1	0.4	0.6	2.2	1.8	1.9	1.8	1.2	-1.1	-4.2	-3.1	-2.6	-0.7	1.2	2.3	3.1
Monthly average	7.6	8.6	8.9	8.4	8.7	7.9	8.7	8.2	8.4	7.7	5.6	6.2	7.2	8.2	10.1	10.2	9.3
Absolute max.	20.0	19.4	20.0	18.9	20.0	18.3	17.8	17.8	17.8	18.9	16.7	17.8	19.4	20.0	21.7	21.7	18.3
Absolute min.	-4.4	-3.9	-3.9	-1.1	0	-3.3	-3.3	-0.6	-1.1	-4.4	-7.8	-6.1	-5.6	-2.8	-1.1	0	0
Absolute range	24.4	23.3	23.9	20.0	20.0	21.6	21.1	18.4	18.9	23.3	24.5	23.9	25.0	22.8	22.8	21.7	18.3
Ave. diurnal range	19.0	17.0	17.0	15.7	13.1	12.3	13.5	12.9	14.5	17.7	19.6	18.5	19.5	17.8	17.7	15.8	12.3
Percent days 0° C. or below	90	56	52	50	13	19	15	14	24	80	100	100	97	56	23	3	3

Table II-2

TEMPERATURE DATA (°C.)

HACIENDA LLULLUCHANI AT 4, 250 METERS

	1964					1965							
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Av. daily max.	12.4	11.7	11.6	10.4	10.3	9.2	10.1	9.3	11.4	12.4	10.9	10.9	12.8
Av. daily min.	-1.2	-1.4	-0.9	-1.2	-0.2	-0.5	0.1	-0.6	0.9	0.4	-2.1	-2.4	-1.4
Monthly Av.	5.6	5.2	5.3	4.6	5.1	4.3	5.1	4.4	6.2	6.4	4.4	4.4	5.7
Absolute max.	15.6	16.1	14.4	13.9	14.4	13.3	14.4	12.2	14.4	14.4	12.8	13.9	15.6
Absolute min.	-4.4	-3.9	-4.4	-2.8	-2.2	-2.8	-2.2	-2.8	-2.2	-1.7	-5.0	-4.4	-3.9
Absolute range	20.0	20.0	18.8	16.7	16.6	16.1	16.6	15.0	16.6	16.1	17.8	18.3	19.5
Av. diurnal range	13.6	13.3	12.5	11.6	10.5	9.7	10.0	9.9	10.5	12.0	13.0	13.3	14.2
Percent days 0° C. or below	81	97	78	93	68	77	56	74	41	54	89	100	86

Table II-3

TEMPERATURE DATA ($^{\circ}$ C.)

HACIENDA LLULLUCHANI AT 4,550 METERS

	1964					1965							
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Av. daily max.	10.0	9.4	8.9	6.3	6.6	5.8	6.4	6.1	8.0	8.7	5.7	6.9	9.1
Av. daily min.	-4.1	-3.6	-3.4	-3.5	-3.0	-2.8	-2.3	-2.5	-1.2	-3.6	-5.9	-5.9	-4.8
Monthly av.	3.1	2.9	2.8	1.4	1.8	1.5	2.1	1.8	3.4	2.6	-0.2	0.6	2.1
Absolute max.	13.3	12.2	12.2	12.2	10.6	11.1	8.9	9.4	11.1	11.1	8.3	11.7	12.8
Absolute min.	-6.1	-5.6	-7.2	-5.0	-5.0	-4.4	-3.3	-3.9	-3.9	-5.6	-8.9	-8.3	-6.7
Absolute range	19.4	17.8	19.4	17.2	15.6	15.5	12.2	13.3	15.0	16.7	17.2	20.0	19.5
Av. diurnal range	14.1	13.0	12.3	9.8	9.6	8.6	8.7	8.6	9.2	12.3	11.6	12.8	13.9
Percent days 0° C. or below	100	100	100	100	100	100	100	100	87	97	100	100	100

changes that take place throughout the wet and dry seasons, as well as the similar temperature trends at different altitudes.

The monthly temperatures enumerated in Tables II-1, II-2, and II-3 show values covering a 17-month period for the town station and a 13-month period for each of the higher stations. Maximum temperatures were usually attained somewhere between 12:00 noon and 2:00 p.m., and minimum temperatures between 4:00 a.m. and 6:00 a.m. The monthly average value was calculated by taking the mean of the daily maximum and minimum temperatures, and the diurnal range is the difference between the two. The final value (percentage of days at 0°C or below) is a measure of freezing temperatures and nighttime frosts.

When the average daily maximum temperatures taken from the highest and lowest stations are compared, the differences throughout the year range between about 7 and 9°C. Altitude differences are not as pronounced, however, for the average daily minimum temperatures where the annual range falls between 3 and 6°C. The generalization that can be made, then, is that with increases in altitude, the daytime decrement in ambient temperatures is greater than the decrement in nighttime temperatures. This is reflected by the average diurnal range which decreases at higher elevations.

The values given for absolute maximum and minimum temperatures and the percentage of days during each month that are below freezing are measures of temperautre extremes. The lowest minimum temperature and the greatest proportion of days below freezing are found during the dry months.

Cultural Background

History of the Population

Man is known to have been present in South America at least 10,550 years ago according to Carbon-14 dates from caves at the southern tip of the continent (Bennett and Bird, 1960). Based upon the grounds that migrations moved in roughly a north to south direction (Newman, 1948), it would then follow that human populations inhabited the more northern regions of the continent at much earlier time levels. Recent work carried out in the highlands of Ecuador (Mayer-Oakes and Bell, 1960) and on the coast of Peru (Lanning and Patterson, 1967) tends to support this hypothesis with the correlation of stone tool assemblages and additional Carbon-14 dates. It is safe to conclude, then, that as a conservative estimate man has inhabited the Andean regions of Ecuador, Peru, and Bolivia for the past 10,000 years.

In Nuñoa, archaeological evidence suggests that the time depth of habitation is great. Two village sites are known from within the district, and one shows architectural signs of occupation during a period that antedates the Inca conquests--ca. 1400 A.D. (Tschopik, 1946). In addition, pottery found in the town shows stylistic resemblances to a form that was common at about 1000 A.D. Other evidence that clearly demonstrates continuous settlement in the district up to the present includes church records of births, deaths, and marriages that date back to 1650. At that time, many of the Quechua family names, as well as the name of the town, were the same as those at present. The first census data was collected for the district of

Nuñoa in 1797 (Kubler, 1952), and since that time, the boundaries of the district have been unchanged.

The Present Population

According to the 1961 Peruvian census (Sexto Censo Nacional, 1964) the population of Nuñoa District was 7,750 persons with 2,137 listed as living in the town and 5,613 from the surrounding rural area. At the time when the present study was carried out, the population was probably over 8,000 persons. When the urban and rural populations are compared, differences are apparent in social and economic organization, as well as in the general style of life. For example, most of the economic pursuits in the countryside center around animal herding, while shopkeeping, trading, and agriculture are primarily the activities of town residents.

Social Organization

Social class structure in the district is similar to the general pattern found throughout most of the highlands (Mishkin, 1946; Tschopik, 1947; Vázquez V., 1965; Adams, 1959; Beals, 1953). There tends to be three roughly defined social classes: (1) the Indigena, (2) the Cholo, and (3) the Mestizo. Members of the Mestizo class are characterized by Western machine-made clothing, Spanish as the primary language, and a level of literacy that is beyond the elementary school. Most shopkeepers, hacienda owners, school teachers, and district officials would be included in this class designation. The Cholo class differs from the Mestizo class in that the Cholo is

an upwardly mobile Indian who has acquired the use of Spanish and who wears machine-manufactured clothing, although of a distinctive style. For the greater part, members of this class comprise the small shop-owners, craft specialists, and hacienda foremen. They may be literate but usually at an elementary school level. The lowest class designation is the Indigena, perhaps the most easily defined, and the one that is least closely tied to Western society. This class makes up the bulk of the population in the district and includes laborers, hacienda tenants, and members of native rural communities called ayllus. Indigenas can be identified by their use of coca, a mild narcotic leaf that is chewed, by wearing home-spun clothing, by their use of Quechua as a primary language, and, in general, illiteracy.

The class designations outlined here are quite flexible and some individuals are definitely marginal. Moreover, upward mobility from one class to the next is a common phenomenon and may occur over the space of one generation. Downward mobility, on the other hand, is much less common. With regard to urban-rural differences in class composition, the town residents tend to fall into the Mestizo and Cholo categories, while most of the Indigenas living in the town are marginal because of their expanded contacts with members of the other classes.

A note that bears on the above discussion is that assignment to social class does not necessarily correspond to any racial affiliation. It is true that members of the Cholo and Indigena classes are usually Indian; however, Mestizos may range from almost entirely

Spanish derived to what might be called genetically "pure" Andean Indians. There is, nevertheless, general agreement that between 80 and 90 percent of this population shows little European admixture, and hence the community is essentially a biologically Indian one (Baker, et al., 1965). For the purposes of this study, an important point to be made is that the cold exposure experienced by an individual varies according to his behavior and the extent to which protection is afforded by the culture. The role of culture and its effects on the degree of cold exposure will be discussed further.

Subsistence and Economic Practices

For the majority of the rural Indigenas, the hacienda system is the dominant way of life. Under this system of privately owned farms and estates, the Indian is a landless tenant who must perform services for the hacienda in exchange for the privilege of living on the lands. Discussions of the hacienda system can be found in the works of Holmberg (1960) and Núñez del Prado (1965), although there is a great deal of variability in the system throughout Peru. The primary service that the Indians discharge in the Nuñoa region is to graze the hacienda herds with their own and to shear the animals once a year. Addditional services that might be required are cultivation of a plot of land for the hacienda and the performance of duties at the main hacienda buildings. Since many of the hacienda landlords maintain homes in the town, the tenant may periodically work in the town as well. Although the Indian tenant is dependent

upon the hacienda for grazing and farming lands, he is not completely subservient to the landlord and can leave the hacienda at any time that he wishes. For this reason, the landlord must exercise a certain amount of care in his treatment of the tenant to prevent a major loss of manpower.

The economy of the hacienda and its Indian residents is essentially centered around the pastoral herding of llamas, alpacas, and sheep. These animals contribute hides and skins for bedding, wool for clothing and blankets, dung for fuel and fertilizer, and meat products for food. The hides and animals are often sold in the market system, although the greater part of the family income is derived from the sale of wool in December. With this income, cereal foods, additional clothing, dyes for yarn, coca, alcohol, kerosine, and small luxuries can be purchased. All of the meat and wool for basic clothing are provided by the herds. Every Indian family owns some llamas, alpacas or sheep, and many own at least one horse. Llamas and horses are used to transport goods and people respectively, while alpacas and sheep are the most important sources of meat.

When some of the hacienda lands are either below about 14,000 feet or situated on sheltered hillsides, then agriculture is practiced. Above this altitude nighttime frosts are common at any time of the year which prevents plant cultivation. Thus, at elevations below this level the Indian engages in a mixed economy of agriculture and animal herding, while the economy shifts fully to pastoralism above this elevation.

About four or five weeks of intensive work are expended each year in agricultural activities. Half of the time is spent in planting, and the other half in harvesting the crops. The agricultural year commences in late August or early September when cañihua, (Chenopodium pallidicaule) and quinua (Chenopodium quinoa), which are native seed corps related to the goosefoot and amaranth families (Sauer, 1950), are planted. This is followed in September and October by the planting of potatoes, first papas amargas and then papas dulces. Barley and oats are also grown in the area but are not as important as staples, and oats seem to be used principally as animal forage. All plant foods grown by the hacienda tenant are either for consumption by his own family or contributed to the hacienda. Light rain showers in Spetember and October are important in serving to assist the crops in their early growth. In the process of potato planting, two men wield foot plows side by side uncovering a furrow about 6 inches deep and 12 inches wide. A woman follows the men and turns over each clod of earth, after which a boy or girl breaks up the clod with a stone hammer. On slopes, the furrows are always cultivated by working uphill. The rows or furrows are about one meter apart and a team of four persons can cultivate roughly one and a half meters per minute. Using these as average work rates, it appears that one hectare of land can be cultivated by four persons in about 14 full days.

Potatoes are planted in the mounds of the earth and are then covered with a layer of dung. Cañihua and quinua, on the other hand, are simply cast over roughly prepared ground and worked into the

soil by making criss-cross cuts with the hand plow. The grain is then superficially buried to a depth of less than one inch. Dung is also used to fertilize cañihua and quinua. The only other activities that take place during the growing season are weeding the grains once or twice, and heaping fresh soil on the potatoes. The harvests take place in early April for cañihua, late in the same month for quinua, and in May for potatoes. The total time spent in harvesting activities does not usually exceed two weeks.

Agricultural activities are carried on in any kind of weather, including snow, rain, and high winds. On one occasion, the present writer and a Mestizo informant from the same area were forced to seek shelter during an especially severe sleet and wind storm, whereas the Indian farmers were observed to have continued plowing in bare feet for the rest of the afternoon. Work periods usually last for an hour or two, at which time a period of rest will be taken to renew coca.

Division of labor is present in the home, in herding activities, and in agricultural practices. Patterns of residence are unilocal and usually include only the nuclear family (father, mother, and children), although a family may adopt an orphan or illegitimate child, or may take in an unmarried relative or a parent. In the home, the female normally keeps the settlement in order by preparing meals, tending the stove or fogon, and weaving and sewing. The male is responsible for building living and storage structures, for repairs on these structures, for directing the herding activities, and for

dealing with the hacienda foreman or mayordomo and the landlord. Children run errands and perform minor tasks, such as fetching water and collecting animal dung for storage and for the stove. In herding activities, all members of the family participate, and very young children are often seen in charge of large flocks of animals. In agricultural activites, adult males always use the foot plow for heavy work, while women and children assist in breaking up the clods of earth and in planting.

Food Preparation and Diet

Although many haciendas grow none of their own food, plant foods are still an important part of the diet. Dried potatoes (chuño negro and chuño blanco), fresh potatoes, corn, barley, and flour are included in the usual dietary regimen. Animal products include charqui (dried, salted meat), fresh meat, cebo (rendered fat), eggs, milk, and cheese. There are ordinarily two main meals during the day; the first at between 7:00 and 8:00 a.m. and the second at between 5:00 and 7:00 p.m. Formal, cooked meals are seldom prepared at midday. Differences between the morning and evening meals are slight, except that the evening meal is more likely to contain some meat, while for the morning meal this is less likely. At midday, toasted barley or corn may be eaten. This food is prepared either in the morning or the previous evening, and members of the family take a small amount to eat at their leisure during the day.

A typical cooked meal consists of a thick porridge containing dried potatoes, flour or ground barley, onions, some spices, and

either meat or cebo. The variations on this standard theme depend upon what foods are used (1) as thickeners, (2) as the staple, and (3) for additional flavor. For example, thickeners include flour, and ground grains such as quinua, barley, and corn, as well as pulverized dried potatoes. Staples or bulk ingredients would include dried or fresh potatoes and corn, and charqui or fresh meat and cebo would make up the additional foods for flavor. Only one ingredient from each category is customarily used in preparing the porridge.

A dietary survey of 39 families was carried out in Nuñoa during the month of July 1962 (Mazess and Baker, 1964). The methods employed in the study included use of the questionnaire to determine daily and seasonal food consumption patterns, as well as direct measurement of food by weight. Dietary intakes were calculated by use of food consumption tables, and then compared to tables of minimum requirements and data reported from other areas of Peru. The results of this survey were surprising in light of other Peruvian studies. The Nuñoa families tended to have higher dietary intakes in gross calories, protein, and some vitamins than Indians from lower elevations in Peru. Caloric intake alone of the Nuñoa residents exceeded the values surveyed for the other communities by at least 1000 kcal. These findings were attributed to (1) the higher intake of animal foods because of the prevalence of pastoral herding, and (2) the increased use of dried potatoes (chuño) as a concentrated source of calories.

The vitamin and mineral deficiencies that seemed apparent from the survey conformed to the general highland pattern and included low levels of vitamin A, ascorbic acid, and calcium. In another report by the same authors (Baker and Mazess, 1963), however, it was suggested that the minimum calcium requirements may be attained by Nuñoa residents by way of two high-calcium substances that are often consumed. The first is called catahui and is an earth used for flavoring foods, while the second is a plant ash called llipta that is used with coca to release the alkaloids in the leaf.

House Structures and Settlements

Living structures in the town are almost all constructed of adobe brick with either thatched or corrugated tin roofs. The thickness of the adobe walls is roughly one foot. The layout of the town is typically Spanish with contiguous dwellings arranged on a grid pattern of narrow streets, and surrounding a central plaza.

A family settlement located on hacienda lands consists of from two to as many as eight separate house structures. Each building usually comprises one room, although two-room complexes can be found. The average number of buildings in a family settlement is between three and four. These can be classified as (1) dormitory, (2) storage, and (3) kitchen structures. They are grouped around a central dirt patio, with stone-walled corrals adjacent to the settlement. Each structure is approximately rectangular and constructed of irregular field stones and mud mortar. The walls are about one foot thick and range from three to four feet in height.

None of the structures contain window openings of any sort. The roof material is thatch and is supported by irregular branches arranged in a hip-roofed form. The roof supports are tied together with rawhide strips and attached to the wall by a combination of mud and stones. The overlying thatch is a native grass that covers the branch supports and is prevented from blowing off of the roof by stone weights connected by rawhide or rope or by laying thin strips of sod across the roof peak. The entrance to a typical structure is about two and a half feet wide and about the height of the wall. Doors of tin or skin attached to wooden frames are always present on storage structures but generally not on dormitories or kitchens. Often entrances to dormitories will be covered at night by a poncho draped over a rope.

The floors of all buildings are dirt covered and normally are from three to six inches lower than the outside ground level. Storage and dormitory structures have, in most instances, broad platforms on one or both sides of the interior. These platforms are from six inches to one foot in height and are constructed of earth and stones. They are utilized both as sleeping platforms and for storage above ground levels. In the kitchen structure, one platform may be present if the kitchen is used for sleeping; if not, then the only permanent object in the kitchen would be the fogon or adobe stove. The fogon occupies the space of one wall and can be described as a low, hollow structure with a central opening for dung fuel and circular openings on the top surface for ceramic pots. Numerous air spaces in the thatch roof allow smoke from the fogon to escape, and the

interior of the roof is stained a glossy dark brown from grease and the smoke that fills the room. The kitchen structure can be easily identified from the outside by the discoloration of the thatch due to the smoke and soot.

The total time required for two men to construct one building is about eight hours, given all supplies at hand. Extra time is necessary to prepare the rope and rawhide and to collect the thatch and branches for the roof.

During the day, little time is spent indoors by the family except for preparation and consumption of meals. At night, the family sleeps together on one or more of the sleeping platforms in the dormitory structure. Since there may or may not be a door on the structure, the dormitory affords little protection against the cold, but rather serves to give some shelter against wind and precipitation.

Material Culture and Technology

One of the most important aspects of native technology is weaving. Almost every family owns a backstrap or belt loom while upright or foot looms are found in about twenty percent of the households. The former is used, generally, for weaving ponchos, carrying cloths, shawls, saddle bags and coca bags. The latter is almost wholly restricted to the weaving of everyday clothing such as shirts, trousers, jackets, and skirts. There is some division of labor involved in the use of these looms in that women tend to weave on the belt loom, whereas men usually use the foot loom. If a family does

not own a foot loom, utility cloth is often woven on the hand loom. Other tools associated with the production of clothing and textiles are the wooden spindle whorl and a simple wooden instrument used in winding yarn on to bobbins. The spinning of raw wool, using only the spindle whorl, is an activity carried out by both men and women during any spare time and especially while tending the herds. Knitting is also practiced by men and women.

The clothing worn by the Indigenas is virtually all homespun, and there is only slight variation among members of similar sex and age groups. Some articles of clothing such as cotton shirts and blouses, and fiesta costumes are manufactured. Homespun garments worn by a man during cold or inclement weather would consist of trousers, a shirt, a sweater, a vest, a short jacket, a traditional cap called a chullu, and a heavy poncho. In addition, he may wear rubber-tire sandals and a soft felt hat. This amount of clothing is generally worn in the early morning hours and after dark in the evening as well. Under normal daytime weather conditions, the chullu, poncho, and jacket are not worn. Many men own one pair of manufactured leather shoes, but these are only worn during fiestas or other special occasions. Under normal circumstances, the Indian will either wear the rubber-tire sandals or go barefoot.

The homespun garments that a woman might wear would include a number of skirts, a blouse, a short jacket or vest, and a shawl. Purchased garments are restricted to a soft felt hat or derby, a cotton blouse, and in a few cases, rubber sandals. Most often women

go barefoot. The amount of clothing that a woman will wear depends, of course, on the weather; yet the everyday costume includes between three and seven skirts. It is often suggested that this is principally for warmth, but tradition is also an important factor governing the style of dress. Children wear much the same type of clothing as adults, but almost always go barefoot. Infants and children younger than four or five years of age wear a long length of cloth as a kilt that is held in place by a sash tightly bound around the abdomen.

No gloves and socks or any other protection for the hands and feet and no undergarments are worn by either adults or children.

Animal hides are used as padding on the sleeping platform, as rugs, and as covers, and are very effective insulators. The hides are crudely prepared by scraping free the flesh and by stretching them in the sun to dry. When skins are to be used for rawhide or rope, they are first scraped on both sides and then left to dry. The rawhide is then cut in a spiral fashion and rubbed with cebo or lard, after which the strips are placed under a compost pile of dung to cure. Other types of rope are braided by using llama wool and horsehair.

Agricultural tools such as the foot plow, the hand plow, and a stone hammer for breaking up clods of earth are all homemade. The steel blades for these tools, however, are purchased items. Other tools utilized for subsistence include a sickle employed in agriculture and in collecting thatch, and shears for clipping wool-bearing animals.

The Daily Routine

All members of the family arise between 5:00 and 6:00 a.m. The first person to get up is the woman who attends to the stove and begins to prepare breakfast. The other members of the family may remain in bed a short time after awakening. As it has been noted, more clothing is worn during these early hours since temperatures are generally below freezing and a light frost covers the ground. Breakfast is a hot meal and is eaten by the whole family inside the kitchen structure. After breakfast, the herds are moved off to the grazing areas by one or more of the family, either on horseback or by foot, but usually the latter. Herds may be pastured up to about a half mile from the settlement.

Activities in the fields are confined to keeping watch on the herds, spinning wool into thread, and knitting. There is very little other activity, and attending to the animals appears to be a quite leisurely task. At the settlement, female members of the household spend the day weaving, spinning, knitting and preparing skins. Occasionally members of the family may relieve one or more of the herders who return to the settlement.

At between 4:00 and 6:00 p.m. the herds are brought back to the settlement and remain for the night in corrals or open areas in close proximity to the buildings. These areas can be easily identified by their dark covering of dung. The stove is rekindled at between 4:00 and 5:00 p.m., at which time water is put on to heat. The evening meal is usually eaten sometime between 6:00 and 8:00 p.m. The preparation of cooked meals, especially with dried foods, requires a

greater amount of time than it would at sea level, since at 4,000 meters water boils at only 87°C (189°F).

Activities after the evening meal are limited to taking coca and conversation inside the kitchen or dormitory. The family retires between the hours of 8:00 and 9:00 p.m., and all at the same time. Sleeping conditions are cramped, and often six persons will sleep in the same dormitory structure. Women sleep in a shirt and one skirt while men sleep in a shirt and trousers. The sleeping platform is covered by animal hides, and a poncho and three or four blankets or ponchos are used as covers. Children may sleep on the floor on hides and wrapped in carrying cloths or shawls. Infants and very young children sleep with their parents in one corner of the platform. Most individuals tend to sleep with their heads under the bed covers, and generally assume a fetal position to conserve heat. Adults do not go to sleep immediately upon retiring, but may lie awake conversing for 30 minutes to an hour.

The Annual Cycle

During the year, pastoral activities vary only slightly. Each day the herds are taken out to graze, and this schedule is kept throughout the year. A change in the basic activity patterns, however, occurs in late November or early December, at which time most wool-bearing animals are sheared. The raw wool is then brought to the town of Nuñoa on pack animals for sale in the market. In early December, Nuñoa holds a grand fiesta and market at which most of the wool is sold. This is the most important economic activity of the year.

At other times of the year, trips may be made to the town or other cities to purchase food or other items. Depending upon the distance of the settlement from the town, a trip may require up to a day on foot and perhaps slightly less on horseback. They are made quite frequently at the rate of at least once each month for the purpose of buying coca, alcohol, kerosene, sugar, and other commonly consumed items. The purpose of travel to larger markets in more distant cities is to purchase food and other products at lower prices than in Nuñoa and to sell hides and agricultural products.

Fiestas and large markets present opportunities for some variation in the normal routine of life for the Indian. At the fiesta, social contacts, buying and selling, dancing, and heavy consumption of alcohol and beer take place. The town of Nuñoa holds at least three fiestas or grand markets each year, and other towns also have annual fiesta days.

Discussion: Factors of Cold Stress

The amount of cold exposure that an individual experiences depends, to a large degree, upon his social class ties and the culture that corresponds to his class. For example, Mestizos and Cholos almost always wear shoes and stockings, and thus members of these classes have better protection of the lower extremities than have Indigenas. In the same manner, the two higher classes may on occasion wear gloves, while the Indigena never does. The clothing covering the trunk and upper parts of the extremities, however,

seem to give adequate protection for all classes. Any exceptions to this statement would only be found among extraordinarily poor Indigenas, and this condition is rare in Nuñoa.

Seasonal changes in climatic conditions present different types of cold stress to the incompletely protected individual. During the dry season, temperatures are below freezing every night, and the possibility of cold exposure exists for at least 14 to 16 hours for each 24-hour period. The wet season might be less stressful because of warmer nights, yet during the day the feet are directly exposed to icy water and snow. In fact, while walking in rain or snow the native will usually remove his rubber sandals and go barefoot to avoid slipping on wet stones. In addition to cooling the lower extremities, the whole body may frequently become wet and chilled, while the individual is outside tending the herds on rainy mornings or afternoons.

Under these conditions, the danger to the lower extremities of acute cold injury such as frostbite is probably slight, principally because the low temperatures required to produce tissue freezing are not common. Foot immersion, resulting from chronic exposure to wet cold, might be more of a risk to the Indian. This risk, on the other hand, is probably reduced since the Indian's bare feet dry rapidly indoors. Serious cold injury might occur during a state of alcohol intoxication. At the time of fiestas, many Indians reach such a high level of inebriation that they loose consciousness on the street. They may then remain there throughout the night. Similar situations have been documented for the United States (Simeone, 1964)

and Alaska (Mills and Whaley, 1964).

In 1965, the present writer took part in a study to measure body temperature responses of the Nuñoa Indian during the night (Baker, 1966a). A number of complete families living in rural settelments that included 56 men, women, and children were tested. Rectal and skin temperatures at three sites (hand, foot, and chest), as well as indoor and outdoor temperatures were monitored throughout the night. Attempts were made to maintain conditions as closely as possible to the normal sleeping patterns. The results indicated that the dormitory structure affords little in the way of protection from the cold (Table II-4). Temperatures inside the sleeping structure were only 3 to 4°C higher on the average than the outside air temperatures. In a few cases, the inside temperatures nearly fell to outside levels.

Table II-4

Temperatures Inside and Outside of Sleeping Structures
N = 21 Households (After Baker, 1966a)

Hour of Sleep	Mean Temp. Inside	Mean Temp. Outside	Difference
0	4.5°C	0.5°C	4.0°C
1	3.9	-0.1	4.0
2	2.5	-0.8	3.3
3	2.4	-1.3	3.7
4	2.0	-1.5	3.5
5	1.7	-2.0	3.7
6	1.0	-2.9	3.9
7	0.5	-3.0	3.5
8	0.0	-3.1	3.1

From the body temperatures that were recorded at night, it appears as if the Indian suffers only slight to virtually no cold stress after the initial hour or two of sleep. Both the rectal and the three skin temperatures were generally maintained at normal levels after the subjects had remained in bed for about two hours. An interesting relationship between age and rectal temperature, however, was uncovered for the children. During the initial period of sleep, there is a steep and positive relationship such that the older the child, the higher the rectal temperature. With the subsequent hours of sleep, the curve approaches the horizontal and the relationship breaks down. This was interpreted to mean that among younger children, the cold stress prior to and immediately after going to bed is much greater than among older children and adults. Later in the night, then, rectal temperatures are quite similar among the children, although the mean values of the children are never as high as the adults.

CHAPTER III

METHODS AND PROCEDURES

The Subjects

A total of 120 individuals comprise the main sample tested under conditions of cold air. These include 59 highland Quechua Indian males whose responses were measured at the high altitude station in Nuñoa, Peru, and 54 United States White males of European derivation tested at the Pennsylvania State University. In addition, seven English and United States White males were tested at the Nuñoa station after a residence of at least two months at altitude. Throughout the study, the Peruvian and the United States samples tested in air were analyzed according to the divisions of "young" and "adult" groups. This was done in order to examine more clearly developmental factors in these samples. The age range of the young U. S. sample is one year less than that of the young Peruvian sample. Such a division is justified by growth data from the same area in Peru that indicates that Nuñoa males do not reach adult stature until the age of at least 20 years (Baker, et al., 1966a). Normal values for the United States White males show that adult stature is achieved at between 18 and 19 years of age (Stoudt, et al., 1960).

Foot calorimetry was carried out on 24 subjects, some of whom were included in the sample tested in air. Of these 12 were Indian

Males tested in Nuñoa and 12 were U. S. white males tested in Pennsylvania. A synopsis of the samples under study is given in Tables III-1 and III-2.

Table III-1

Age Characteristics of the Subjects Tested in Air

Group	N	Mean Age (Years)	s. d.	Range
Peruvians at Altitude				
Young	29	14.1	3.6	7-19
Adult	30	31.6	12.8	20-62
U.S. Whites at Sea Level				
Young	28	12.9	3.2	7-18
Adult	26	27.0	7.5	19-46
U.S. Whites at Altitude	7	24.4	3.1	20-28

TABLE III-2

Age Characteristics of the Subjects Tested in Water

Group	N	Mean Age (Years)	s. d.	Range
Peruvians	12	24.4	3.9	20-35
U. S. Whites	12	26.2	2.5	23-30

Each subject was symptom-free of and had had no past history of cardiovascular or debilitating diseases. All subjects were volunteers; however, the Quechua Indians received some payment for their services while the United States subjects did not. Before testing, the procedures were carefully outlined for each subject, in part, to attempt to mitigate any anxiety in the subject (Vanderhoff and Clancy, 1962; Abramson and Ferris, 1940; Glaser et al., 1959; Teichner, 1965). A clear statement was also made regarding the time involved in testing and whether or not the subject was likely to feel discomfort at any time during the test.

Peruvian Indian Sample

The Indian sample from Nuñoa was recruited from a number of sources. Most of the boys younger than 14 years of age were attending the elementary school that serves the town of Nuñoa. The school officials cooperated by giving the boys who volunteered time off from school. Other boys offered to act as subjects after hearing about the study from their friends. Some of the men who were tested had participated in prior experiments, and these men were offered a small payment in exchange for recruiting additional subjects. All participants received some payment, and attempts were made to reward the subject in proportion to his age and the time spent during the tests.

The decision to use a subject was based upon a number of physical and cultural criteria. By use of these, the choice of individuals with some Spanish admixture was minimized. Subjects were

acceptable if they manifested the following physical traits: (1) dark eye pigmentation, (2) moderate skin pigmentation, (3) straight hair, (4) short stature, (5) relatively short extremities, and (6) relatively sparse amounts of body hair. The cultural criteria were slightly more flexible, but were basically satisfied by an indigenous style of dress. A cultural questionaire that was administered tended to verify the direct observations made with regard to the subjects cultural affiliation.

It was found, for example, that about 73 percent of the subjects were born within the district of Nuñoa, and that the remaining 27 percent were born in neighboring districts at elevations of no less than 12,000 feet above sea level. All of the subjects indicated that they had learned Quechua as their first language, and of these, roughly 60 percent spoke little or no Spanish. The group of subjects who indicated that they speak Spanish fluently is also the group that tends to be literate. There is also the tendency for the literate individuals to be drawn from either the young population or to be residents of the town.

U. S. White Sample

The United States sample was derived, for the most part, from the academic community of the Pennsylvania State University. The younger subjects in the sample were either children of faculty members and graduate students or members of local cub scout and boy scout organizations. Older subjects included undergraduate and graduate students and faculty members from the University. None

of the subjects tested in the United States received payment of any kind, although the very young participants were often given books or other small rewards upon completion of the tests.

Questionnaires were not administered to the United States subjects since it was assumed that socioeconomic differences among the subjects were slight, and that these slight differences would have little effect on their previous cold exposure. The subjects were questioned with regard to past histories of frostbite or cold sensitivity for both the safety of the subject and in order to avoid biasing the sample (Brecht and Pulfrich, 1948; Mendlowitz and Abel, 1950) and were rejected if either had ever occurred.

Experimental Procedures

Subject Preparation

Appointments were made with each subject for a specific time of testing, and certain recommendations were made to the subject at this time. It was explained that a number of factors could affect heat content and regulation in the body (Bader and Macht, 1948; Blaisdell, 1951; Keatinge, 1957; Carlson, et al., 1953; Kerslake and Cooper, 1950; Pickering and Hess, 1933; Rapaport, et al., 1949; Schulze, 1947) and that for purposes of control in the experiment, these should be avoided. Instructions were thus given to avoid eating a large meal, to avoid the consumption of alcohol or drugs, to avoid any strenuous activity, and to avoid any hot or cold showers or baths directly before the appointment. In addition, the subject was instructed if he smoked, to be prepared to suspend the practice

during the period of preparation and actual testing, inasmuch as smoking is known to produce a state of cutaneous vasoconstriction (Abramson, et al., 1939a; Freund and Ward, 1960). Since few of the Indian subjects smoked any form of tobacco, but most adults chewed a mild narcotic leaf called coca, an inspection of each subject was carried out at least an hour before testing to determine if coca was being used. These precautions were taken since it has been reported that small doses of the active narcotic (cocaine) found in coca tend to elevate metabolism with resultant increases in body temperature (Herbst and Schellenberg, 1931; Zapata Ortiz, V., 1944). Elsner and Bolstad (1963), however, found no systematic differences between coca users and non-users in metabolic responses and attributed these results to the small amounts of cocaine actually introduced into the system.

When the subjects were participating in the cold air test, they were requested to arrive at the laboratory by 9:00 a.m. Upon arrival, a series of physical measurements was taken on each subject. These are described in a following section. After completion of the physical measurements, thermocouples were attached to the foot and the subject was seated before a small electric heater with the left foot resting on a shelf in front of the heater. A heater was used rather than a warm foot bath to avoid water uptake by the skin (Buettner, 1959). The foot was then comfortably warmed until the skin temperatures at each thermocouple site on the foot had stabilized at a temperature above 32°C (90°F). The heater was periodically turned off to determine if the foot had reached a stable temperature. When

the foot temperatures had reached a steady state, the subject then moved to his position in front of the air chamber and the test was begun. In general, all attempts were made to simulate the pretest conditions as outlined by Carlson (1966).

The total elapsed time between the arrival of the subjects and the cold test in air was never less than 1 1/2 hours. This period was viewed not only as required time for preparation, but also as a period to enable the subject to rest and achieve some approximation of a steady state. All subjects were encouraged to either add or remove clothing at any time during the preparation or test in order to maintain thermal comfort.

The subject preparation procedures as outlined for the foot cooling test in air are essentially the same for the subjects who were tested in cold water. The U. S. subjects were supplied with reading materials before and during the test, and the Peruvian subjects, many of whom were illiterate, were given picture books and magazines.

Test Conditions for Local Foot Exposure to Cold Air

The cold test in air consisted of locally exposing the left foot to air temperatures maintained at about 0°C (32°F) for a sixty-minute period. The test was carried out once in the morning and repeated during the afternoon of the same day. However, the interim period between the end of the morning test and the beginning of the afternoon test was never less than three hours. Skin tempera-

ture responses were recorded during the sixty-minute cold test as well as for a ten-minute recovery period after the foot had been removed from the cold air. All temperature measurements, including ambient, chamber, and skin temperatures were recorded at two-minute intervals by use of copper-constantan thermocouples and a Honeywell multi-switch potentiometer.

The test chamber was constructed of styrofoam for maximum insulation and was designed to accomodate four test subjects at a time. Because of some difficulty in recruiting subjects, the number of subjects tested on any given day amounted to between two and four individuals.

Skin Temperature Sites

Skin temperatures were recorded at three sites on the foot. The sites are: (1) the distal pad of the hallux or large toe at about 0.5 cm. from the upper border of the nail (referred to as toe 1); (2) the distal pad of the small toe at the same distance from the nail (toe 5); (3) the dorsal surface of the foot at the midpoint of the second metatarsal bone (dorsum). A thermocouple was attached to the toe by soldering the two leads to form a loop and placing this over the toe. The loop was held in place by a small piece of adhesive tape loosely wound around the toe without covering the temperature sensing junction. Attachment of the dorsum thermocouple was facilitated by fixing the positive and negative leads through a nylon ring and then cementing the ring to the skin with a liquid surgical adhesive. Care was taken not to place the

dorsum thermocouple in close proximity to any superficial veins, since the return of venous blood would tend to increase the skin temperature in the area.

Chamber Conditions

Foot chamber temperatures were regulated by influxes of outside or room air, and there was no dependence upon thermostatic controls. When temperatures fell below -0.6°C, more outside air was channeled into the chamber, and when the chamber temperatures rose above +0.6°C, the influx of outside air was reduced. By these methods, the chamber temperature was maintained at 0 ± 0.6°C (32 ± 1.5°F). Two thermocouples were placed in the chamber to monitor the temperature: the first was located at foot level and this was taken as a measure of the chamber temperature, while the second was positioned in front of the cooling unit as a continual check on the temperature of the output air. The turbulent air movement within the chamber was measured with a wind speed indicator and found to be within the range 25 to 35 m/min. Relative humidity was always quite low within the chamber; however Burton and others (1955) and Iampietro and his colleagues (1958) found that the effects of humidity on skin temperature were minimal in studies of total body cooling.

Ambient Conditions

Room temperatures were maintained at 24°C (75°F) with a maximum variation of 2.2°C (±4°F) throughout the preparatory and cold exposure periods. Wall temperatures did not differ significantly from the room temperatures. The room temperature was recorded from a thermocouple placed within a few feet of the subjects during the test. Relative humidity in the test room was determined on a number of occasions in Peru and found to be generally constant within the range of 20 to 35 percent. In the United States, relative humidity readings indicated a somewhat broader range of variation between about 30 and 65 percent. Air movement in the test room was low and estimated to be less than 6 m/min.

Differences Between Test Procedures Used in the U. S. and Peru

Attempts were made to minimize any differences in the procedures that would tend to bias the results. The foot-cooling chambers were constructed to the same specifications and of the same materials, and no systematic differences were observed between the temperature, humidity, or wind flow in the two chambers. The temperature recording apparatus remained at the high altitude station in Peru, and duplicate instruments and supplies were either purchased or borrowed for use in the United States.

There were some differences in the ambient conditions of the testing room. No controls were available either in Peru or in the United States to regulate the humidity. Since the climate of the

altiplano tends to be dry and that of the eastern United States tends to be more humid, there were consistent differences in relative humidity.

Oral temperatures were recorded after 12 minutes of cold exposure for the U. S. subjects, while this procedure was not followed in testing the Peruvian subjects.

Test Conditions for Local Foot Exposure to Cold Water

The cold test in water was designed primarily as a calorimetric experiment whereby the heat loss from the foot could be quantified by measuring the temperature changes in a known volume of water. Methods for determining heat loss were relatively crude since the "water equivalent" of the calorimeter was not calculated. The water equivalent is a factor in ml. that is added to the formula for heat output to correct for the heat lost to the calorimetry apparatus. Thus, the values for heat output from the foot in the present study should be higher than they actually are. The formula used to determine heat output is:

$$\text{Heat Loss/100 ml Foot Tissue} = \frac{\Delta \text{ in Water Temp. (°C)} \times \text{Water Vol. (L)}}{\text{Foot Vol. (ml)}} \times 100$$

The apparatus was simply a well insulated styrofoam container with a tight-fitting cover. The containers used in both Peru and the United States are sold commercially for the purpose of short-term storage of cold foods. The wall thickness of the container was between 2 and 3 cm. and the total capacity was 22 liters. About 18 liters of cold water was used during the test to avoid a rapid

water temperature increase. An opening for the foot was cut in the lid of the container and an ankle cuff was prepared out of styrofoam to reduce the heat influx from the outside. A stirring motor attached to the lid at one end was incorporated to maintain constant ciruulation of water throughout the container.

Each subject was tested for 30 minutes at each of the three water temperatures, 5°C (41°F), 10°C (50°F), and 15°C (59°F). No two tests were ever performed on the same day. The coldest exposure (5°C) was usually carried out on the first day with successively warmer exposures on subsequent days. However, on four occasions, insufficient quantities of ice necessitated a change in the order of the tests, although no consistent differences in the responses of these subjects when compared with the others were observed (Table III-3).

Table III-3

Foot Temperatures at a Water Temperature of 5°C: Comparison of U.S. Subjects Who Were Initially Tested at 5°C (N=8) with Subjects Initially Tested at 15°C (N=4)

	0 min.		min. 1		min. 15		min.30	
	5→15	15→5	5→15	15→5	5→15	15→5	5→15	15→5
Toe 1	34.8°C	34.9°C	6.7°C	7.3°C	6.7°C	7.0°C	7.5°C	7.3°C
Toe 5	35.9°	35.8	7.4	7.4	6.9	6.9	7.8	7.5
Dorsum	34.7	35.8	8.2	8.1	7.3	7.4	7.8	7.9

Skin Temperature Sites

Skin temperatures were recorded at the same three thermocouple sites on the surface of the foot as described above. Recordings were made at one-minute intervals. Since cold water as a medium tends to act as a "heat-sink" when contrasted with the effects of cold air, it was hoped that comparisons could be made between the moderate cold exposure responses to air and the more acute responses to water.

Water Bath Conditions

Temperatures were recorded from two thermocouples positioned at opposite ends of the bath. Water temperatures were quite uniform and differences between the two temperatures never exceeded 0.1°C, an indication that the water circulation was effective.

The water was brought to the test temperature by adding ice. When the water temperature fell to between 0.3 and 0.6°C below the test temperature, the ice was removed. This was done to avoid the thermal effects of the phase change from ice to water. Ice was not required to lower the temperature of the bath for the 15°C cold exposure, and thus carefully mixed tap water was found to be sufficient. The volume of water was determined by weighing the bath and subtracting the weight of the dry container. The balanced used for this purpose had a minimum sensitivity of 5.0 g. as determined by measurement with known weights.

Ambient Conditions

Temperature, humidity, and air movement conditions in the testing room were essentially the same as those outlined for the cold exposure to air. All attempts were made to maintain a state of thermoneutrality in the subject.

Differences Between Test Procedure Used in the U. S. and Peru

The methods used for foot calorimetry in the U. S. and Peru were the same. Differences in relative humidity, as discussed in the previous section, were unavoidable but present for the foot test in water also.

In the determinations of both water volume and foot volume by weighing, two different balances were employed. The balance used in Peru had a sensitivity equal to 5 g., while the balance used in the U. S. was sensitive to 1 g. In either case, the maximum possible error introduced by weighing procedures alone would be less than 2 percent.

Test Apparatus

Temperature Recorder

A Honeywell potentiometer (Electronik 15 Precision Indicator) was used to record temperatures. The instrument contains a built-in reference junction and a self-balancing mechanism, and the model used for the present study incorporates a multi-point panel of pushbuttons for rapid temperature recording at a number of sites. The circular

scale has a range of 0°F to 150°F and is graduated in 0.5°F divisions. It is, however, possible to read temperatures to within 0.1°F with some practice and careful estimates. Observer error from this source was judged to be less than 0.5 percent. Accuracy for the instrument is listed as ± 0.2 percent of the scale span or ± 0.3°F, and sensitivity is on the order of 0.05°F. All temperatures were converted to Celsius (°C).

Thermoelectric Recording Devices

All air, water, and skin temperatures were recorded by the use of copper-constantan thermocouples. The thermocouples were prepared from 26-gage polyvinyl insulated wire (Thermo-Electric Co.). A maximum temperature range for the thermocouple wire is given as between -75 and + 200°F (-60 and 93°C), and limits of error are listed as ± 1.5°F (± 0.8°C).

Tests were performed on the thermocouples to estimate more closely their accuracy when wired to the potentiometer. Comparisons were made with a mercury thermometer in an ice-water bath and at other temperatures in water and air. No systematic error was found among the thermocouples, and all gave readings within a total range of 0.1°C. Deviations from the mercury readings were less than 0.2°C at all temperatures. Recalibration was carried out at frequent intervals as an additional check on the stability of the potentiometer.

Body Composition and Physical Measurements

As an additional source of information, certain physical measurements were taken on each subject in order to test for associations of growth and body composition variables with the temperature responses. The physical characteristics measured directly are:

1. STATURE - Measured with an anthropometer in centimeters to the nearest 0.1 cm. The subjects were measured in either stocking or bare feet.
2. WEIGHT - Measured with a platform scale in kilograms to the nearest 0.2 kg. The U. S. subjects were weighed fully clothed whereas the Peruvian subjects were weighed only while wearing trousers. Estimates were made of clothing weight according to body weight by weighing clothing sampled from both groups of subjects. These estimates were subtracted from the body weight measures to arrive at an approximate of the nude weight. These estimates are as follows:

Body Weight	U. S. Clothing Estimate	Peruvian Clothing Estimate
20 - 29 kg.	0.7 kg.	0.5 kg.
30 - 39	0.8	0.6
40 - 49	0.9	0.7
50 - 59	1.0	0.8
60 - 69	1.1	0.9
70 - 79	1.2	1.0
80 - 89	1.3	
90 - 99	1.4	

3. SKINFOLDS - Measured with a constant-tension Lange Skinfold Caliper to the nearest 0.5 mm. The calipers provided a constant pressure of 10 gm/cm^2 over the entire range. Procedures for

taking skinfold measurements are discussed elsewhere (Brozek, 1961). Three measurements were taken at each of 8 skinfold sites and a mean value was calculated for each site. These 8 sites follow:

(1) CHIN - Directly inferior to the mandibular symphysis with the head in a horizontal plane.

(2) FOREARM - On the radial-medial surface of the forearm slightly distal to the olecranon fossa, and with the elbow in a 90 degree position of flexion.

(3) UPPER ARM - On the posterior surface of the upper arm above the triceps, and midway between the olecranon and acromion processes.

4. FOOT LENGTH - Maximum length of the foot measured with an anthropometer.

5. FOOT BREADTH - Maximum breadth of the foot measured with an anthropometer.

6. METATARSAL DEPTH - Depth of the foot at the midpoint of the first metatarsal measured with the sliding calipers.

7. HEEL BREADTH - Maximum breadth of the heel measured with sliding calipers.

8. HALLUX LENGTH - Maximum length of the hallux or large toe measured with sliding calipers.

9. HALLUX BREADTH - Maximum breadth of the hallux measured with sliding calipers and very slight pressure.

10. FOOT VOLUME - Measured by use of Archimedes Principle by displacement of water. The foot was immersed in a container of water to

the level of the internal malleolus without touching either the sides or the bottom of the container. The weight of the container was recorded before and during immersion, and the difference in grams was taken as the volume in milliliters. This is based upon the assumption that the density of the foot closely approximates that of water (1 gm/ml).

Where measurements refer to one or the other side of the body, the left was chosen for consistency.

From these direct measurements outlined above, other variables were derived. They include:

1. SURFACE AREA - Calculated from stature and weight according to the formula derived by DuBois and DuBois (1916). The formula is:

   $$\log S.A. = 0.425 \log \text{weight} + 0.725 \log \text{stature} + 1.8564$$

   where: weight is in kilograms and stature is in centimeters.

2. PERCENT BODY FAT - Calculated from skinfold measurements taken at the upper arm, chest I, and chest II sites according to the procedures of Pascale, et al. (1956).

3. LEAN BODY MASS - Determined by calculating the weight of body fat from the percentage value and subtracting this from the total body weight.

4. SUM OF SKINFOLDS - The sum of the mean values for the 8 skinfold sites.

5. FOOT INDEX - This is taken as an estimate of the Foot shape. The index is: Foot Breadth/Foot Length x 100.

6. HALLUX INDEX - This is taken as an estimate of the shape of the large toe. The index is: Hallux Breadth/Hallux Length x 100.

Data Analysis

Statistical methods of analysis were applied to the data. These included single and multiple correlation tests, covariance analysis, and "T" tests for differences between means. Most statistical analyses were carried out with the aid of computer facilities at the Pennsylvania State University and the Ohio State University. Statistical significance was taken to be at 0.05 and 0.01 levels of probability, with the latter figure considered highly significant. Measures of central tendancy and measures of dispersion are always indicated by the mean ($\bar{X}$) $\pm$ one standard deviation (SD). When other descriptive statistics are used, they are noted otherwise.

CHAPTER IV

PHYSICAL CHARACTERISTICS OF THE SAMPLES

It has been well documented that certain body size and composition parameters have an effect on temperature regulation during total body cold exposure (Baker and Daniels, 1956; Baker et al., 1967; Buskirk et al., 1963; Daniels and Baker, 1961; Elsner, 1963; LeBlanc, 1954; Wyndham et al., 1968). The bulk of these studies have been concerned with the value of subcutaneous fat as an insulative tissue against cold, although the significance of other parameters such as lean body mass and surface area has also been noted.

Less emphasis has been placed on studying the effects of these physical characteristics on temperature responses where only the extremity is exposed to cold. This is understandable in light of the overwhelming evidence pointing to the importance of vascular responses in temperature control. Nevertheless, it was felt that for the purposes of the present study it would be of some value to inspect more closely any relationships that might exist between local temperature responses and physical characteristics.

The following sections of this chapter will include a description and comparison of the physical characteristics of the Peruvian and United States samples, as well as an examination of the interrelationships among these variables. A discussion of the relationships between physical characteristics and temperature responses will be reserved for Chapter V.

Differences Between Samples

Means and standard deviations of some physical measures are shown in Tables IV-1 and IV-2 for young and adult subjects from both the Peruvian and United States samples. "T" values for differences between means are included. The differences in the mean ages for both the young and the adult groups are slight and do not reach levels of statistical significance. For the other characteristics, the White groups are on the average taller, heavier, and show a great deal more body fat than the Indian groups. The derived values for surface area and lean body mass reflect the differences in size between the groups. Percent fat and lean body mass were not determined for the young groups, since the regression formula only applies to adult males (Pascale et al., 1956). In almost every measure, the White subjects show more variation than the corresponding Indian subjects. This is especially pronounced for weight, lean body mass, percent fat, and the sum of 8 skinfolds.

Most of the differences between the young and adult groups are simply the result of the incompleted growth of the former. A notable exception is the similarity between the young and adult Indians for the sum of 8 skinfolds.

Tables IV-3 and IV-4 give mean skinfold values at each of the 8 sites. A comparison of the Indian values with norms from the same population (Frisancho, 1966) indicate that these fall within the normal range. The adult White values also compare favorably with other United States measurements (Baker et al., 1958; Brozek, 1952),

Table IV-1

GENERAL PHYSICAL CHARACTERISTICS: YOUNG GROUPS

	Peruvian Indians (N=29)		U. S. Whites (N=28)		'T' Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 55
Age, yrs.	14. 1	3. 6	12. 9	3. 2	1. 33
Stature, cm.	139. 1	15. 2	158. 8	19. 2	4. 24***
Weight, kg.	37. 7	11. 3	51. 9	20. 5	3. 22**
Surface Area, M^2	1. 20	0. 25	1. 50	0. 38	3. 51***
Sum of 8 Skinfolds, mm.	43. 0	8. 7	76. 5	49. 4	3. 54***

Table IV-2

GENERAL PHYSICAL CHARACTERISTICS: ADULT GROUPS

	Peruvian Indians (N=30)		U. S. Whites (N=26)		'T' Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 54
Age, yrs.	31. 6	12. 8	27. 0	7. 5	1. 66
Stature, cm.	158. 2	5. 3	176. 5	5. 0	13. 28***
Weight, kg.	56. 3	5. 5	73. 1	7. 8	9. 18***
Surface Area, M^2	1. 56	0. 09	1. 89	0. 09	13. 69***
Percent Fat	8. 1	0. 9	12. 2	4. 1	5. 00***
Lean Body Mass, kg.	51. 7	5. 0	63. 9	5. 1	9. 01***
Sum of 8 Skinfolds, mm.	45. 1	11. 0	88. 2	43. 2	4. 95***

$P < .05 = *$, $P < .01 = **$, $P < .001 = ***$

Table IV-3

SKINFOLD VALUES (mm.): YOUNG GROUPS

	Peruvian Indians (N=29)		U. S. Whites (N=28)		'T' Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 55
Chin	4.5	1.5	6.1	4.0	1.99
Forearm	4.7	1.1	8.1	4.6	3.81***
Upper Arm	6.0	1.7	12.9	7.3	4.88***
Chest I (Juxta-nipple)	5.1	1.5	8.8	7.0	2.74**
Chest II (Mid-axillary)	4.6	1.1	7.7	5.8	2.78**
Abdomen	5.0	1.4	11.7	9.9	3.55***
Back	6.3	1.4	9.2	6.9	2.18*
Calf	7.1	1.7	12.4	6.8	4.01***

Table IV-4

SKINFOLD VALUES (mm.): ADULT GROUPS

	Peruvian Indians (N=30)		U. S. Whites (N=26)		'T' Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 54
Chin	4.5	1.4	5.8	2.8	2.21*
Forearm	3.9	1.1	6.6	2.7	4.91***
Upper Arm	5.8	2.1	11.4	5.9	4.74***
Chest I (Juxta-nipple)	5.4	1.6	12.3	7.6	4.70***
Chest II (Mid-axillary)	5.4	1.6	12.0	7.3	4.68***
Abdomen	6.3	2.5	15.6	9.0	5.27***
Back	7.9	1.9	14.6	8.1	4.27***
Calf	6.3	2.0	10.2	5.0	3.84***

$P < .05 = *$, $P < .01 = **$, $P < .001 = ***$

however, the young White group seems to have a slightly greater fat deposition than normal (Baker et al., 1958; Hammond, 1955; Malina, 1966). The White subjects tend to show more fat deposition than the Indian subjects at all skinfold sites and at all ages.

In addition to the above mentioned 8 skinfold sites, another was taken on the dorsal surface of the foot in order to test for the effect of fat deposition on skin temperature at one site where temperature responses were recorded. The fold was measured over the midpoint of the second metatarsal while the foot was in a position of dorsiflexion. This procedure was carried out only for the United States sample and is shown in Table IV-5. No differences are observable between young and adult White subjects and moreover, this skinfold site has the lowest mean value of all that were taken.

TABLE IV-5

Mean Dorsum Skinfolds (mm.) for Young and Adult White Groups

	Young			Young		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Dorsum Skinfold	3.1	1.09	24	3.1	0.42	14

A number of anthropometric measurements were taken on the foot, since the shape and size of this structure might have some influence on temperature responses. Tables IV-6 and IV-7 list these measurements. There are no major differences between the Indian and White

Table IV-6

PHYSICAL CHARACTERISTICS OF THE FOOT: YOUNG GROUPS

	Peruvian Indians (N=29)		U. S. Whites (N=28)		'T' Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 55
Foot Length, cm.	21. 7	2. 2	24. 1	2. 6	3. 75***
Foot Breadth, cm.	8. 4	1. 0	8. 9	0. 9	1. 98
Foot Breadth/Length Index	38. 6	1. 8	37. 3	1. 9	2. 65*
Metatarsal Depth, cm.	4. 1	0. 5	4. 2	0. 6	0. 68
Heel breadth, cm.	5. 6	0. 7	5. 7	0. 8	0. 50
Hallux Length, cm.	3. 7	0. 5	4. 3	0. 7	3. 71***
Hallux Breadth, cm.	2. 8	0. 3	2. 9	0. 4	1. 06
Hallux Breadth/Length Index	75. 5	7. 4	67. 0	5. 6	5. 07***
Foot Volume, ml.	685	200	837	226	2. 68***

Table IV-7

PHYSICAL CHARACTERISTICS OF THE FOOT: ADULT GROUPS

	Peruvian Indians (N=30)		U. S. Whites (N=26)		'T'Value
	$\bar{X}$	S. D.	$\bar{X}$	S. D.	df = 55
Foot Length, cm.	24. 2	1. 3	26. 2	1. 0	6. 50***
Foot Breadth, cm.	9. 6	0. 6	9. 7	0. 4	0. 74
Foot Breadth/Length Index	39. 5	2. 4	37. 0	1. 6	4. 27***
Metatarsal Depth, cm.	4. 6	0. 4	4. 7	0. 4	0. 93
Heel Breadth, cm.	6. 5	0. 4	6. 3	0. 4	1. 87
Hallux Length, cm.	3. 9	0. 4	4. 7	0. 5	6. 54***
Hallux Breadth, cm.	3. 2	0. 2	3. 2	0. 2	0. 00
Hallux Breadth/Length Index	82. 6	7. 6	68. 7	6. 7	7. 27***
Foot Volume, ml.	968	110	979	92	0. 41

$P < .05 = *$, $P < .01 = **$, $P < .001 = ***$

samples in the breadth and depth measurements, although the foot and the hallux of the Indian are substantially shorter than in the White. Thus, the Indian can be typified as having a broad, short foot, while the White is represented by a longer and more linear foot structure. These shape differences are expressed by the foot and hallux indices where higher values are present for the Indian groups. Foot volumes are greater among the White but the differences between the two adult groups are slight. Volume differences between the young groups are one indication of the size differences between the United States Whites and the Peruvian Indians at all ages (Frisancho, 1966).

Interrelationships Among Variables

Correlation matrices for young and adult Indian subjects (Tables IV-8 and IV-9* and young and adult White subjects (Tables IV-10 and IV-11*) generally show high degrees of interrelatedness among the physical characteristics. The young and adult groups are dealt with separately to avoid confusing the correlations due to changes during growth with those correlations found in the adult. The pattern of relationships disclosed for young Indians and young Whites is similar for age, stature, weight, and surface area. All of these variables are interrelated, and at generally high levels of statistical significance.

Among the adult Indian subjects there is a high degree of interrelatedness for age, stature, weight and surface area that is not

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* The abbreviations used for these tables are listed in Appendix A.

Table IV-8

INTERRELATIONSHIPS AMONG PHYSICAL CHARACTERISTICS: YOUNG INDIANS (N = 29)

	Stat.	Wt.	S. A.	S. S. F.	Ft. L.	Ft. B.	Ft. I.	Met. D.	Heel B.	Toe. L.	Toe B.	Toe I.	Ft. Vol.
Age	.93**	.91**	.93**	.21	.89**	.89*	.41*	.86**	.84**	.88**	.79**	-.33	.90**
Stat.		.96**	.99**	.29	.97**	.93**	.36	.85**	.87**	.88**	.84**	-.28	.96**
Wt.			.99**	.33	.93**	.94**	.46*	.86**	.87**	.82**	.88**	-.15	.97**
S. A.				.32	.95**	.95**	.42	.87**	.88**	.86**	.87**	-.21	.97**
S. S. F.					.26	.37*	.38*	.29	.41*	.17	.21	.00	.34
Ft. L.						.93**	.28	.85**	.87**	.87**	.80**	-.30	.95**
Ft. B.							.61**	.86**	.89**	.80**	.84**	-.16	.97**
Ft. I								.43*	.44*	.23	.45*	.19	.49**
Met. D.									.85**	.77**	.74**	-.22	.87**
Heel B.										.74**	.79**	-.14	.88**
Toe L.											.72**	-.58**	.83**
Toe B.												.14	.86**
Toe I.													-.18

Table IV-9

INTERRELATIONSHIPS AMONG PHYSICAL CHARACTERISTICS: ADULT INDIANS (N = 30)

	Stat.	Wt.	S. A.	% Fat	L. B. M.	S. S. F.	Ft. L.	Ft. B.	Ft. I.	Met. D.	Heel B.	Toe L.	Toe B.	Toe I.	Ft. Vol.
Age	.61**	.45*	.54**	-.28	.48**	-.30	.22	.57**	.37*	-.10	.37*	.22	.40*	.05	.48**
Stat.		.67**	.86**	-.26	.69**	-.22	.52**	.39*	-.07	-.02	.32	.34	.66**	.12	.67**
Wt.			.96**	.02	.99**	.12	.41*	.47**	.10	.40*	.61**	.43*	.64**	.02	.67**
S. A.				-.09	.96**	-.01	.50**	.48**	.04	.27	.54**	.42*	.70**	.06	.73**
% Fat					-.08	.95**	-.10	-.18	-.10	.08	-.12	.15	-.15	-.25	-.14
L. B. M.						.02	.42*	.49**	.12	.39*	.62**	.42*	.65**	.04	.69**
S. S. F.							-.04	-.23	-.19	.12	-.04	.09	-.06	-.12	-.11
Ft. L.								.42*	-.43*	.27	.24	.13	.34	.14	.55**
Ft. B.									.64**	.21	.44*	.16	.23	.00	.54**
Ft. I.										-.02	.23	.03	-.07	-.11	.05
Met. D.											.47**	.05	.27	.17	.48**
Heel B.												.30	.54**	.09	.50**
Toe L.													.36	-.75**	.38*
Toe B.														.34	.59**
Toe I.															.05

Table IV-10

INTERRELATIONSHIPS AMONG PHYSICAL CHARACTERISTICS: YOUNG WHITES (N = 28)

	Stat.	Wt.	S. A.	S. S. F.	Ft. L.	Ft. B.	Ft. I.	Met. D.	Heel B.	Toe L.	Toe B.	Toe I.	Ft. Vol.
Age	.93**	.89**	.93**	.31	.91**	.84**	-.23	.74**	.76**	.89**	.84**	-.46*	.84**
Stat.		.90**	.96**	.32	.95**	.89**	-.22	.72**	.73**	.91**	.91**	-.39*	.92**
Wt.			.98**	.58**	.90**	.89**	-.11	.85**	.85**	.87**	.88**	-.36	.94**
S. A.				.49**	.94**	.91**	-.16	.82**	.83**	.91**	.92**	-.38*	.95**
S. S. F.					.33	.37	.05	.52**	.48**	.31	.30	-.17	.45*
Ft. L.						.89**	-.35	.71**	.79**	.95**	.89**	-.50**	.94**
Ft. B.							.12	.71**	.80**	.86**	.90**	-.32	.93**
Ft. I.								-.07	-.06	-.29	-.08	-.43*	-.12
Met. D.									.69**	.64**	.78**	-.09	.75**
Heel B.										.79**	.82**	-.30	.84**
Toe L.											.85**	-.63**	.91**
Toe B.												-.14	.92**
Toe I													.39*

Table IV-11

INTERRELATIONSHIPS AMONG PHYSICAL CHARACTERISTICS: ADULT WHITES (N = 26)

	Stat.	Wt.	S. A.	% Fat	L. B. M.	S. S. F.	Ft. L.	Ft. B.	Ft. I.	Met. D.	Heel B.	Toe L.	Toe B.	Toe I.	Ft. Vol.
Age	-.22	.08	-.02	.28	-.05	.23	-.25	.08	.30	-.33	-.05	-.38	-.14	.26	-.11
Stat.		.03	.43*	-.40*	.28	-.37	.25	.03	-.19	.09	.08	.06	.38	.09	.32
Wt.			.91**	.71**	.90**	.75**	-.01	.36	.29	.28	.49*	-.20	.03	.22	.29
S. A.				.47*	.93**	.52**	.10	.35	.19	.28	.47*	-.16	.19	.23	.38
% Fat					.34	.99**	-.16	.20	.30	.03	.28	-.25	-.23	.13	.04
L. B. M.						39*	.08	.36	.22	.33	.49*	-.12	.18	.20	.34
S. S. F.							-.12	.23	.28	.07	.29	-.21	-.18	.13	.08
Ft. L.								.37	-.63**	.26	.12	.27	.54**	.02	.42*
Ft. B.									.49*	.05	.42*	-.29	.26	.41*	.43*
Ft. I.										-.19	.24	-.48*	-.28	.32	-.01
Met. D.											.27	.50**	.47	-.17	.49*
Heel B.												.09	-.10	-.15	.51**
Toe L.													.22	-.83**	.14
Toe B.														.33	.51**
Toe I.															.15

present for the adult White subjects. This, perhaps, reflects the greater variation found in the White sample for these variables.

The index that estimates the shape of the foot (the higher the value of the index, the broader the structure in proportion to the length) is unrelated to the other measures of body size and composition among both adult and young white subjects. There are some correlations with other foot variables for these groups, but this would be expected. In the young Indian sample, the foot index is correlated with age, weight, and surface area. The age relationship suggests that the Indian's foot may develop into a more compact structure from childhood to adulthood. This would have an obvious selective value for cold protection of the feet, since less heat would then be dissipated because of the reduction in surface area. This may also simply reflect the foot's response to the lack of restriction of the shoe, since a significant correlation of age with foot index persists for the adult Indians as well as the young.

CHAPTER V

FOOT EXPOSURE TO COLD AIR

Skin temperatures were recorded at two-minute intervals during the test in cold air. For every exposure, a total of 108 temperature values were recorded at three skin sites for each subject. These data were analyzed by a simple comparison of the groups. In order to deal more efficiently with this amount of data for more complex analyses, running mean values were calculated for ten-minute periods for the hour of cold exposure and recovery period. These ten-minute mean temperature values were used in tests for associations with other variables. In addition, running mean values for the first and second half hours and the full hour of exposure were determined. These are listed in Appendix B. Another series of variables was calculated for the purpose of inspecting cycling phenomena or Lewis waves among each of the subjects.

Temperature Changes During Exposure and Recovery

Figures V-1, V-2, and V-3 illustrate the mean patterns of temperature responses for the Indian and White groups. The mean values for a sample of seven White adults who were tested in Nuñoa are also included in the graphs of the first run. The temperature responses of this group, however, may not be representative, since the subjects were tested only once and at different times during the day (six were tested in the evening and one in the morning).

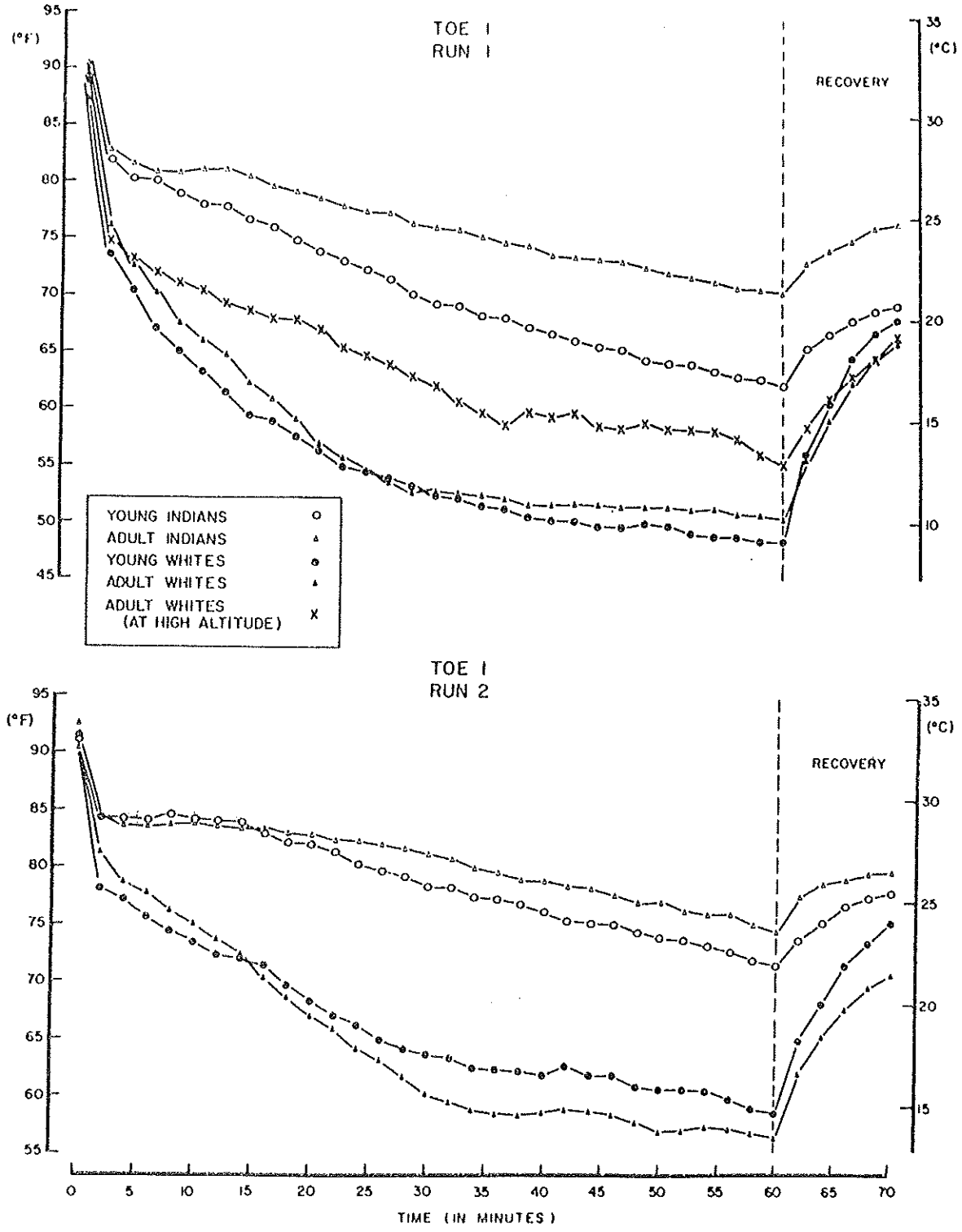


Figure V-1: Mean skin temperatures of the pad of the large toe (toe 1) during 60 minutes of cold exposure at 0 °C and 10 minutes of recovery at 24 °C.

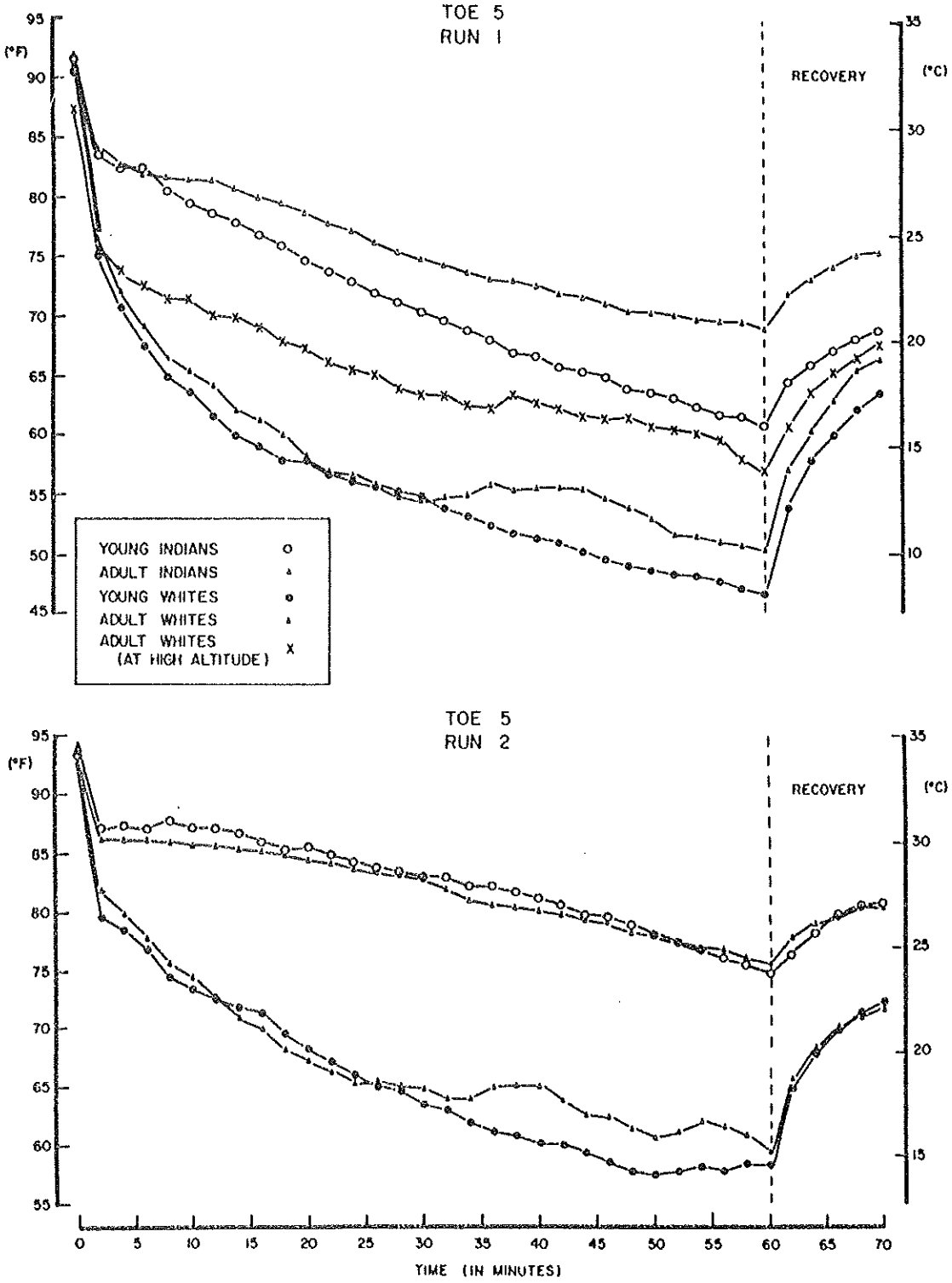


Figure V-2: Mean skin temperatures of the pad of the small toe (toe 5) during 60 minutes of cold exposure at 0 °C and 10 minutes of recovery at 24 °C.

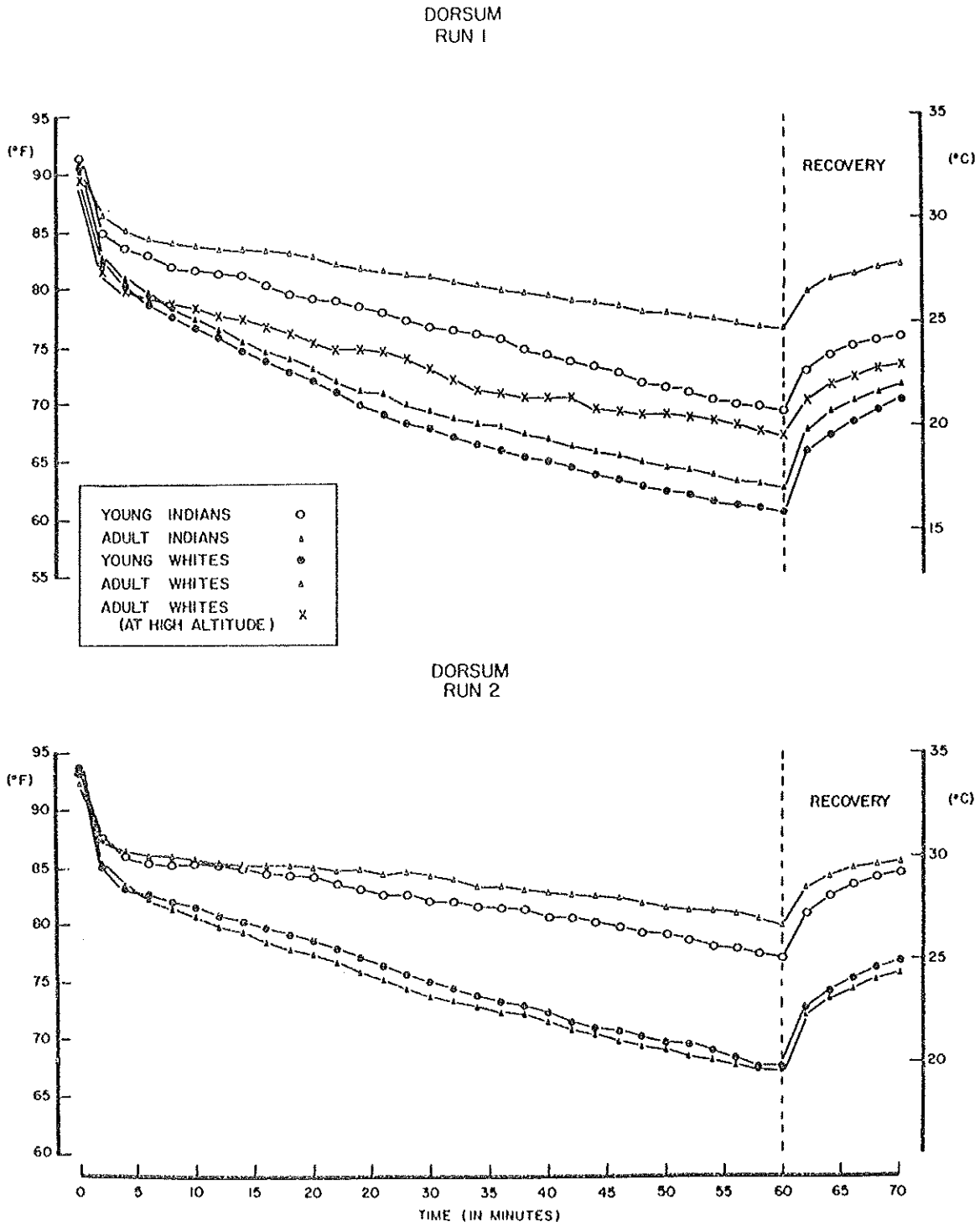


Figure V-3: Mean skin temperatures of the dorsum of the foot during 60 minutes of cold exposure at 0 °C and 10 minutes of recovery at 24 °C.

The pattern of response for all groups upon first cold exposure shows a steep drop in skin temperature followed by a less pronounced decline that may persist for the full hour. When the foot is removed from the cold air chamber, the skin temperature increases rapidly and appears to begin leveling off after ten minutes.

Comparisons Between Indian and White Subjects

The major differences between the Indian and White groups seem to be attributable to a more rapid decline among the White subjects during the first half hour. After the first half hour, the differences remain constant or in some instances even show a decrease. All differences between the two young groups and between the two adult groups are statistically significant at less than the 1% level of probability after about ten minutes of exposure. Differences between these groups at the end of the cold exposure are listed in Table V-1.

The group of adult Whites from high altitude was not included in the statistical analysis because of the small sample size and for the reasons noted above. These values fall midway between those of the Whites tested in the United States and those of the Indians tested in Nuñoa. However, if these values are plotted on the graph for the afternoon run, they fall closer to the U. S. White responses.

Comparisons Between Young and Adult Subjects

During the first run, the temperature curves representing the young Indians show greater rates of decline than those of the adult Indians. At the toe 1 site, the differences are significant begin-

ning with the 30th minute, and at the dorsum site, the significant differences begin at the 18th minute of exposure. The differences at the toe 5 site, however, do not show statistical significance until after the 54th minute of exposure. The temperature responses of the young and adult Indians during the second run show relationships that are similar to the first run, yet none of the differences are significant.

There are no consistent patterns of difference between the young and adult White groups for either the first or the second run. The only statistically significant differences for these groups are at the 60th minute of cold exposure and the second minute of recovery during the first run at the toe 5 site.

The temperature values and differences between the young and adult groups at the end of the cold exposure are listed in Table V-2.

Differences Between Exposures

Consistent differences in skin temperatures between the first and second cold exposures were observed for all groups (see Figures V-1, V-2, and V-3). Throughout the 60-minute test, average skin temperatures were always higher during the afternoon exposure (Run 2). These differences after 60 minutes of cold exposure are listed in Table V-3. The reasons for this lack of comparability between the two exposures are not readily apparent; however, one or more of the following factors may be operating. (1) The effects of the morning run may increase temperatures during the afternoon run. Short-term acclimatization studies, however, have shown that systematic temperature changes only occur after several weeks of cold exposure

Table V-1

Mean Differences (in °C) Between Young Indians and Whites, and Adult Indians and Whites at the End of 60 Minutes of Cold Exposure

	Run 1			Run 2		
	Toe 1	Toe 5	Dorsum	Toe 1	Toe 5	Dorsum
Young (df = 55)						
Indian	16.6	16.0	20.7	21.9	23.8	24.9
White	9.1	8.1	15.8	14.7	14.6	19.6
Difference	7.6	7.9	4.9	7.2	9.2	5.3
Significance Level	.001	.001	.001	.01	.001	.001
Adult (df = 54)						
Indian	21.2	20.4	24.7	23.6	24.1	26.6
White	10.2	10.2	17.0	13.5	15.4	19.6
Difference	11.0	10.2	7.7	10.1	8.7	7.0
Significance Level	.001	.001	.001	.001	.001	.001

Table V-2

Mean Differences (in °C) Between Young and Adult Indians, and Young and Adult Whites at the End of 60 Minutes of Cold Exposure

	Run 1			Run 2		
	Toe 1	Toe 5	Dorsum	Toe 1	Toe 5	Dorsum
Indian (df = 57)						
Young	16.7	16.0	20.7	21.9	23.8	24.9
Adult	21.2	20.4	24.7	23.6	24.1	26.6
Difference	4.5	4.4	4.0	1.7	0.3	1.7
Significance Level	.05	.05	.01	N.S.	N.S.	N.S.
White (df = 52)						
Young	9.1	8.1	15.8	14.7	14.6	19.6
Adult	10.2	10.2	17.0	13.5	15.4	19.6
Difference	1.1	2.1	1.2	1.2	0.8	0.0
Significance Level	N.S.	.05	N.S.	N.S.	N.S.	N.S.

Table V-3

Mean Differences (in °C) Between Morning and Afternoon Exposures for Young and Adult Indians and Whites At the End of 60 Minutes of Cold Exposure.

	Toe 1	Toe 5	Dorsum
Young Indians (df = 56)			
Morning Run (Run 1)	16.7	16.0	20.7
Afternoon Run (Run 2)	21.9	23.8	24.9
Difference	5.2	7.8	4.2
Si Significance Level	.05	.001	.01
Young Whites (df = 54)			
Morning Run (Run 1)	9.1	8.1	15.8
Afternoon Run (Run 2)	14.7	14.6	19.6
Difference	5.6	6.5	3.8
Significance Level	.01	.001	.001
Adult Indians (df = 58)			
Morning Run (Run 1)	21.2	20.4	24.7
Afternoon Run (Run 2)	23.6	24.1	26.6
Difference	2.4	3.7	1.9
Significance Level	N.S.	N.S.	N.S.
Adult Whites (df = 50)			
Morning Run (Run 1)	10.2	10.2	17.0
Afternoon Run (Run 2)	13.5	15.4	19.6
Difference	3.3	5.2	2.6
Significance Level	N.S.	N.S.	N.S.

(LeBlanc and Rosenberg, 1957; Davis, 1961; Skreslet and Aarefjord, 1968). (2) Anxiety produced by the novelty of the experimental procedure can contribute to the reduction of peripheral temperatures by constricting the superficial blood vessels in the skin (Meehan, 1957; Teichner, 1965). An increase in temperatures might be expected with subsequent cold exposures under the assumption the subject would then be more emotionally adjusted to the experimental procedures. (3) Most

individuals experience a regular diurnal body temperature cycle with maximum and minimum values occurring at specific times during the 24-hour day (Aschoff, 1965). Hildebrandt (1952) recorded daily temperature rhythms on the surface of the foot and finger pad, and noted that skin temperatures at these sites tended to be warmer in the afternoon than in the morning. Others (Yoshimura and Iida, 1950) in studies of frostbite resistance found that vascular responses to cold water were more active and skin temperatures were higher in the late afternoon. The least active responses occurred between 6:00 and 7:00 a.m. In males, rectal temperatures reach a maximum between 6:00 and 8:00 p.m. and fall to a minimum between 4:00 and 6:00 a.m. (Mellete et al., 1951). Therefore, rectal temperatures would tend to be slightly higher in the afternoon than in the morning. This may contribute to the higher skin temperatures found during the afternoon exposure. Oral temperatures, measured in the United States sample after 12 minutes of cold exposure, tend to fit the circadian pattern (Table V-4). There are, however, no statistically significant differences between the oral temperature means of the morning and afternoon exposures.

Table V-4

Mean Oral Temperatures (in °C) for Young and Adult White Subjects Taken After 12 Minutes of Cold Exposure

	Morning Run		Afternoon Run	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Young (N = 28)	37.17	0.24	37.26	0.28
Adult (N = 26)	37.06	0.27	37.11	0.28

Recovery Temperatures

Differences between the Indian and White subjects appeared to be present in the rates of recovery of foot temperatures after removing the foot from the cold chamber. That is, the slope of the recovery temperature change is always steeper for the White subjects (see Figures V-1, V-2, and V-3). It was felt, however, that there might be a relationship between the final skin temperature and the rate of recovery, such that the amplitude of the recovery temperature would depend upon the final temperature. The relationship between final skin temperatures and temperature changes during recovery for the combined groups verifies this hypothesis and is illustrated in Figure V-4. The relationship is curvilinear, but the correlation is quite high when logarithmic transformation is carried out.

Relationships Between Toe 1 and Toe 5

Regression lines expressing the relationships between the 60-minute average skin temperatures of the two toe sites are shown in Figure V-5. Correlations between the two skin sites are highly significant at less than the 0.1% level for both Indians and Whites. The type of relationship that would be expected is one that shows temperatures at the toe 1 site approximately equal to temperatures at the toe 5 site. The regression for this expected relationship can be expressed as $Y = X$, where the slope equals 1 and the Y intercept equals 0. The regressions for the White subjects are roughly

equivalent to this equation, whereas the Indian regressions are not. Covariance analysis was then applied to test for differences between the Indian and White regressions for each of the two runs (Tables V-5 and V-6).

There are no significant differences between the Indian and White samples for the first run. For the second run, F ratios show significant differences between the two groups at less than the 1% level of probability for both the slope and the elevation of the regressions. The biological significance of these differences is not clear. At lower mean foot temperatures (5 - 25°C), the small toe is consistently warmer than the large toe among the Indian subjects, while the reverse is true at temperatures above 25°C.

Within-Individual Replicability of Responses

It would appear that the ability to replicate skin temperature responses is low, since outstanding differences were observed between the morning and afternoon exposures. Yet it has been noted that afternoon skin temperatures were almost always warmer than morning temperatures, and hence, factors other than simple random variation are operating to produce these diurnal differences.

Only one subject participated in repeated tests (three) for the standard series of morning and afternoon exposures (Figure V-6). Two of the tests were carried out in the United States (June and August), and the other was carried out in Nuñoa (December) at 4,000 meters above sea level. Each of the cold exposures began between

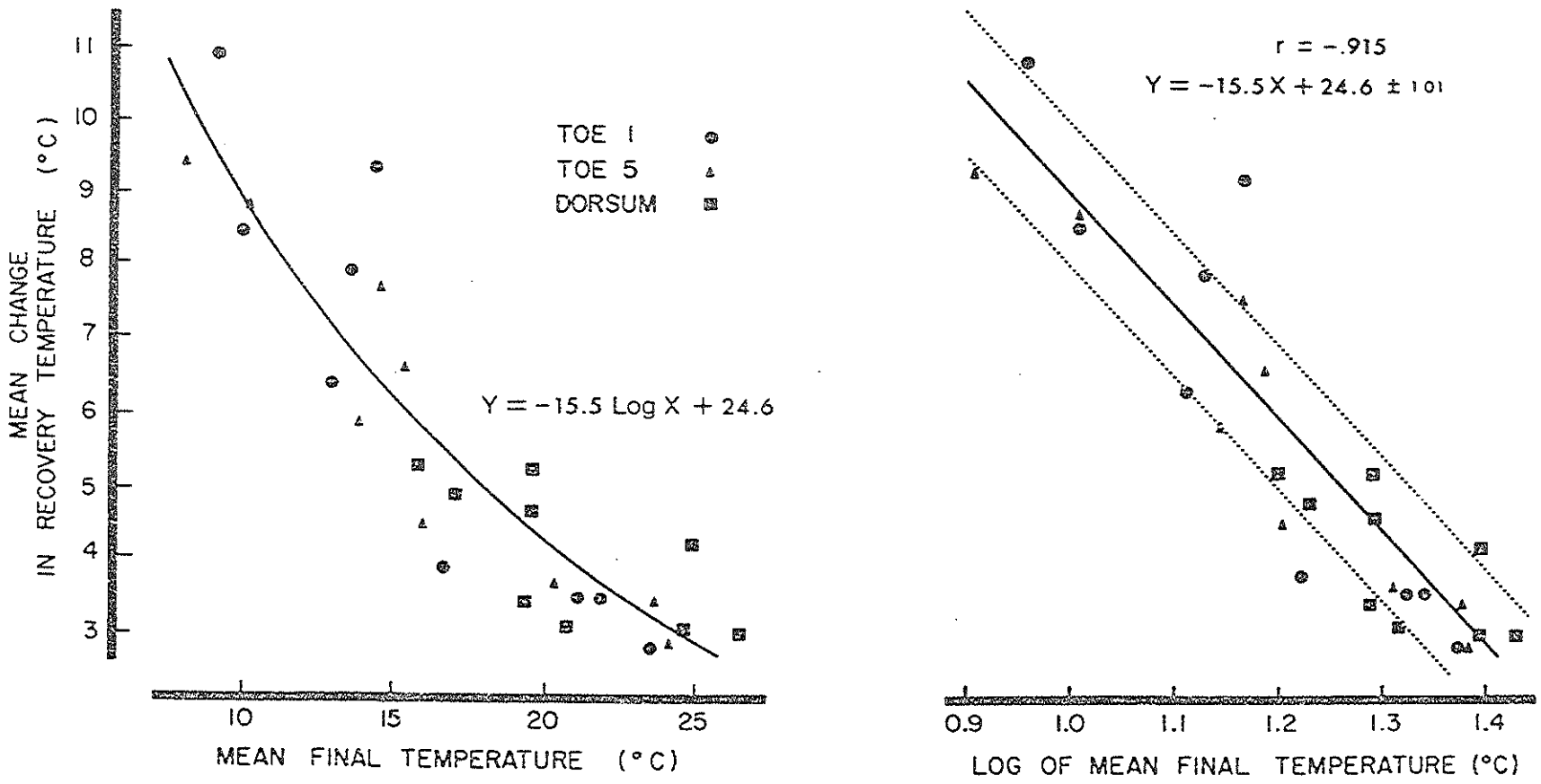


Figure V-4: (left) The curvilinear relationship between final skin temperatures after 60 minutes of cold exposure at 0°C and maximum recovery temperatures after 10 minutes at room temperature (24°C). (right) The same relationship after transformation of the abscissa to a logarithmic scale.

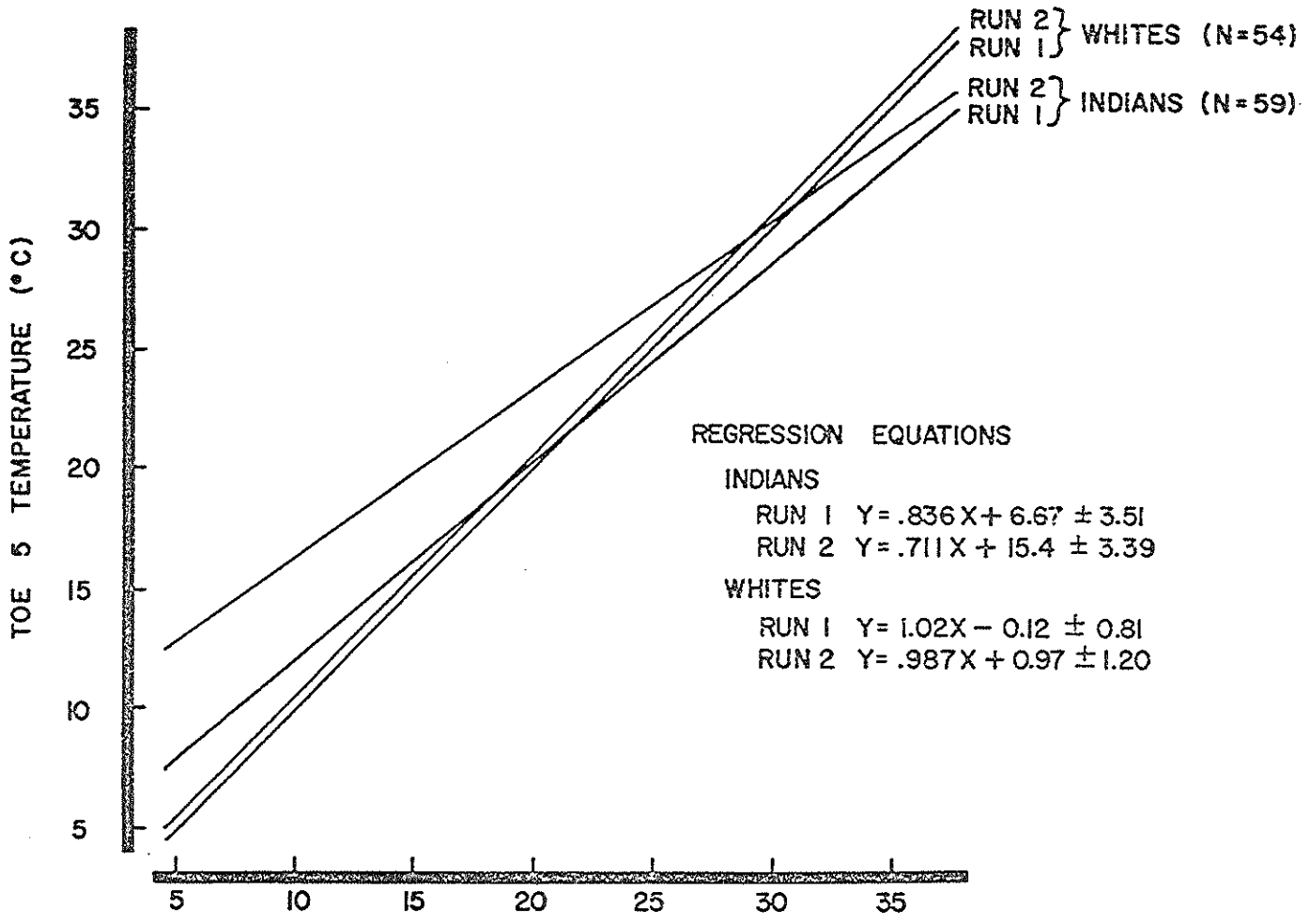


Figure V-5: Relationships between temperatures of the large (toe 1) and small (toe 5) toes for Indians and Whites.

Table V-5

Analysis of Covariance: Indian and White Regressions of Toe 1 (X) and Toe 5 (Y) Temperatures for Run 1.

	Regression Coefficients	d.f.	$\sum d_{y.x}^2$	Mean Square	F Ratio
Indians (N = 59)	0.836	57	1284	22.53	
Whites (N = 54)	1.016	52	333	6.40	
Within Reg. Coef.		109	1617	14.83	
Between Reg. Coef.		1	36	36.00	2.43 N.S.
Within Adj. Means	0.884	110	1653	15.03	
Between Adj. Means		1	17	17.00	1.13 N.S.
Total		111	1669		

Table V-6

Analysis of Covariance: Indian and White Regressions of Toe 1 (X) and Toe 5 (Y) Temperatures for Run 2.

	Regression Coefficients	d.f.	$\sum d_{y.x}^2$	Mean Square	F Ratio
Indians (N = 59)	0.711	57	1208	21.19	
Whites (N = 54)	0.987	52	743	14.29	
Within Reg. Coef.		109	1951	17.90	7.21**
Between Reg. Coef.		1	129	129.00	
Within Adj. Means	0.841	110	2081	18.92	9.57**
Between Adj. Means		1	181	181.00	
Total		111	2261		

P < .01 = **

10:15 and 11:00 a.m., and 2:30 and 3:00 p.m., at least two hours post prandium. Average oral temperatures for the three runs was 36.83°C. in the morning and 37.11°C in the afternoon. The results from Figure V-6 clearly show differences between the morning and afternoon exposures, as well as a relatively consistent pattern of response. The only pronounced irregularities resulted from spontaneous cold-induced vasodilations in the large toe. Moreover, the temperature responses at 4,000 meters do not seem to deviate appreciably from those recorded in the United States at sea level.

Subjective Responses

None of the subjects who were tested in air, either in the United States or in Peru, experienced severe pain at any time during the 60-minute exposure period. All but one subject completed the morning and afternoon series of cold exposures, and this one exception was an Indian child whose parents would not allow him to continue the test. The extent of discomfort, however, was much greater among the United States subjects. This may be due to the generally lower skin temperatures of this group. Discomfort was expressed in the White subjects by restlessness, an inability to concentrate on reading, and verbal complaints. When asked if the foot felt cold, many of the White subjects, especially the children, said that the feeling was roughly equivalent to a dull ache. In contrast, even when Indian skin temperatures fell to low values, the subjects seemed to show no feelings of discomfort. In fact, it was often necessary

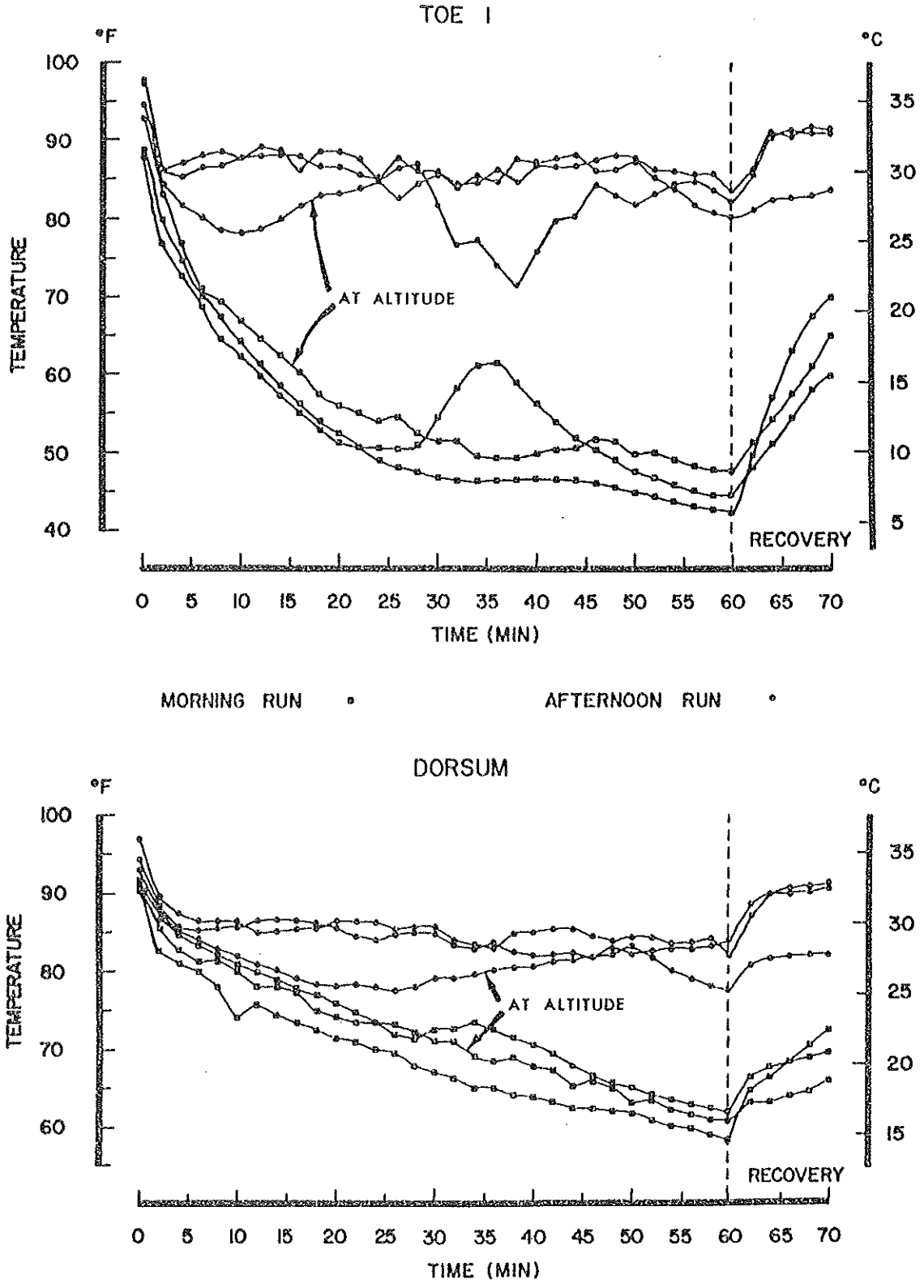


Figure V-6: Skin temperatures of the large toe (toe 1) and dorsum during cold exposure and recovery of one individual who was tested on three occasions.

to watch the Indian subjects quite closely to prevent their falling asleep. This procedure was required since foot temperatures are known to increase with the onset of sleep (Geschickter et al., 1966; Kleitman et al., 1948).

Temperature Cycling Responses

Spontaneous rewarming responses or cold-induced vasodilations occurred in at least 50 percent of the subjects who were tested in Peru and the United States. These responses were classified as weak, moderate, or strong according to temperature increases of 1.1 to 2.7°C (2.0 to 4.9°F), 2.8 to 5.5°C (5.0 to 9.9°F), and greater than 5.6°C (10.0°F), respectively. It was felt that any temperature increase of less than 1.1°C would have little biological or protective significance to the organism.

In an attempt to quantify the temperature changes during rewarming, a number of variables were calculated for each individual. The criteria for the determination of these variables, as well as the symbols used for their identification, are listed in Table V-7.

Group Differences

The Quechua Indians and United States Whites responded quite differently with respect to cold-induced vasodilatory responses. White subjects, both young and adult, showed a higher percentage of individuals who fell into the moderate and strong cycle amplitude category (Figure V-7). Less than 10 percent of the Indian subjects

Table V-7

Abbreviations and Explanation of Cycling Variables

t_1	Time to onset of first rewarming cycle (min)
T_1	Temperature at onset of first rewarming cycle (°C)
A_1	Amplitude of first rewarming cycle (°C)
T_{max}	Maximum temperature after a rewarming cycle begins (°C)
T_{min}	Minimum temperature after a rewarming cycle begins (°C)
$T_{max-min}$	Difference between the maximum and minimum temperatures (°C)
TC_{max}	Maximum temperature (peak) of the maximum cycle (°C)
TC_{min}	Onset temperature (low point) of the maximum cycle (°C)
A_{max}	Amplitude of the maximum rewarming cycle (°C)
tc	Duration of the maximum rewarming cycle (min)
NC	Number of rewarming cycles 1.1°C (2.0°F)

responded with an amplitude of this magnitude was found in between 30 and 40 percent of the White subjects.

In general, rewarming responses were more frequent and with a greater amplitude during the second exposure. The more labile rewarming responses in the afternoon probably contributed to the higher average skin temperatures found for both Indians and Whites during the afternoon cold exposure.

There are no pronounced differences between the number of young and adult Indian subjects who manifested rewarming responses, although slightly fewer adults exhibited rewarming cycles in the weak

amplitude category. Among the White subjects, the young group cycled to a greater extent than the adult group for toe 1, while the reverse took place in the case of toe 5. This pattern was consistent for the two exposures.

Means and standard deviations for the derived cycling variables are listed in Table V-8 for the Peruvian subjects and Table V-9 for the U. S. subjects. T-tests for differences between means were applied to these variables and the results are given in Tables V-10, V-11, V-12, V-13, and V-14 for Indian-White and young-adult comparisons.

The t-values in Tables V-10, V-11, and V-12 illustrate the marked differences that were observed in the derived cycling variables between the Indian and White samples. Indians rewarmed earlier (t_1) and at higher onset temperatures (T_1) than the Whites, yet the Whites showed a much greater amplitude of the rewarming response both for the first rewarming cycle (A_1) and for the maximum rewarming cycle (A_{max}). Absolute maximum and minimum values (T_{max} and T_{min}) and cycle maximum and minimum values (TC_{max} and TC_{min}) were always higher for the Indian subjects. These last results are consistent with the generally higher temperatures maintained by the Indians. The value for the temperature range between the absolute maximum and minimum ($T_{max-min}$), however, is less for the Indians, again because the Indians were able to maintain skin temperatures with less decrement than the Whites. Interestingly, even though the White subjects manifested high amplitude cycles, very little difference was observed between the Indians and Whites in either the duration of the maximum

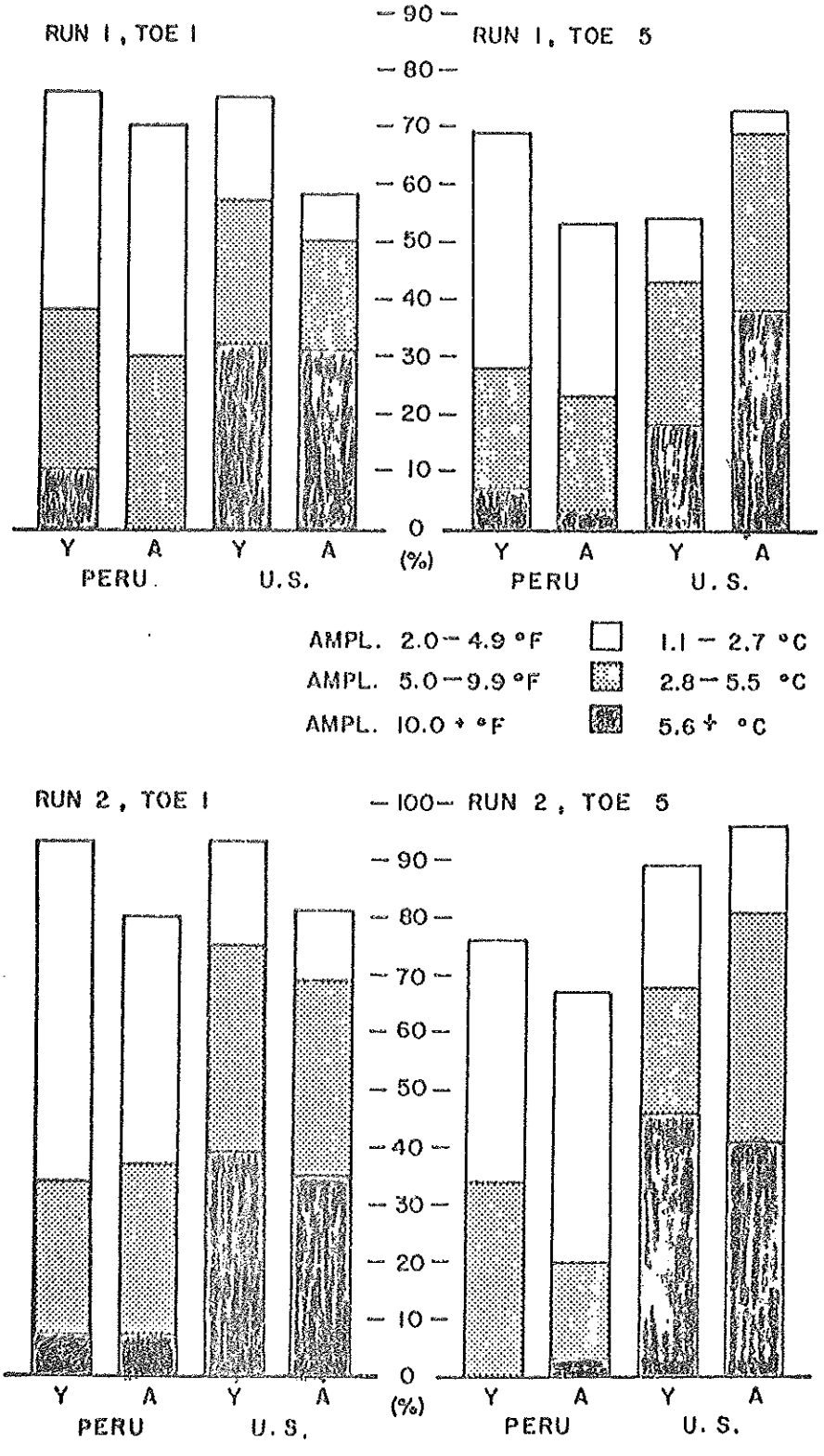


Figure V-7: Percentage of subjects who showed rewarming responses (Y = Young, A = Adult).

Table V-8

MEANS AND STANDARD DEVIATIONS OF CYCLING VARIABLES FOR FOOT COOLING IN AIR: INDIANS WHO CYCLED

	t_1		T_1		A_1		T_{max}		T_{min}		$T_{max-min}$		TC_{max}		TC_{min}		A_{max}		tc		NC		N
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	
Run 1, Toe 1																							
Young	13.2	16.6	24.1	7.1	2.9	1.6	27.3	7.4	17.3	5.8	10.0	6.1	26.2	7.7	22.7	7.3	3.4	1.7	7.0	4.7	2.8	1.7	22
Adult	13.6	13.5	25.4	6.2	2.4	1.4	28.1	6.7	22.9	7.0	5.2	4.3	27.9	6.6	25.2	6.0	2.7	1.4	8.0	3.7	2.0	1.1	21
Combined	13.4	15.0	24.8	6.6	2.7	1.5	27.7	7.0	20.1	6.9	7.6	5.8	27.0	7.1	23.9	6.7	3.1	1.6	7.5	4.2	2.4	1.4	43
Run 1, Toe 5																							
Young	11.6	12.9	24.9	6.7	2.6	1.4	28.6	6.8	17.1	6.4	11.4	6.6	27.6	7.3	24.9	7.2	2.8	1.3	5.7	3.8	2.2	1.0	20
Adult	14.6	15.8	26.4	6.0	2.2	1.3	28.9	6.3	22.3	7.8	6.6	4.8	28.4	6.1	25.6	5.7	2.9	1.5	8.1	3.5	1.7	0.7	16
Combined	12.9	14.1	26.1	6.3	2.4	1.4	28.7	6.5	19.4	7.4	9.3	6.3	28.0	6.7	25.2	6.5	2.8	1.4	6.8	3.8	1.9	0.9	36

Table V-8 (cont.)

MEANS AND STANDARD DEVIATIONS OF CYCLING VARIABLES FOR FOOT COOLING IN AIR: INDIANS WHO CYCLED

	t_1		T_1		A_1		T_{max}		T_{min}		$T_{max-min}$		TC_{max}		TC_{min}		A_{max}		tc		NC		N
	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	X	S.D.	
Run 2, Toe 1																							
Young	14.7	18.3	26.3	6.3	2.6	1.4	29.1	6.8	22.3	7.7	6.8	5.2	28.9	6.6	26.3	6.3	2.8	1.4	6.1	3.5	2.8	2.0	27
Adult	11.5	16.0	27.6	4.5	2.8	1.8	30.4	4.1	25.1	6.1	5.3	4.1	30.2	4.1	27.3	4.4	2.9	1.7	8.3	3.9	1.7	0.8	24
Combined	13.2	17.2	26.9	5.5	2.7	1.6	29.7	5.7	23.6	7.1	6.1	4.7	29.6	5.6	26.8	5.4	2.8	1.6	7.2	3.8	2.3	1.6	51
Run 2, Toe 5																							
Young	9.0	12.8	29.9	1.3	2.4	0.9	32.6	1.1	24.7	5.2	7.9	5.2	32.1	1.2	29.2	1.4	2.8	1.0	6.0	2.6	3.0	1.6	22
Adult	6.8	11.3	29.8	1.8	2.3	1.2	32.4	1.5	26.0	5.2	6.4	4.7	32.2	1.4	29.5	1.6	2.4	1.1	8.4	4.2	2.1	1.1	20
Combined	8.0	12.0	29.9	1.5	2.4	1.1	32.5	1.3	24.3	4.2	7.2	5.0	32.0	1.3	29.3	1.5	2.7	1.1	7.1	3.6	2.5	1.5	42

Table V-9

MEANS AND STANDARD DEVIATIONS OF CYCLING VARIABLES FOR FOOT COOLING IN AIR: WHITES WHO CYCLED

	t_1		T_1		A_1		T_{max}		T_{min}		$T_{max-min}$		TC_{max}		TC_{min}		A_{max}		tc		NC		N
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	
Run 1, Toe 1																							
Young	19.9	11.7	13.2	7.0	3.8	2.4	17.5	6.8	7.9	2.8	9.5	6.1	15.5	5.7	10.2	5.1	5.3	3.1	6.9	3.7	2.1	1.3	21
Adult	19.9	14.2	15.6	8.1	4.9	2.7	21.2	7.0	9.6	3.4	11.4	5.9	19.0	5.9	12.5	6.6	6.3	3.7	8.7	5.3	2.0	0.9	15
Combined	19.9	12.6	14.2	7.4	4.3	2.6	19.1	7.0	8.7	3.1	10.3	6.0	16.9	5.9	11.1	5.8	5.7	3.3	7.7	4.4	2.1	1.2	36
Run 1, Toe 5																							
Young	15.9	12.9	16.2	8.0	5.4	5.0	21.7	7.6	8.8	3.4	12.8	6.6	20.7	7.8	14.7	7.6	6.0	4.7	5.9	3.3	2.1	1.4	16
Adult	18.4	15.6	15.7	8.6	5.1	4.4	21.6	7.9	9.5	3.6	12.4	6.8	19.7	7.3	12.6	6.4	7.4	4.8	6.2	3.4	2.6	1.6	19
Combined	17.3	14.3	15.9	8.2	5.3	4.6	21.7	7.6	9.2	3.5	12.4	6.8	20.2	7.4	13.6	6.9	6.8	4.7	6.1	3.3	2.4	1.5	35

Table V-9 (cont.)

MEANS AND STANDARD DEVIATIONS OF CYCLING VARIATIONS FOR FOOT COOLING IN AIR: WHITES WHO CYCLED

	t_1		T_1		A_1		T_{max}		T_{min}		$T_{max-min}$		TC_{max}		TC_{min}		A_{max}		tc		NC		N
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	
Run 2, Toe 1																							
Young	14.3	13.5	20.3	8.2	8.3	1.8	24.6	7.3	13.3	7.7	11.3	6.7	22.0	7.1	16.2	7.9	5.9	3.4	5.9	2.6	2.9	1.6	26
Adult	20.8	17.6	18.7	9.3	6.0	5.8	25.0	7.5	10.8	4.9	14.2	7.7	22.8	7.2	15.8	7.6	7.0	5.3	7.4	4.7	2.4	1.4	22
Combined	17.3	14.7	19.6	8.7	4.6	4.3	24.8	7.3	12.1	6.7	12.7	7.2	22.3	7.1	16.0	7.7	6.4	4.3	6.6	3.7	2.7	1.5	48
Run 2, Toe 5																							
Young	11.7	11.4	21.3	8.4	4.1	3.6	25.8	7.3	12.8	7.3	12.9	6.7	22.1	7.3	16.5	8.2	5.6	3.6	4.6	2.6	2.9	1.6	25
Adult	15.2	13.5	20.3	9.3	3.3	4.3	25.5	7.9	12.4	6.3	13.1	6.9	23.9	7.7	16.5	8.2	7.4	5.9	7.7	5.0	2.9	1.7	24
Combined	13.4	12.5	20.8	8.7	3.7	3.9	25.7	7.6	12.7	6.8	13.0	6.7	23.0	7.4	16.5	8.1	6.5	4.9	6.2	4.2	2.9	1.6	49

Table V-10

T-Values for Differences Between Means of Cycling Variables: All Indians vs. All Whites Who Showed Rewarming

	Run 1		Run 2	
	Toe 1	Toe 5	Toe 1	Toe 5
t_1	2.06*	1.28	1.23	2.11*
T_1	6.68**	5.90**	5.04**	6.64**
A_1	3.46**	3.56**	2.95**	2.17*
T_{max}	5.46**	4.20**	3.78**	5.83**
T_{min}	9.10**	7.38**	8.32**	9.83**
$T_{max-min}$	2.01*	2.09*	5.35**	4.62**
TC_{max}	6.73**	4.66**	5.61**	7.71**
TC_{min}	8.96**	7.30**	8.06**	10.10**
A_{max}	4.70**	4.81**	5.46**	4.91**
tc	0.18	0.85	0.72	1.17
NC	1.04	1.53	1.30	1.22
d. f.	77	69	97	89

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

Table V-11

T-Values for Differences Between Means of Cycling Variables: Young Indians vs. Young Whites Who Showed Rewarming

	Run 1		Run 2	
	Toe 1	Toe 5	Toe 1	Toe 5
t_1	1.53	0.99	0.10	0.76
T_1	5.11***	3.98***	2.99**	4.81***
A_1	1.45	2.46*	1.68	2.15*
T_{max}	4.51***	2.86**	2.34*	4.28***
T_{min}	6.68***	4.62***	4.25***	6.26***
$T_{max-min}$	0.25	0.66	2.75**	2.85**
TC_{max}	5.17***	2.75**	3.65***	6.29***
TC_{min}	6.53***	4.14***	5.16***	7.17***
A_{max}	2.60*	2.95**	4.41***	3.43**
tc	0.04	0.15	0.26	1.80
NC	1.46	0.06	0.22	0.07
d. f.	41	34	51	45

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

Table V-12

T-Values for Differences Between Means of Cycling Variables: Adult Indians vs. Adult Whites Who Showed Rewarming

	Run 1		Run 2	
	Toe 1	Toe 5	Toe 1	Toe 5
t_1	1.34	0.71	1.89	2.20*
T_1	4.12***	4.21***	4.15***	4.50***
A_1	3.62***	2.54*	2.65*	1.02
T_{max}	3.00**	2.99**	3.08**	3.88***
T_{min}	6.80***	6.45***	8.73***	7.66***
$T_{max-min}$	3.67***	2.73**	4.93***	3.66***
TC_{max}	4.18***	3.80***	4.36***	4.61***
TC_{min}	6.00***	6.25***	6.33***	6.95***
A_{max}	4.07***	3.62***	3.56***	3.67***
tc	0.45	1.63	0.70	0.46
NC	0.14	2.18*	2.23*	1.97
d. f.	34	33	44	42

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

Table V-13

T-Values for Differences Between Means of Cycling Variables: Young vs. Adult Indians

	Run 1		Run 2	
	Toe 1	Toe 5	Toe 1	Toe 5
t_1	0.10	0.62	0.68	0.59
T_1	0.67	0.25	0.80	0.28
A_1	1.16	0.70	0.47	0.21
T_{max}	0.39	0.19	0.85	0.30
T_{min}	2.88**	2.17*	1.47	0.85
$T_{max-min}$	2.99**	2.54*	1.17	0.97
TC_{max}	0.82	0.36	0.87	0.12
TC_{min}	1.21	0.31	0.68	0.61
A_{max}	1.50	0.32	0.41	1.02
tc	0.78	1.98	2.08*	2.20*
NC	2.05*	1.64	2.65*	2.13*
d. f.	41	34	49	40

$P < .05$ = *, $P < .01$ = **

Table V-14

T-Values for Differences Between Means of Cycling Variables: Young vs. Adult Whites

	Run 1		Run 2	
	Toe 1	Toe 5	Toe 1	Toe 5
t_1	0.01	0.52	1.45	0.98
T_1	0.98	0.19	0.63	0.37
A_1	1.24	0.19	2.31*	0.66
T_{max}	1.61	0.02	0.19	0.14
T_{min}	1.62	0.58	1.32	0.22
$T_{max-min}$	0.94	0.33	1.38	0.07
TC_{max}	1.78	0.38	0.37	0.88
TC_{min}	1.21	0.89	0.16	0.01
A_{max}	0.85	0.89	0.89	1.38
tc	1.15	0.29	1.43	2.73**
NC	0.35	0.97	1.07	0.01
d. f.	34	33	46	47

$P < .05$ = *, $P < .01$ = **

cycle (tc) or the number of cycles that occurred during the hour exposure (NC). The overall pattern of differences is quite uniform for both toes and both expsosures, as well as in tests comparing the subjects by young and adult age groups (Tables V-11 and V-12).

Comparisons between young and adult Indians (Table V-13) show limited differences in the cycling values. For example, the absolute minimum temperature (T_{min}) is always lower in the young group, although the differences are statistically significant for only the morning exposure. There are, nonetheless, consistent if not statistically significant differences between the young and adults in the duration of the maximum cycle (tc) and the number of rewarming cycles (NC). The young Indians' maximum rewarming period is shorter by an average of about 2 minutes, and the number of cycles is slightly greater than the adults.

Among the White subjects (Table V-14), significant differences are virtually nonexistent. The only differences that tend to agree for the two toe sites and both exposures are in the duration of the maximum cycle (tc). Here, as in the Indian comparison, the young subjects have shorter cycles than the adults, although in addition, the young Whites have a slightly smaller maximum rewarming amplitude (A_{max}).

An illustration of the differences in cycling patterns between Indians and Whites is represented by Figure V-8. These are ideal rewarming curves and were only roughly estimated from the average values in Tables V-8 and V-9. Nevertheless, the earlier onset of

the rewarming response and the low amplitude cycling of the Indians can be contrasted with the later rewarming onset and high amplitude cycling of the Whites in this figure.

Cycling Relationships with Skin Temperatures

An attempt was made to determine if the subjects who showed a rewarming response also maintained higher average skin temperatures. Higher skin temperatures among cyclers would tend to substantiate the adaptive value of the rewarming response under conditions of moderate cold stress in air. To test this, half-hour and one-hour running mean toe temperatures of subjects who rewarmed at some time during the 60-minute cold exposure were compared with the same temperatures of subjects who did not show a rewarming response. Means and standard deviations of these values are given in Table V-15. Young and adult subjects were combined for both racial groups in calculating these values for two reasons: first, the samples of non-cyclers were quite small when contrasted with those who cycled, and second, no pronounced differences were observed in the cycling variables between the young and adult groups for either Whites or Indians. Mean differences between the cyclers and non-cyclers are well defined with cyclers howing consistently higher skin temperatures. The range of average differences falls between 3.6 and 10.1°C, although the maximum differences tend to occur during the second half-hour of the exposure. An inspection of skin temperature differences between the cyclers and non-cyclers by ten-minute running means (not shown) discloses a gradual divergence of the two groups with the

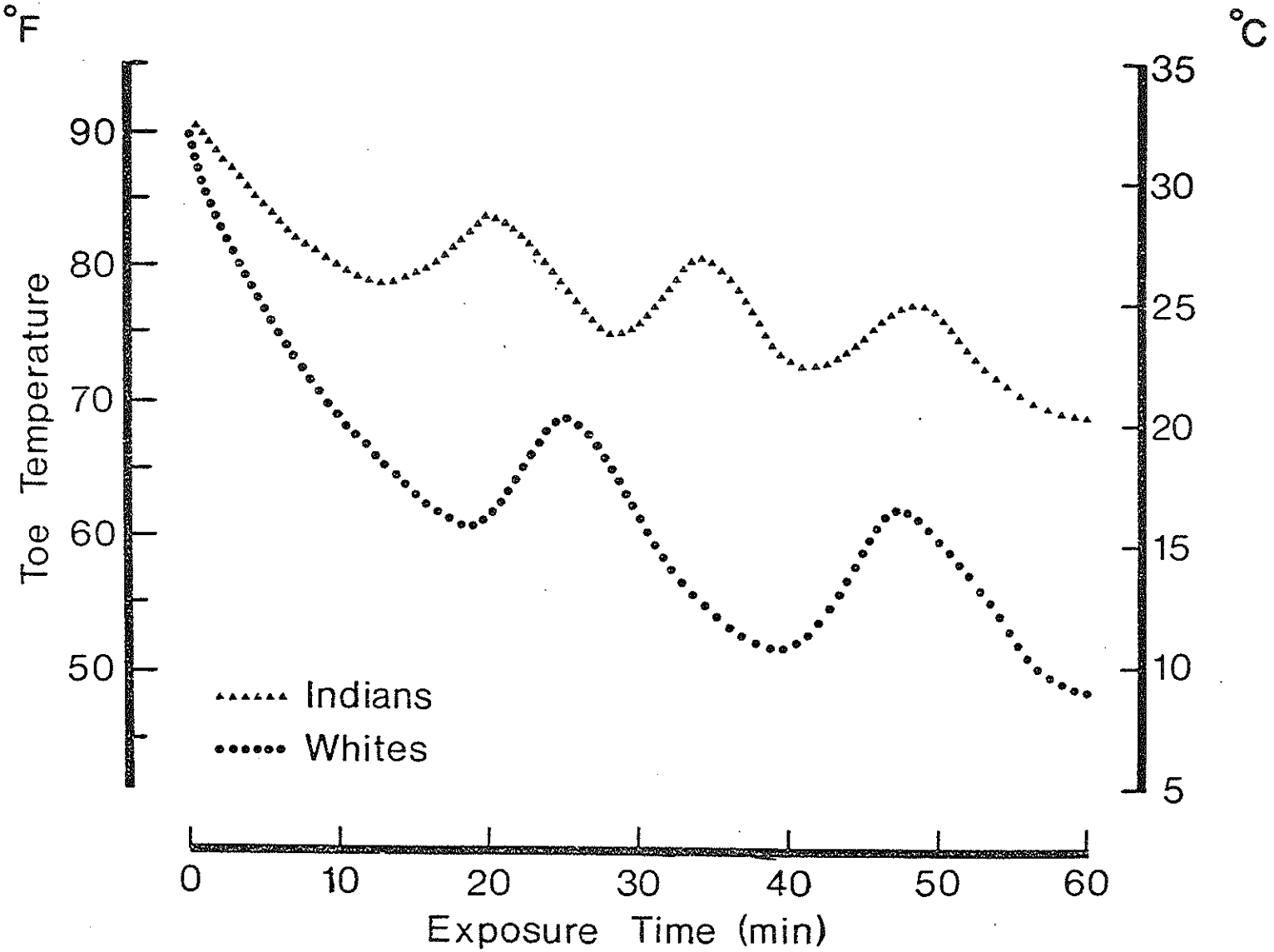


Figure V-8: Ideal rewarming curves expressing the general characteristics of White and Indian responses.

greatest temperature disparity during the last ten minutes of cold exposure. T-tests were applied to the 30-minute and 60-minute average ages (Table V-16). Almost all of the t-values are at high levels of statistical significance, despite the small sample sizes of a few of the non-cycling groups. Both Indians and Whites exhibit the same consistent pattern of differences.

Correlation analysis was performed to examine further the relationships between skin temperatures and rewarming responses. With this type of analysis, it should be possible to determine the temperature cycle characteristics that contribute most to the maintenance of higher skin temperatures at the two toe sites. Correlation coefficients expressing these relationships are listed for Indian subjects in Table V-17 and for White subjects in Table V-18. Again, the young and adult groups have been combined for the reasons noted above.

The time to onset of the first rewarming cycle is, in most cases, negatively related to the average toe temperatures for both Whites and Indians. This is a relatively consistent association that demonstrates the advantage of an early rewarming phase in maintaining higher skin temperatures. All cycling variables that are measures of skin temperatures themselves (T_1, T_{max}, T_{min}, TC_{max}, and TC_{min}) are positively correlated with average skin temperatures and generally at levels of probability less than 0.01. The degree of association, however, tends to be somewhat stronger during the first half hour of cold exposure. Subjects who rewarmed more frequently (NC) were inclined to show higher skin temperature, yet the amplitude

Table V-15

Means and Standard Deviations of 30-minute and 60-minute Running Temperature Means for Indians and Whites (°C). Comparison of subjects Who Showed Rewarming Responses with Those Who Did Not Rewarm.

	1st 30 MIN		2nd 30 MIN		60 MIN		N
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	
Toe 1, Run 1							
Indians							
Rewarming	26.7	5.01	22.9	6.97	24.8	5.76	43
No Rewarming	21.3	4.62	14.1	4.65	17.7	4.50	16
Whites							
Rewarming	17.1	5.00	12.2	3.78	14.7	3.98	36
No Rewarming	13.7	2.02	6.6	1.51	10.2	1.55	18
Toe 5, Run 1							
Indians							
Rewarming	27.7	4.70	22.5	7.40	25.1	5.80	36
No Rewarming	22.6	4.79	16.2	6.39	19.4	5.46	23
Whites							
Rewarming	17.9	5.37	12.7	4.67	15.3	4.62	35
No Rewarming	13.7	1.91	7.7	1.64	10.7	1.70	19
Toe 1, Run 2							
Indians							
Rewarming	28.9	3.91	25.9	6.48	27.4	5.08	51
No Rewarming	22.9	5.59	15.8	7.31	19.3	6.36	8
Whites							
Rewarming	21.9	6.04	16.2	6.61	19.1	5.76	48
No Rewarming	16.7	2.40	8.4	1.36	12.6	1.80	6
Toe 5, Run 2							
Indians							
Rewarming	31.2	1.28	28.4	3.69	29.8	2.30	42
No Rewarming	25.7	5.95	20.4	8.99	23.0	7.42	17
Whites							
Rewarming	22.2	6.29	16.8	7.27	19.4	6.34	49
No Rewarming	16.5	3.02	8.7	1.95	12.6	2.43	5

Table V-16

T-Values for Differences Between Means of 30-minute and 60-minute Running Temperature Means (°C). Indians and Whites Who Rewarmed vs. Indians and Whites Who Did Not Rewarm.

	1st 30 MIN	2nd 30 MIN	60 MIN
		Toe 1, Run 1	
Indians (df = 57)	3.65***	4.60***	4.36***
Whites (df = 52)	2.75**	5.97***	4.57***
		Toe 5, Run 1	
Indians (df = 57)	3.92***	3.29**	3.67***
Whites (df = 52)	3.23**	4.46***	4.13***
		Toe 1, Run 2	
Indians (df = 57)	3.75***	3.98***	3.97***
Whites (df = 52)	2.06*	2.82**	2.70**
		Toe 5, Run 2	
Indians (df = 57)	5.62***	4.82***	5.26***
Whites (df = 52)	1.95	2.42*	2.35*

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

Table V-17

Correlation Coefficients (r) for Relationships Between 30-Minute and 60-Minute Running Skin Temperature Means and Cycling Variables: All Indians Who Showed Rewarming Responses.

	Toe 1, Run 1 (N = 43)			Toe 5, Run 1 (N = 36)		
	1st 30 Min	2nd 30 Min	60 Min	1st 30 Min	2nd 30 Min	60 Min
t_1	-.66**	-.52**	-.60**	-.59**	-.32*	-.45**
T_1	.91**	.76**	.86**	.91**	.65**	.78**
A_1	.13	.17	.16	.05	.10	.08
T_{max}	.91**	.78**	.87**	.91**	.68**	.80**
T_{min}	.74**	.96**	.90**	.76**	.98**	.93**
$T_{max-min}$	.22	-.22	-.04	.03	-.46**	-.28
TC_{max}	.91**	.80**	.88**	.85**	.67**	.77**
TC_{min}	.90**	.78**	.86**	.84**	.63**	.74**
A_{max}	.26	.29	.29	.18	.28	.25
tc	.09	.23	.18	.16	.20	.19
NC	.42**	.40**	.43**	.25	.37*	.34*

	Toe 1, Run 2 (N = 51)			Toe 5, Run 2 (N = 42)		
	1st 30 Min	2nd 30 Min	60 Min	1st 30 Min	2nd 30 Min	60 Min
t_1	-.52**	-.43**	-.47**	.15	.11	.13
T_1	.91**	.83**	.88**	.82**	.28	.46**
A_1	.02	.01	.00	-.29	-.03	-.11
T_{max}	.90**	.83**	.88**	.76**	.43**	.55**
T_{min}	.86**	.98**	.96**	.51**	.95**	.91**
$T_{max-min}$	-.20	-.47**	-.38**	-.34*	-.88**	-.81**
TC_{max}	.90**	.82**	.87**	.62**	.37*	.47**
TC_{min}	.91**	.82**	.88**	.62**	.30*	.41**
A_{max}	.05	.08	.07	.12	.03	.01
tc	.05	.15	.12	.00	.23	.18
NC	.43**	.44**	.45**	.16	.14	.15

$P < .05$ = *, $P < .01$ = **

Table V-18

Correlation Coefficients (r) for Relationships Between 30-Minute and 60-Minute Running Skin Temperature Means and Cycling Variables: All Whites Who Showed Rewarming Responses.

	Toe 1, Run 1 (N = 36)			Toe 5, Run 1 (N = 35)		
	1st 30 Min	2nd 30 Min	60 Min	1st 30 Min	2nd 30 Min	60 Min
t_1	-.62**	-.49**	-.62**	-.50**	-.36*	-.47**
T_1	.93**	.59**	.86**	.87**	.57**	.79**
A_1	-.24	.14	-.09	-.17	.04	-.08
T_{max}	.83**	.70**	.86**	.81**	.68**	.81**
T_{min}	.64**	.85**	.81**	.70**	.83**	.82**
$T_{max-min}$	.63**	.36*	.57**	.56**	.35*	.50**
TC_{max}	.73**	.71**	.79**	.70**	.56**	.69**
TC_{min}	.75**	.55**	.73**	.79**	.40*	.66**
A_{max}	.01	.32	.16	-.03	.29	.13
tc	-.33*	-.05	-.23	-.34*	-.11	-.25
NC	.47**	.64**	.60**	.55**	.67**	.66**

	Toe 1, Run 2 (N = 48)			Toe 5, Run 2 (N = 49)		
	1st 30 Min	2nd 30 Min	60 Min	1st 30 Min	2nd 30 Min	60 Min
t_1	-.58**	-.26	-.45**	-.53**	-.38**	-.48**
T_1	.92**	.48**	.76**	.89**	.64**	.81**
A_1	-.33*	-.01	-.18	-.24	-.13	-.19
T_{max}	.81**	.59**	.77**	.80**	.66**	.77**
T_{min}	.69**	.91**	.89**	.80**	.89**	.91**
$T_{max-min}$	.19	-.24	-.04	.09	-.16	-.04
TC_{max}	.67**	.64**	.72**	.65**	.74**	.75**
TC_{min}	.82**	.56**	.75**	.80**	.65**	.77**
A_{max}	-.36*	.04	-.17	-.34*	.06	-.13
tc	-.53**	-.13	-.36*	-.32*	.03	-.14
NC	.57**	.55**	.62**	.55**	.59**	.61**

$P < .05$ = *, $P < .01$ = **

(A_1 and A_{max}) and duration (tc) of the rewarming cycle seem to have had little effect on skin temperatures. Thus, the individual, either White or Indian, who rewarms rapidly and at a high onset temperature, and who cycles frequently, is best able to maintain higber average toe temperatures.

One apparent association of two of the cycling variables has some bearing on the differences in rewarming patterns between the Indian and White subjects. In prior studies where extremity-cooling has been carried out in an ice water bath, the individual who displayed high amplitude rewarming usually sustained the warmest skin temperatures (Meehan, 1955; Hanna, 1965; Yoshimura and Iida, 1950). This is true for an acute exposure to cold water but does not occur during a moderate exposure to cold air. The reason for this disparity in rewarming responses between cold water and cold air exposure is related to an observation that Lewis made as early as 1930. Lewis noted that the rewarming response was more labile and occurred with greater frequency at water bath temperatures below 15°C.

In the present study, Indians rewarmed with lower amplitude cycles than Whites because the Indians' skin temperatures seldom fell to levels where the strong rewarming responses were triggered. The relationship between cycling onset temperature and amplitude of the response is presented in Figure V-9 for Indian and White subjects. The relationship between these two variables is good for Whites but not clear for Indians. A large proportion of the Indians who cycled did so at temperatures above 20°C, while over half of the rewarming responses of the Whites were elicited at temperatures

below 20°C. The data points in Figure 9 represent all of the cycles that were elicited from subjects of both groups. To verify this relationship, correlation coefficients were determined for comparisons between 1) initial onset temperature (T_1) and initial amplitude (A_1) and 2) onset temperature of the maximum rewarming cycle (TC_{min}) and amplitude of the maximum cycle (A_{max}). These coefficients are listed in Table V-19.

Table V-19

Correlation Coefficients (r) for Relationships Between Onset Temperatures and Amplitudes of Rewarming Cycles.

RUN 1

	Toe 1			Toe 5		
	T_1 vs A_1	TC_{min} vs A_{max}	N	T_1 vs A_1	TC_{min} vs A_{max}	N
Indians	.06	.14	43	-.02	.05	36
Whites	-.27	-.24	36	-.42*	-.18	35

RUN 2

Indians	-.12	-.02	51	-.60**	-.53**	42
Whites	-.48**	-.42**	48	-.36*	-.43**	49

$P < .05$ = *, $P < .01$ = **

The values in Table V-19 tend to confirm the results of Figure V-9. Nearly all of the relationships are negative and many of the coefficients for Whites are statistically significant, whereas the relation-

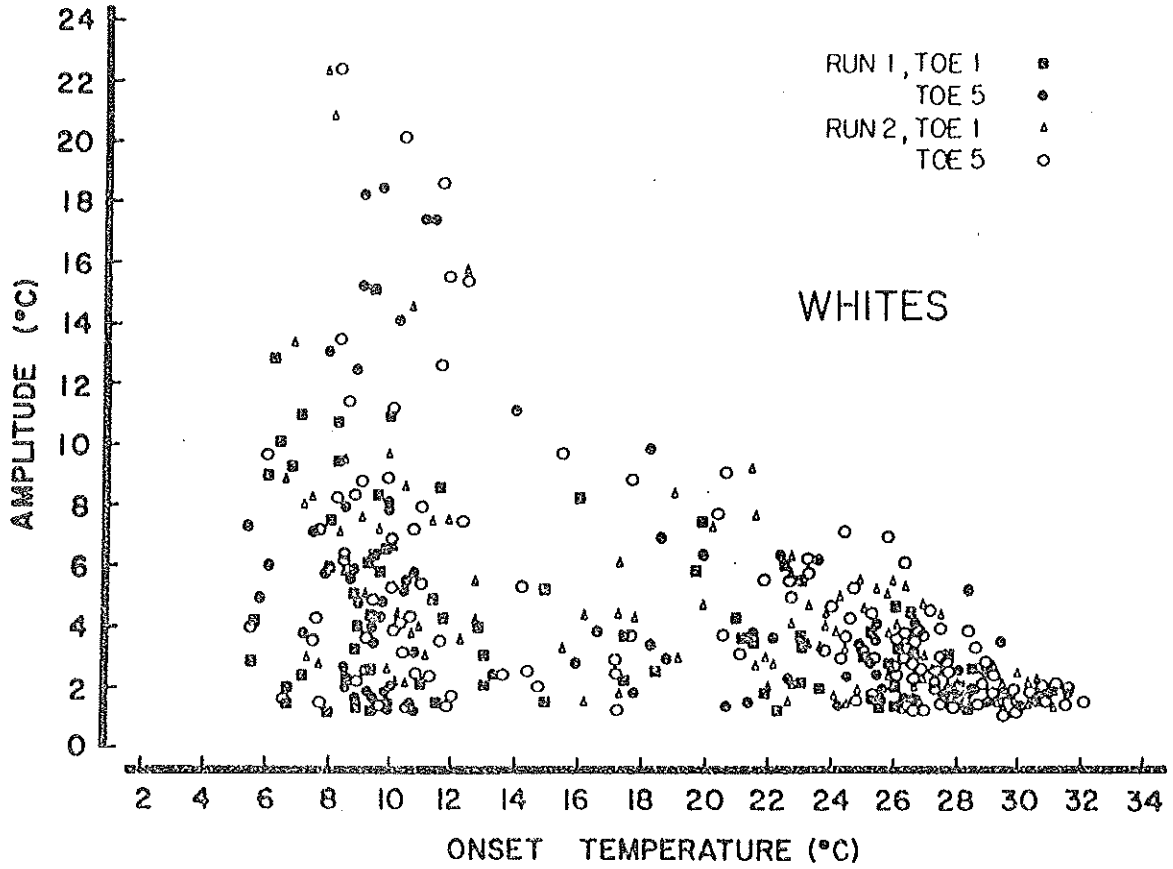
ships for the Indians are only significant at the toe 5 site for the second run.

Relationships Among Temperature Variables and Physical Characteristics

In order to test for the influence of body composition and size on skin temperature responses, correlation analysis was applied to these two sets of variables. Correlation coefficients expressing the relationships between physical characteristics and skin temperature means for the first 30, second 30, and full 60 minutes of cold exposure to air are reported in Appendix C (8 tables). Young and adult Indian and White groups have been treated separately because of the nature of the variables.

Comparisons between the first and second exposures for each of the groups show generally poor patterns of agreement in the significant relationships that are present. Also, only one of the four groups shows comparable patterning with any of the others. A discussion of the relàtionships for each group follows below.

Young Whites: There are moderately high correlations between sum of skinfolds values and average temperatures at all skin sites for run 1, whereas for run 2 there are none. This relationship for toe 1 during the first run is illustrated in Figure V-10. The relationships for run 1 tend to persist throughout the full hour and suggest that the individual with greater body fat maintains warmer skin temperatures.



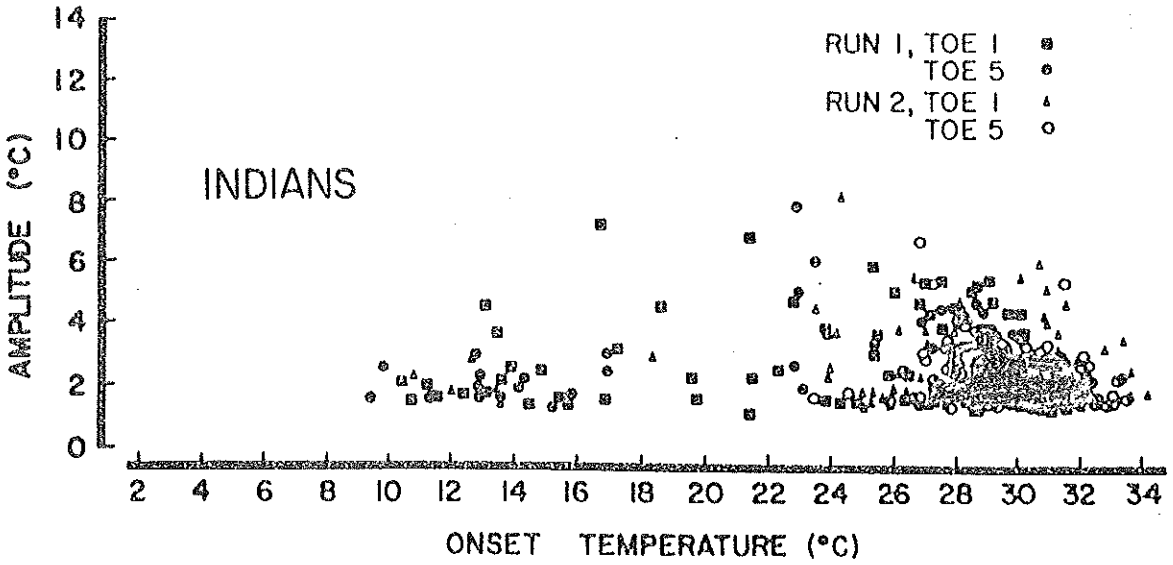


Figure V-9: Relationship between all cold-induced vasodilation onset temperatures and the amplitude of the rewarming response.

Adult Whites: The associations for this group are reasonably uniform for the first and second runs. In both exposures, there are statistically significant correlations between the average skin temperature during the first half-hour of exposure with weight, percent fat, and sum of skinfolds. Percent fat and sum of skinfolds, however, can be treated as a single "fat" variable since the two are highly interrelated ($r = .99$). These relationships tend to be in conformity with those of the young Whites (see Figure V-10) and again suggest that fat deposition in some way contributes to the maintenance of warm skin temperatures.

Young Indians: For the first exposure, there are no statistically significant correlations between skin temperatures and physical characteristics. A number of the correlations for the second run are significant, but only for the dorsum skin site. In fact, the only morphological variables that are unrelated to the average dorsum skin temperatures during the second run are sum of skinfolds, foot index, and toe index. This pattern of correlations reflects the high degree of interrelatedness among most of the variables. For example, all of the variables that are significantly correlated with skin temperature are themselves interrelated with correlation coefficients greater than $r = .70$. Multiple regression analysis was applied to the data to examine these relationships more closely. The results comparing the mean skin temperature for 60 minutes of exposure with the physical characteristics suggest that the most important variables are related to foot size and shape. The multi-

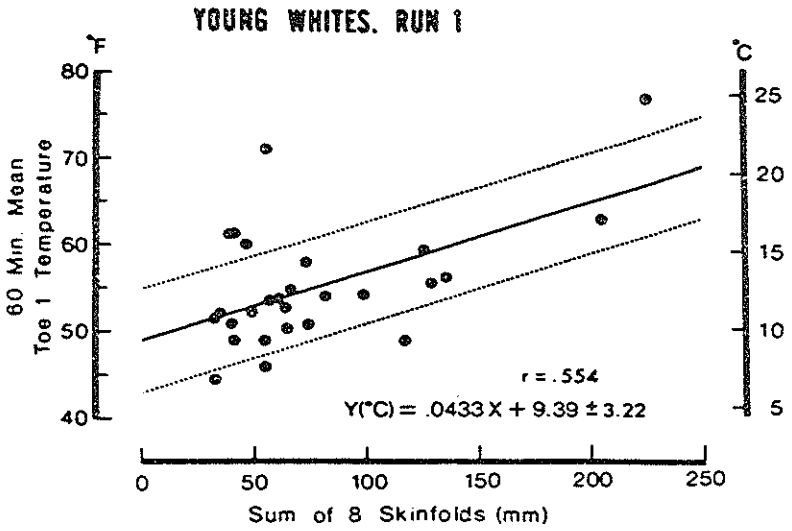
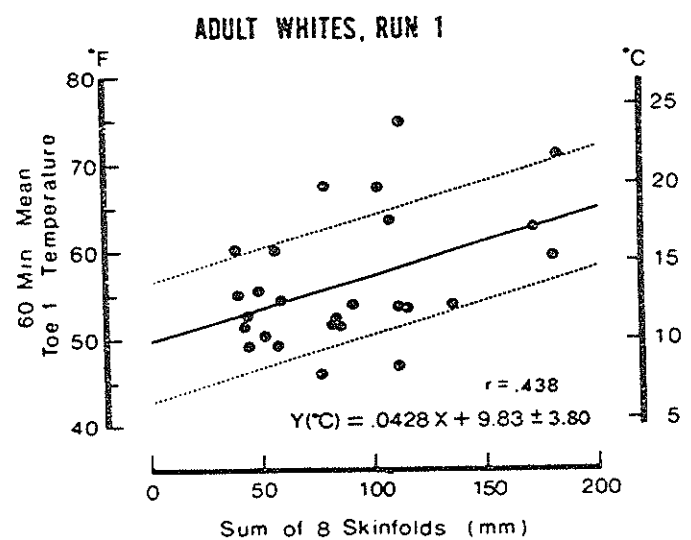
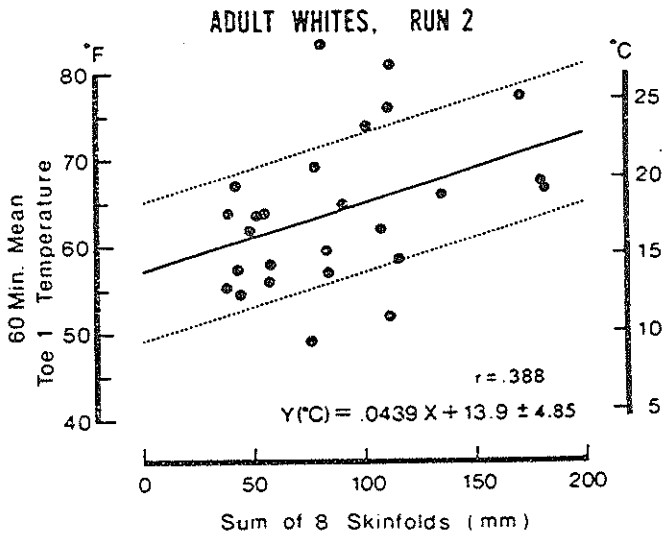


Figure V-10: Relationship between sum of 8 skinfolds and 60-minute mean skin temperatures of toe 1 during exposure of the foot to cold air at 0°C. Young Whites, N = 29; Adult Whites, N = 30.





ple correlation coefficient for foot length, foot breadth, and foot index is R = .672, although these three variables only account for 45.1 percent of the total variation in skin temperature.

Adult Indians: There is an inconsistency between the two exposures with respect to the significant correlations that are present. In the first run, weight and lean body mass are related to dorsum skin temperature at moderate to low levels of statistical significance. Weight and lean body mass, however, are strongly interrelated (r = .99), and hence the two variables are a measure of the same body parameter. The negative relationships between toe temperatures and foot length and breadth during the second run show statistical significance from the pre-exposure period. These coefficients may simply be statistical artifacts and not in any way related to cold exposure. Thus, the only relationships that hold up are those with measures of body weight during the first exposure. It is likely, also, that if these relationships are valid, then lean body mass may be the more important of the two, since correlations of skin temperature with sum of skinfolds and percent body fat are low.

There is a considerable risk of misinterpretation when large numbers of correlation coefficients are dealt with. If, for example, the data are randomly distributed and the 0.05 level of probability is taken for significance, then by chance factors alone, roughly 1 out of 20 coefficients should show a statistically significant relationship. It is then more profitable to search for patterns of relationships rather than accepting each significant correlation at its face value.

With this in mind, there are conditionally two groups of body size and composition variables that contribute to the maintenance of foot skin temperatures. First, for the White subjects thicker fat deposits tend to be related to higher skin temperatures among both adults and the young. The fact that this relationship does not appear for the Indian subjects might be explained by the narrow range in variation of skinfold thickness observed for the Indians (Table V-20).

Table V-20

Comparison of Measures of Variation in Sum of 8 Skinfolds for Indians and Whites

	Mean	S. D.	Range	Coefficient of Variation ($C.F. = \frac{S.D.}{Mean} \times 100$)
Adult				
Indians	45.1 mm.	11.0 mm.	29-74 mm.	24.39%
Whites	88.2	43.2	38-182	48.97
Young				
Indians	43.0	8.7	30- 64	20.23
Whites	76.5	49.4	33-225	60.57

A second series of variables that tends to have an effect on skin temperatures among the young is gross body size. The evidence for these relationships is not solid since the only example is from one exposure at one skin site for the young Indian group. It may be

that larger foot dimensions in some way facilitate the maintenance of higher skin temperatures. Since virtually no metabolic heat is produced by the foot, then tissue volume per se would not be important. There could, however, be foot surface area relationships to skin temperature that are not apparent from the variables that were measured.

Discussion

Marked differences were observed between the highland Quechua Indian and United States White groups in their responses to local foot exposure to cold air. Both young and adult Indians displayed significantly warmer skin temperatures at all sites than comparable White age groups. A small sample of English and American White subjects who were tested at high altitude responded to the cold exposure with skin temperatures that were intermediate to those of the Indians tested at altitude in Peru and the Whites tested at sea level in the United States. These findings are attributed, at least partially, to the disparity between the morning and afternoon skin temperatures of all other groups, since nearly all of the Whites at altitude were tested in the early evening. Thus, when skin temperature values for Whites at altitude were compared with those for Indians at altitude and Whites at sea level during the morning exposure, they fell midway between the two. On the other hand, when they were compared during the afternoon exposure, they coincided with the values of the sea-level whites. Therefore, it is not possible to draw inferences concerning the combined effects of altitude and local cold from this evidence alone.

Comparisons between the young and adults of both race groups failed to show differences among the Whites. Among the Indians, however, the adults maintained higher temperatures during the morning and afternoon exposures, although the differences were statistically significant only during the morning. The implications from this evidence are that developmental acclimatization may be operating among the Indians, but not among the Whites due to the absence of significant cold exposure throughout the lives of members of the latter group. Conversely, significant correlations between age and skin temperatures were conspicuously absent among young Indians, a finding that does not support this hypothesis.

It was hoped that some of the mechanisms contributing to Indian-White and young-adult skin temperature differences could be uncovered by inspecting patterns of cold-induced vasodilation or phasic skin rewarming. Within each race group there were essentially no differences between the young and adults in rewarming patterns or number of cycles. Between Indians and Whites, there were pronounced differences with Indians displaying an earlier cycle onset and higher temperature onset but lower amplitude cycling. The lower amplitude cycling of the Indians was attributed to a negative relationship between cycle amplitude and onset temperature that appeared unrelated to Indian-White differences. Skin temperature comparisons of those who rewarmed and those who did not rewarm within each race group clearly demonstrated the advantage of rewarming in maintaining higher skin temperatures. Yet, even though Whites rewarmed with high amplitude cycles, they still maintained lower average skin temperatures

than Indians who did not rewarm at all. The sequence of groups from those who maintained warmest to those who maintained coldest skin temperatures is: (1) Indians who rewarmed, (2) Indians who did not rewarm, (3) Whites who rewarmed, (4) Whites who did not rewarm. It can be concluded, then, that although the rewarming response is important to both Whites and Indians, the Indians' maintenance of warm skin temperatures is not wholly dependent upon this response under conditions of moderate cooling.

Despite the large differences in gross body morphology and body composition between Indians and Whites as outlined in Chapter IV, variables measuring these parameters seemed to contribute little to skin temperature responses. The thickness of adipose tissue was positively related to skin temperatures among White subjects but not Indian subjects. This suggests, since Indians had much lower fat deposits, that if skin temperatures had been corrected for fat deposition, there would have been an even greater difference between Indian and White skin temperatures.

CHAPTER VI

FOOT EXPOSURE TO COLD WATER

If exposure of the foot to cold air at 0°C is a moderate cold stress, then exposure to water at temperatures below 15°C can be considered an acute cold stress. When compared to air exposure at low temperatures, exposure to corresponding water temperatures produces a more severe cold stress that is a direct result of the high thermal conductivity of water.* Briefly then, water acts as a heat sink and tends to bring about a rapid cooling of skin temperatures when parts of the body are exposed to this medium.

Few Americans normally experience the degree of extremity cooling tested in this cold water procedure. Highland Peruvian Indians, on the other hand, are often exposed to wet-cold conditions by walking barefoot through snow, slush, and rain pools. This type of cold exposure is usually transient because snow seldom persists beyond midday and shallow rain pools are usually warmed by the sun after a few hours. The highland native would be quite unlikely to make a long journey through snow in bare feet or wearing only sandals. The important point to be made here is that the experimental laboratory conditions do, to some extent, simulate the natural conditions of cold exposure sustained by the highland Quechua Indian.

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* The thermal conductivity of water at 0°C is 1.3×10^{-3} cal/cm^3/sec/°C, while that of air at 0°C is approximately 5.0×10^{-5} cal/cm^3/sec/°C.

In the subsequent sections of this chapter, skin temperature responses to cold water exposure will be dealt with first and will be followed by the results of the calorimetric analysis of heat output from the foot during the same exposures.

Skin Temperature Responses

The results of foot exposure to cold water at 5, 10, and 15°C for Indians and Whites is graphically illustrated in Figure VI-1. The configuration of the cooling curves for skin temperatures in water differs markedly from that observed for skin temperatures in air. When Whites are considered, toe temperature cooling curves in water display a precipitous drop upon first exposure such that the temperature of the skin closely approaches that of the water after about five minutes. This is followed by a gradual skin temperature increase slightly above and paralleling that of the water. Dorsum responses are quite similar, yet these skin temperatures never approach water temperatures as closely as do the toe temperatures. Indian toe temperature responses differ in that the cooling curve tends to level off at a much higher temperature and then gradually falls to converge with the water temperature at close to the end of the thirty minutes of exposure. Dorsum skin responses for this group resemble those for the toe but again remain well above water temperatures.

The major points of difference between the two groups can be found during the first half of the exposure. The White subjects' decline in skin temperature upon initial exposure to the water is

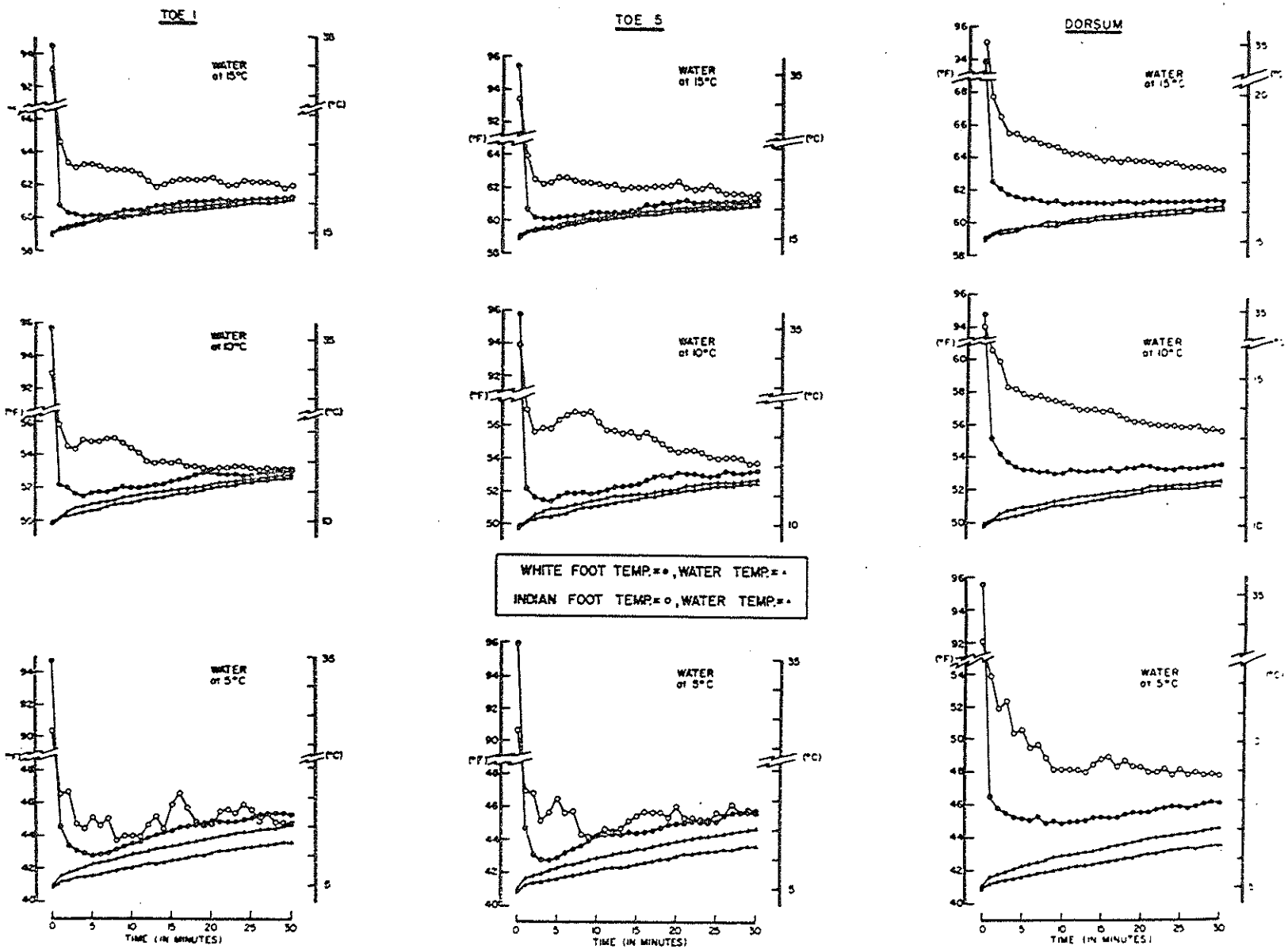

Figure VI-1: Mean skin and water temperatures during 30 minutes of cold exposure to water at initial water temperatures of 5, 10, and 15°C.

much more rapid that the Indians', and the latter group plateaus at temperatures well above the former. This can be expressed more clearly in Figure VI-2 where skin temperatures have been corrected for any slight differences in water temperatures by subtracting the first value from the second. The dotted line is the reference for water temperature.

Values representing the difference between water temperature and skin temperature are given in Table VI-1 for the 1st, 10th, 20th, and final minutes of each cold exposure. The skin temperatures of Indian subjects always remain at a greater elevation above water temperatures than those of the White subjects, although differences between the two groups are more pronounced at the dorsum skin site.

Table VI-1

Means and Standard Deviations of Differences Between Water Temperatures and Skin Temperatures (in °C) During Exposures to Water at Initial Temperatures of 5, 10, and 15°C: Indians (N = 12) and Whites (N = 12).

	Toe 1		Toe 5		Dorsum	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Water at 5°C						
Minute 1						
Indian	2.94	1.67	3.03	1.20	7.09	0.87
White	1.67	0.67	1.71	1.07	2.77	0.82
Minute 10						
Indian	1.08	0.87	1.18	0.70	3.41	0.54
White	0.37	0.31	0.72	0.63	1.11	0.37
Minute 20						
Indian	0.96	0.61	1.70	1.43	3.04	0.61
White	0.54	0.46	0.60	0.43	0.98	0.34
Minute 30						
Indian	0.63	0.56	1.10	0.93	2.37	0.61
White	0.34	0.37	0.58	0.46	0.86	0.29

Table VI-1 (Cont.)

	Toe 1		Toe 5		Dorsum	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Water at 10°C						
Minute 1						
Indian	3.11	1.45	3.76	1.04	5.78	0.91
White	0.96	0.42	0.93	0.32	2.60	0.88
Minute 10						
Indian	1.81	1.15	2.81	1.62	3.45	1.06
White	0.24	0.26	0.29	0.42	0.88	0.27
Minute 20						
Indian	0.66	0.51	1.31	1.30	2.39	0.78
White	0.39	0.56	0.54	0.78	0.80	0.44
Minute 30						
Indian	0.33	0.38	0.66	0.94	1.79	0.76
White	0.17	0.23	0.29	0.62	0.50	0.24
Water at 15°C						
Minute 1						
Indian	2.93	0.81	2.52	1.11	4.67	0.74
White	0.78	0.21	0.75	0.29	1.82	0.47
Minute 10						
Indian	1.49	1.00	1.14	0.89	2.36	0.62
White	0.19	0.33	0.22	0.37	0.64	0.18
Minute 20						
Indian	0.97	1.19	0.99	1.12	1.79	0.92
White	0.17	0.44	0.34	0.76	0.44	0.18
Minute 30						
Indian	0.51	0.62	0.39	0.65	1.24	0.69
White	0.08	0.14	0.18	0.45	0.29	0.10

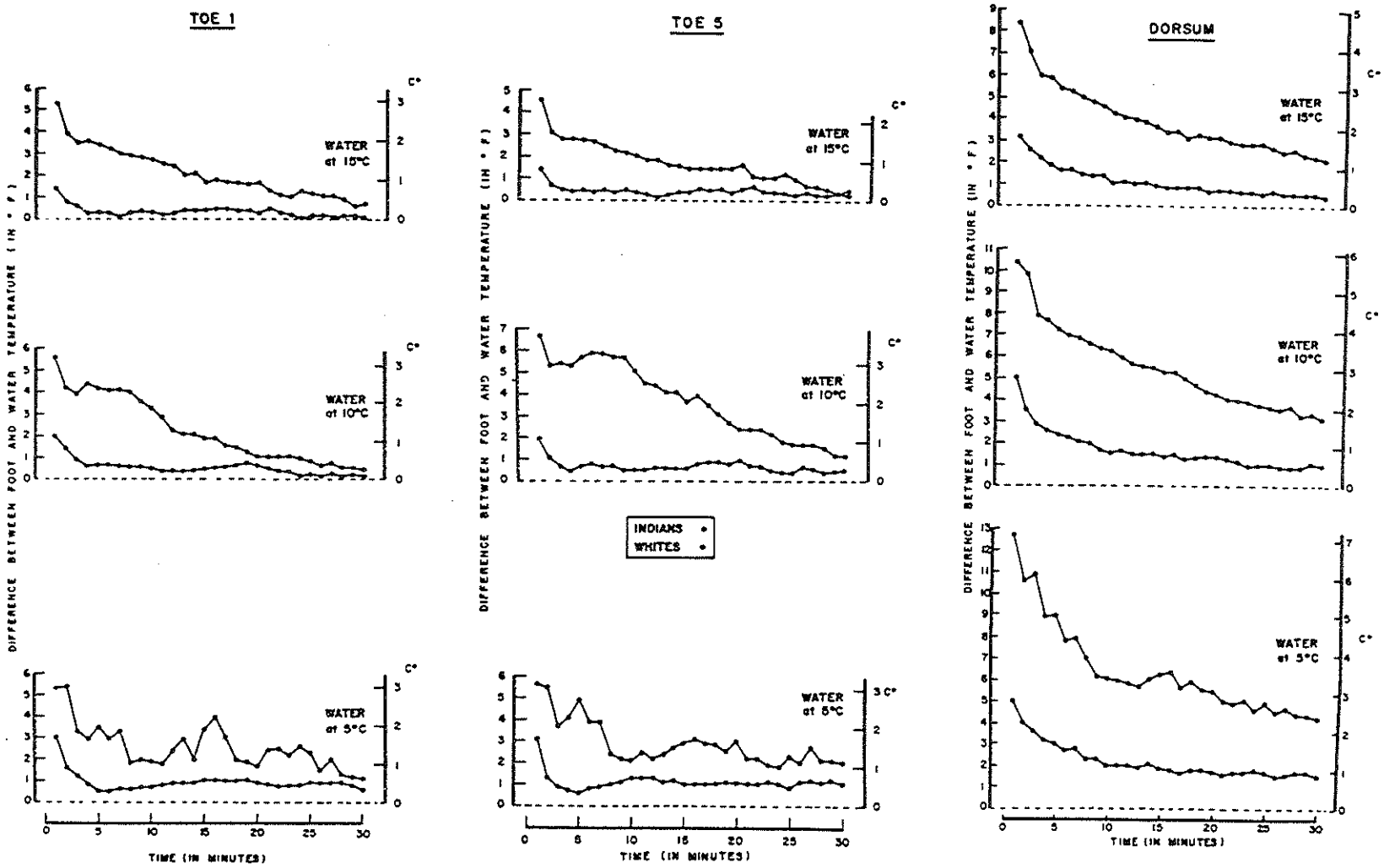

Figure VI-2: Mean differences between skin temperature and water temperature during 30 minutes of cold exposure to water at initial water temperatures of 5, 10, and 15°C. (Indians = o, Whites = ●)

T-tests for differences between the means of Indians and Whites were applied to the data, and the results are listed in Table VI-2. It is apparent that the most distinct differences between the two groups are found at the dorsum skin site. At the toe skin sites, statistically significant t-values are common at the 1st and 10th minutes of exposure, but occur sporadically at times later in the exposure. In addition, the t-values show a strong degree of statistical significance for the two toes during the 10°C and 15°C exposures, whereas the same values during the 5°C exposure are only marginally significant.

The fluctuations of the Indian cooling curves (see Figure VI-2), especially during the 5°C exposure, result from the comparatively high incidence of spontaneous rewarming responses shown by this group. Cycling responses occurred at one or more of the toe sites in over half of the Indian subjects and in only one quarter of the White subjects. Moreover, the Indians cycled earlier, with higher rewarming amplitudes, and more often than the Whites. The small number of subjects who cycled precluded the use of statistical analysis. However, the average values for some of the cycling variables are listed in Table VI-3. Abbreviations for the cycling variables are the same as those listed in Chapter V. Since a greater number of Indians cycled and with more labile and frequent responses than Whites, then it can be concluded that the rewarming responses probably contributed substantially to the maintenance of higher toe temperatures among the Indians.

Table VI-2

T-Values for Differences Between Means of the Difference Between Water Temperatures and Skin Temperatures During Exposures to Water at Initial Temperatures of 5, 10, and 15°C: Indians (N = 12) vs. Whites (N = 12).

	Toe 1	Toe 5	Dorsum
Water at 5°C			
Min 1	2.35*	2.73*	11.98***
Min 10	2.55*	1.62	11.59***
Min 20	1.81	2.44*	9.80***
Min 30	1.44	1.64	7.40***
Water at 10°C			
Min 1	4.73***	8.62***	8.38***
Min 10	4.43***	4.99***	7.77***
Min 20	1.18	1.69	5.93***
Min 30	1.26	1.08	5.32***
Water at 15°C			
Min 1	8.55***	5.09***	10.70***
Min 10	4.10***	3.17**	8.82***
Min 20	2.10*	1.59	4.75***
Min 30	2.27*	0.90	4.54***

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

TABLE VI-3

Mean Values of Cycling Responses* for Indians and Whites at Initial Water Bath Temperatures of 5, 10, and 15°C.

	Toe 1					Toe 5				
	t_1 (min)	T_1 (°C)	A_1 (°C)	NC	N	t_1 (min)	T_1 (°C)	A_1 (°C)	NC	N
Water at 5°C										
Indian	6.8	7.4	6.7	3.2	4	5.0	7.9	5.5	3.4	5
White	23.0	8.6	2.5	1.0	1	12.0	6.3	3.1	1.0	2
Water at 10°C										
Indian	4.5	12.2	3.6	1.0	4	3.4	13.0	3.3	1.4	8
White	14.5	11.3	2.6	1.0	2	15.7	11.7	2.7	1.0	3
Water at 15°C										
Indian	10.3	17.3	3.6	1.3	3	7.3	16.5	3.2	1.3	3
White	7.0	15.9	3.5	1.0	1	9.0	16.0	3.5	1.0	2

Subjective Responses

In contrast to the cold exposure in air, many of the White subjects experienced a great deal of pain during the total foot immersion in water. Among most of these subjects, the phase of severe pain only persisted for about five minutes, while in a few

*t_1 - Time to onset of first rewarming cycle (min)

T_1 - Temperature at onset of first rewarming cycle (°C)

A_1 - Amplitude of first rewarming cycle

NC - Number of rewarming cycles

N - Number of subjects who rewarmed

it remained throughout the test. Other reactions included mild nausea, vertigo, and sweating. These side reactions never persisted beyond the first few minutes and were only observed during the 5°C exposure. Indians, on the other hand, indicated that they experienced no pain and, in fact, little discomfort. The other reactions were also absent in the Indian group. None of the subjects from either group failed to complete the series of exposures to cold water.

Differences in pain experience between native groups who are chronically cold-exposed and Western groups who are not, when tested under conditions of acute local cold exposure, are cited frequently in the literature (Eagan, 1963; Elsner et al., 1960, Hammel, 1960; Krog et al., 1960). The effect of these differences on vascular responses in the present study is not known. It can be suggested, however, that if the pain-anxiety reaction suppresses the blood flow, then there should be some recovery after the first few minutes of exposure.

Foot Calorimetry

During foot-cooling in water, the bulk of the heat given off is derived from two sources: (1) the heat stored by tissues (heat content), and (2) the heat supplied by circulating blood (Elsner et al., 1960). The heat produced by metabolic activity might be considered a third source, yet this is minimal in the foot because of the absence of substantial amounts of muscular tissue (Stewart, 1911; Allwood and Burry, 1954). Heat loss from the foot

to water was determine for each of the three initial water bath temperatures (5, 10, and 15°C) during 0 to 5, 5 to 15, and 15 to 30 minutes (total heat transfer to water) and heat loss from 5 to 30 minutes were determined as well. The latter figure is taken as an estimation of heat output from blood circulation, since it is assumed that most of the heat content or stored heat of the foot was transferred to the water by the fifth minute of the exposure (Greenfield et al., 1951). The values of heat output were standardized to foot volume and expressed as kcal. of heat lost/100 ml. of foot tissue/unit time during the cold exposure. Means and standard deviations of heat output for Indians and Whites are given in Table VI-4, and the means are graphically represented in Figure VI-3.

During the first five minutes of the 5°C exposure, the Whites lost substantially more heat than the Indians. For the remainder of the 30 minutes, the values are essentially the same. This is shown by the heat output values for minutes 5 to 30. The pattern changes during the 10°C exposure. Although the Whites again lost more heat during the first five minutes, the Indians put out more heat during the final 25 minutes. At 15°C, the pattern of responses is similar to that at 10°C, except that differences between the groups are only slight during the initial five minutes.

T-values listed in Table VI-5 can be used to indicate where the greatest differences lie. The statistically significant differences during the first five minutes of cold exposure at 5 and 10° C are probably the result of the higher initial skin temperatures and, thus, greater heat content of the feet of the White subjects (see Figure

Table VI-4

Means and Standard Deviations of Heat Output (kcal/100 ml of foot tissue) for Indians (N = 12) and Whites (N = 12): Different Time Periods During 30 Minutes of Cold Exposure to Water at Initial Temperatures of 5, 10, and 15°C.

	5°C		10°C		15°C	
	Indian	White	Indian	White	Indian	White
Min 0-5						
$\bar{X}$	0.830	1.223	0.840	1.011	0.758	0.729
SD	0.181	0.178	0.210	0.168	0.155	0.165
Min 5-15						
$\bar{X}$	0.975	1.058	1.012	0.819	0.791	0.572
SD	0.309	0.161	0.366	0.154	0.213	0.122
Min 15-30						
$\bar{X}$	1.254	1.219	1.083	0.807	0.805	0.584
SD	0.527	0.281	0.408	0.214	0.356	0.157
Min 0-30						
$\bar{X}$	3.059	3.500	2.935	2.637	2.355	1.885
SD	0.912	0.468	0.848	0.480	0.595	0.361
Min 5-30						
$\bar{X}$	2.229	2.277	2.096	1.626	1.597	1.156
SD	0.780	0.412	0.680	0.339	0.526	0.238

VI-1). There are no significant t-values for the final 25 minutes at 5°C, whereas the t-value for the final 25 minutes at 10°C does show marginal significance. The greatest difference between the two groups in heat output appears during the 15°C exposure. At this water bath bemperature, Indians lost significantly more heat during minutes 5 to 15 but not during minutes 15 to 30.

The results of foot calorimetry and analysis of skin tempera-

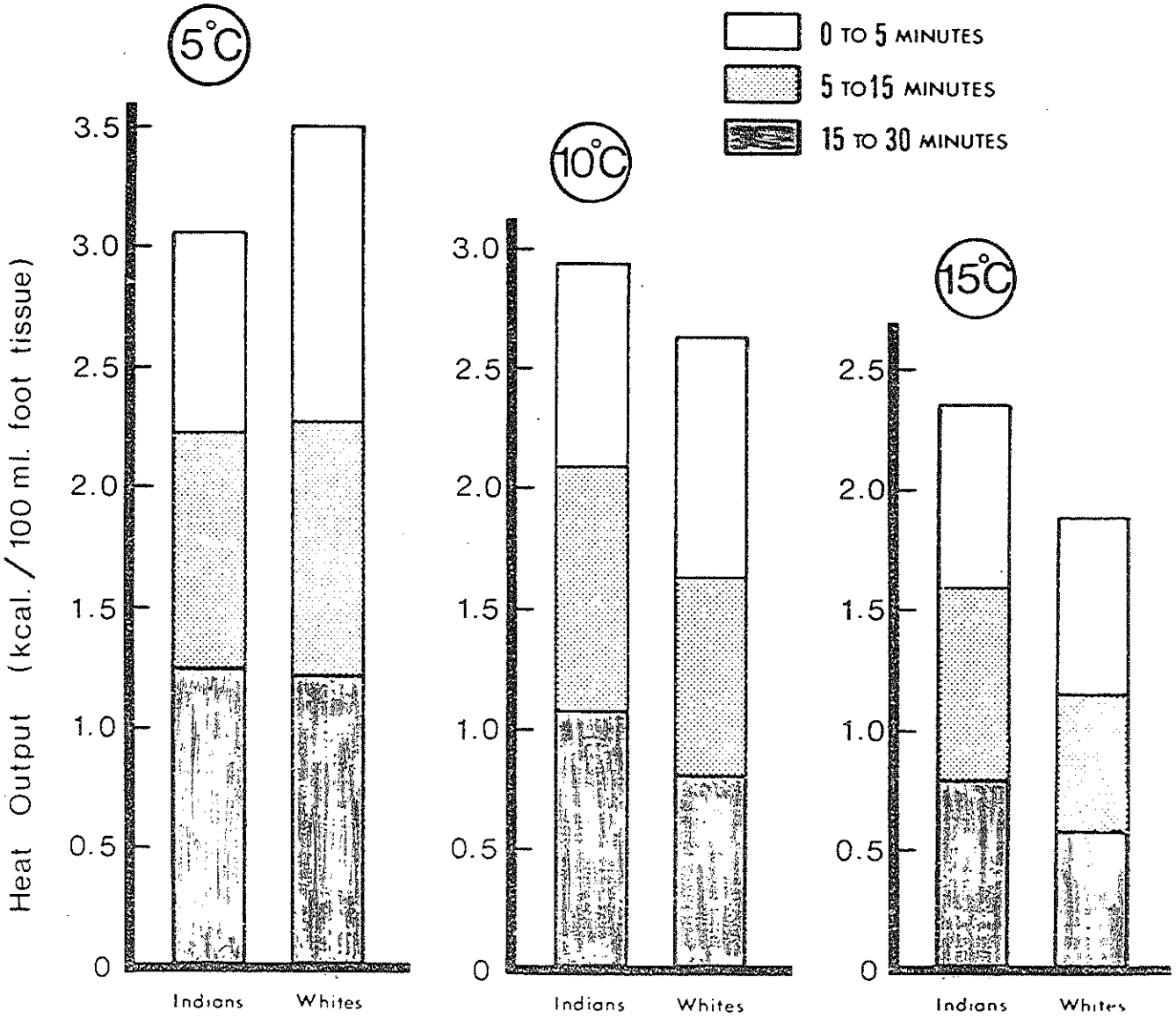

Figure VI-3: Heat output from the feet of Indians (N = 12) and Whites (N = 12) during 30 minutes of cold exposure at initial water bath temperatures of 5, 10, and 15°C.

Table VI-5

T-Values for Differences Between Means of Heat Output (kcal/100 ml of foot tissue) for Indians (N = 12) and Whites (N = 12): Different Time Periods During 30 Minutes of Cold Exposure to Water at Initial Temperatures of 5, 10, and 15°C.

	5°C	10°C	15°C
Min 0-5	5.14***	2.12*	0.42
Min 5-15	0.79	1.62	2.96**
Min 15-30	0.19	1.99	1.89
Min 0-30	1.43	1.02	2.24*
Min 5-30	0.18	2.05*	2.53*

$P < .05$ = *, $P < .01$ = **, $P < .001$ = ***

tures tend to be in agreement. Indian toe temperatures were slightly higher than those of the Whites during the 5°C exposure, yet markedly higher during the first 15 minutes of the 10 and 15°C exposures. The differences between heat output during the 10°C exposure do not fully correspond to those observed for skin temperatures, but at 15°C the findings essentially agree.

Relationship Between Heat Output and Foot Volume

Hildes and his colleagues (1961) have suggested that many of the observed differences between control groups and cold-resistant groups (e.g. Eskimos, Arctic Indians, Gaspé fishermen) in tests of

heat output from the hand can be attributed to smaller hand volumes among the cold-resistant groups. The relationship that Hildes demonstrated is a negative one between heat output/100 ml of hand tissue and hand volume. In the present study, the mean foot volume of the Indian subjects ($\bar{X}$ = 902 ml) is less than that of the White subjects ($\bar{X}$ = 1042 ml). Therefore, since a difference in foot volume exists, it seemed appropriate to test this relationship.

Correlation and regression analysis was applied to the data for each group, and the results are presented in Figures VI-4 and VI-5. All correlations are negative, which lends support to Hildes' findings, yet only one of the six is statistically significant (Indians at 5°C, r = .608). Furthermore, there are differences between the Indian and White regression equations with respect to slope, standard error, and Y-intercept for each water bath temperature. Hence, the negative relationship between heat output from the foot/100 ml of foot tissue and foot volume might explain some of the differences between Indians and Whites. However, the high degree of variation in regression and the generally poor relationships suggest that other factors must also be operating to produce the group differences in heat loss from the foot.

Discussion

It is clear from the combined results of skin temperature changes and heat output during cold water immersion that highland Quechua Indians were able to maintain warmer foot temperatures

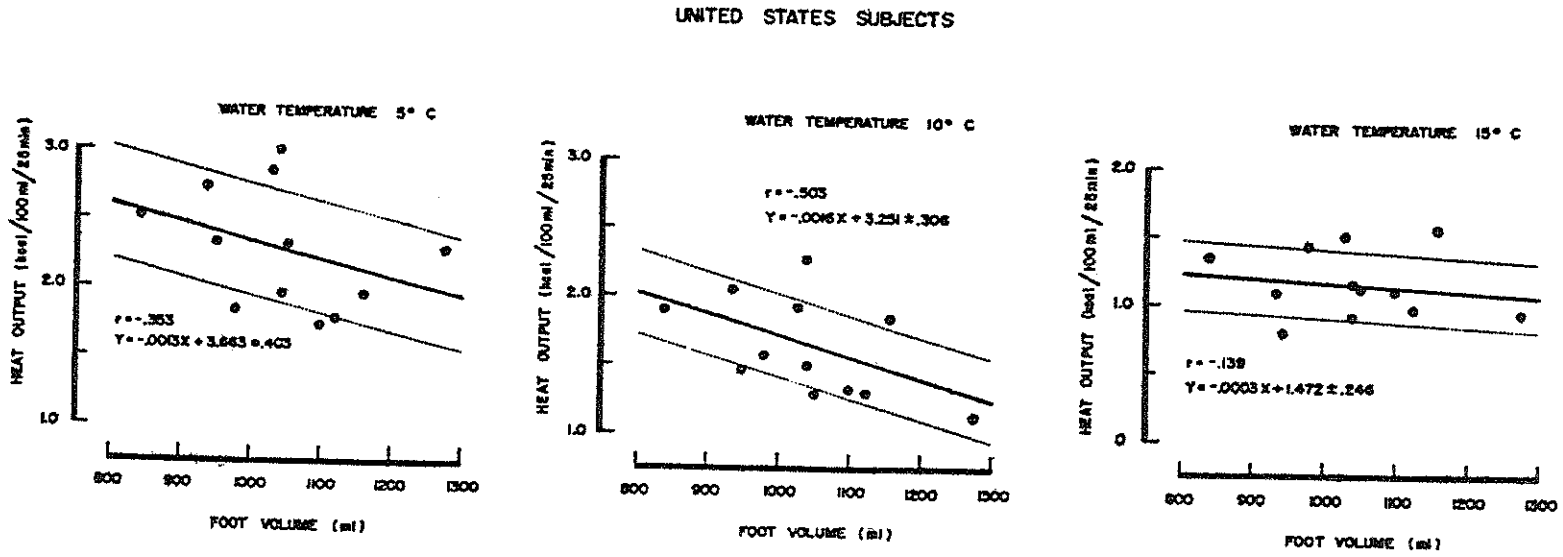

Figure VI-4: Relationship between heat output from the foot and foot volume during the last 25 minutes of a 30-minute cold exposure to water at initial temperatures of 5, 10, 15°C (U.S. White subjects).

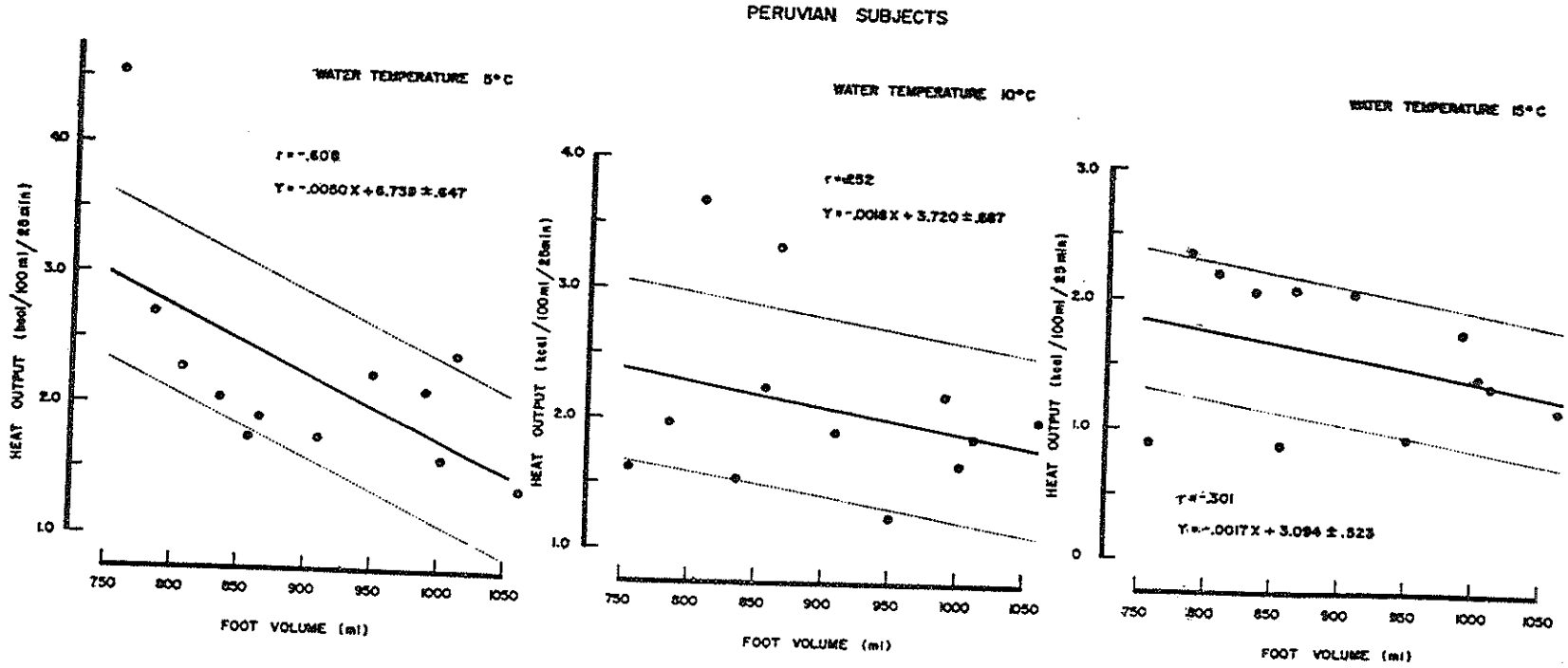

Figure VI-5: Relationship between heat output from the foot and foot volume during the last 25 minutes of a 30-minute cold exposure to water at initial temperatures of 5, 10, and 15°C (Peruvian Indian Subjects).

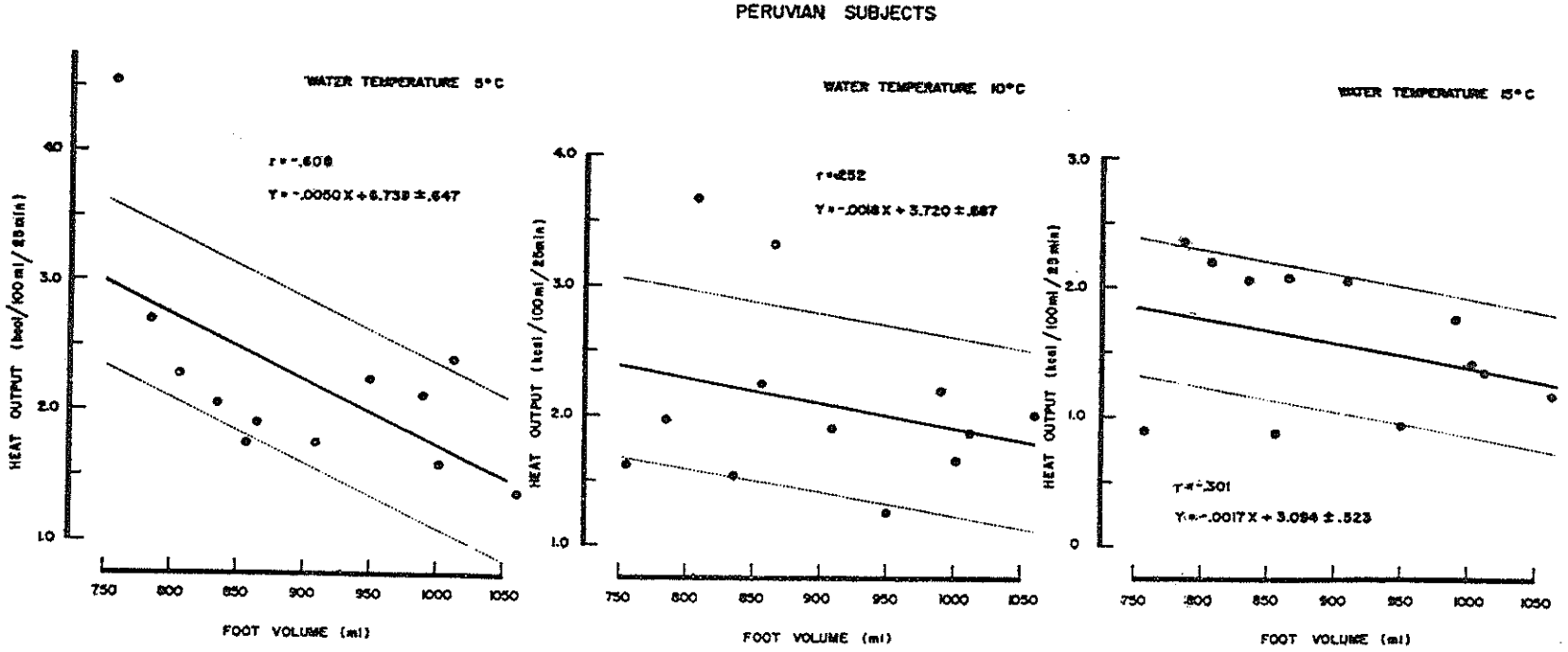

Figure VI-5: Relationship between heat output from the foot and foot volume during the last 25 minutes of a 30-minute cold exposure to water at initial temperatures of 5, 10, and 15°C (Peruvian Indian Subjects).

than Whites who were tested under comparable conditions. Differences between the two groups, however, were not uniform at each of the water bath temperatures. At the lowest bath temperature, Indian toe temperatures were slightly warmer and dorsum temperatures a great deal warmer than those of the Whites after correcting for differences in water temperature. This group difference did not appear in the heat output determinations, although it should be noted that skin temperature measurements at three sites may not give an accurate estimate of heat flow from the entire foot. At the intermediate and highest bath temperatures, heat output values were generally in agreement with skin temperatures, and both methods demonstrated that the differences between the two groups were of a greater magnitude during the first half of the exposure. These differences seem to be attributed, at least in part, to more active and frequent rewarming responses among the Indian subjects.

The poor relationships between foot volume and heat output/-unit volume of the foot diminish the likelihood that the disparity in mean foot volume between Indians and Whites is a major cause of group differences in heat output. There may, however, be a surface area relationship to heat output that is only partially expressed by foot volume. It follows that the surface area of the foot would be proportionately greater per unit volume in smaller feet, and thus the slightly higher ratio of surface area to volume might facilitate more abundant heat loss. Unfortunately the procedures required to determine the surface area of an irregular structure such as the foot are detailed and time consuming. Nevertheless, this deserves

consideration in any future studies.

A number of workers have investigated hand calorimetry with respect to problems of group differences in cold adaptation or acclimatization. The results of the present study of foot calorimetry at three bath temperatures are compared with the results of these other studies on the hand in Table VI-6. The purpose of this comparison is to examine relationships between the loss of heat from the foot and the hand, since prior studies of extremity blood flow and heat output have shown consistently higher values for the hand (Kunkel and Stead, 1938; Abramson et al., 1936b; Greenfield et al., 1951; Allwood and Burry, 1954). Two sets of values are given in Table VI-6. The first is total heat output which should express the combined loss due to stored heat and circulatory heat, and the second is an estimate of heat output due only to circulating blood. The three levels of heat output from the present study include results at temperatures of 5°, 10°, and 15°C.

The heat output from the foot at 5°C falls within the range of values for the hand at 0-5°C, whereas foot values at 10° and 15°C tend to be at the lower range or below those of the hand. At first inspection, these findings do not support the evidence cited above that the hand circulation is usually maintained at higher levels than the foot. However, the range of variation for the hand is large. Moreover, although all initial hand calorimeter temperatures were between 0° and 5°C, the final temperatures at the end of 30 minutes were often as high as 15°C. The pronounced increase in calorimeter water temperature in some of the studies was a

Table VI-6

A Comparison of the Results of Hand Calorimetry Studies with the Results of the Present Study. Subjects in All Studies Are Adult Males and All Values Are Expressed in Calories/100 ml. of hand or foot tissue/minute.

Investigation	Average Total Heat Output During 30 Minutes (cal/100 ml/min)	Average Circulatory Heat Output (cal/100 ml/min)	N
Elsner et al., 1960[1]			
Arctic Indians	128	67	9
White Controls	94	36	8
Hellström and Andersen, 1960[2]			
White Arctic Fishermen	112	52	8
White Controls	135	62	9
Hildes et al., 1961[3]			
Eskimos	138	97	9
White Controls	128	88	4
Krog et al., 1960[4]			
Lapps	---	142	11
N.Norwegian Fishermen	---	131	10
White Controls	---	135	7
LeBlanc et al., 1960[5]			
White Gaspé Fishermen	122	---	8
White Controls	96	---	8
Present Study[6]			
Quechua Indians	102	89	12
U. S. Whites	117	91	12
Present Study[7]			
Quechua Indians	98	84	12
U. S. Whites	88	65	12
Present Study[8]			
Quechua Indians	78	64	12
U. S. Whites	63	46	12

consequence of using small volumes of cold water (ca. 1,350 ml.) for the test. Since maximal blood flow in the cold takes place at water bath temperatures below 10° or 15°C (Lewis, 1930; Abramson et al., 1941a), it is unlikely that the calorimetric data for the hand in Table VI-6 is comparable. Carlson and Hsieh (1965), in a recent review of cold investigations, refer to this as an especially critical problem in evaluating the results of hand calorimetry studies.

The three studies in which final calorimeter temperatures were high indlude Elsner et al. (1960), Hellström and Andersen (1960), and LeBlanc et al. (1960). Of the two remaining studies,

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Footnotes to Table VI-6

[1,3]Hand tested in calorimeter at 4-5°C for 30 min. after 30 min. in water at 28-30°C. Circulatory heat loss was determined by vascular occlusion.

[2]Hand tested in calorimeter at 4°C for 30 min. after 30 min. in water at 30°C. Circulatory heat loss is estimated by the value for the final 20 min. of exposure.

[4]Hand tested in calorimeter at 0-1.0°C for 30 min. after 30 min. in ice water. Circulatory heat loss is estimated by the value for the final 20 min. of exposure.

[5]Hand tested in calorimeter at 5°C for 30 min. after 20 min. in water at 33°C. The values were estimated from a graph illustrating the relationship between total heat flow and hand volume.

[6]Foot tested in calorimeter at 5°C for 30 min. after at least 15 min. warming of the foot by an electric heater. The circulatory heat loss is estimated by the value for the final 25 min. of exposure.

[7]Foot tested at 10°C.

[8]Foot tested at 15°C.

one (Hildes et al., 1961) employed a calorimeter with a water volume of 3,500 ml., and the other (Krog, et al., 1960), although the water volume was not given, did begin the hand tests at lower initial water temperatures (0 - 1.0°C). Therefore, the two investigations in which average 30-minute calorimeter bath temperatures are most comparable to the present study at 5°C are those of Hildes and Krog. When all values for the hand are compared, these two studies show the highest values for heat output. When these same values for the hand are compared with those for the foot, heat output from the foot is markedly lower.

CHAPTER VII

GENERAL DISCUSSION

Extremity Temperatures at Altitude

Some problems of interpretation arise when comparisons are made of two groups who have lived under different cultural and environmental conditions from birth. In the present study, control of an additional parameter was lost by testing one group at sea level and the other at high altitude. The need for such a design rested upon the unavailability of European-derived subjects in the Peruvian highlands. Therefore, a question that may have some bearing on the results is whether or not the higher foot temperatures of Quechua Indians can be attributed to the decreased oxygen tension at altitude. A discussion of this question follows.

In an early study of hand calorimetry (Schneider and Sisco, 1914), a substantial increase in blood flow was found when six men were tested on Pike's Peak (ca. 4,000 m). The tests were carried out after only a few days' residence there. Barcroft and others (1923) studied hand blood flow at a room temperature of 14°C in a series of determinations on one U. S. subject while he was a resident at Cerro de Pasco (ca. 4,300 m), and upon his return to sea level. No differences were observed between the sea level and altitude values. Laboratory tests on man and other animals where low-oxygen mixtures were used have shown conflicting results as well. Kottke

and his colleagues (1944) and Frank and Werzler (1948) found an increase in skin temperatures during anoxia and exposure to cold. Others (Abramson et al., 1941b, 1943; Freeman et al., 1936; Gellhorn and Steck, 1938) were unable to show consistent skin temperature increases and found decreases as well. Still others (Lim and Lulf, 1960, 1963; Jouck, 1944) have failed to observe any skin temperature increases under anoxic conditions. Verzar (1951) and Abramson (1967:362) suggest that if anoxia does increase skin temperatures by relaxing vasoconstrictor tone of the peripheral vessels, then acclimatization may markedly reduce the response to values close to normal.

Other sources of evidence tend to support the assumption that the Indian-White differences observed in the present study are not -produced by altitude effects. Gupta (1964), in a total body cooling study of East Indian Jat subjects at 4,000 m. and at sea level, found very little difference between skin temperatures at these two elevations. When both Quechua Indians and Whites were tested at high altitudes during total body cooling (Baker, 1966b; Baker et al., 1967) and during hand cooling (Thomas, 1967), the same elevated extremity temperatures were observed for the native groups as were observed in the present study. Moreover, the pattern of extremity temperature differences observed during nighttime total body cooling of Quechua Indians at altitude and Whites at sea level (Elsner and Bolstad, 1963) was quite similar to that where both groups were tested at altitude (Baker, 1966b; Baker et al., 1967).

Although much of the evidence is indirect, it may be safe to conclude that under conditions of immediate hypoxia (laboratory tests of breathing oxygen-poor mixtures) and in the unacclimatized individual (only a few days at altitude), there may be a release of vascular tone to produce slight increases in extremity blood flow. Yet in the altitude-acclimatized individual there are no grounds at present to indicate that this response persists. It may then be safe to assume that the Indian-White differences observed in the present study are not the result of altitude differences.

Local Cold Exposure of the Foot

The results of cold exposures to air and water revealed an interesting pattern of differences in thermal responses between Quechua Indians and U. S. Whites. During acute cold exposure to water at 5°C, average foot temperatures of Indians were slightly higher than those of Whites. The difference was not apparent when heat loss from the whole foot was determined. At warmer water temperatures (10 and 15°C), however, Indian skin temperatures were substantially warmer than White skin temperatures, although the differences were more pronounced during the first half of the 30-minute exposure. Values for heat loss tended to substantiate the skin temperature findings.

When larger samples were compared during 60-minute tests in air at 0°C, Indians were able to maintain skin temperatures at even higher levels above the White subjects. Spontaneous rewarming

responses were not wholly responsible for the higher Indian skin temperatures in air, since Whites rewarmed more often and with more active responses than Indians. Furthermore, it was found that Indians who never rewarmed during either test in air were still able to maintain higher average skin temperatures than Whites who actively rewarmed. Rewarming responses may have contributed somewhat to the higher Indian skin temperatures during the tests in water at 5 and 10°C, but only about half of all subjects rewarmed and cycle amplitudes were weak.

It should be noted here that the spontaneous rewarming responses or cold-induced vasodilations observed during the tests in air occurred at much higher skin temperatures than have previously been reported in the literature (Lewis, 1930; Grant and Bland, 1931; Clark et al., 1957; Fox and Wyatt, 1962; Greenfield, 1963; Greenfield et al., 1951). Most of the prior tests to elicit these responses, however, were carried out under conditions where immediate peripheral vasoconstriction was induced by ice or cold water. It might be hypothesized, then, than when an extremity is cooled slowly, the local response may be triggered at a higher skin temperature. This could result from a lack of trauma to the peripheral vessels and nerves. K. Lewis-Anderson (1963) suggested that local tests in cold water baths may not be an ideal procedure and could conceal group differences in local acclimatization by overloading the thermal regulatory system. In two other studies of hand exposure to air (Hellström, 1965; Thomas, 1967), spontaneous rewarming responses were observed at skin temperatures

above 15°C, although in the first study they were dismissed as not being bona fide responses. From the results of the present study, it is difficult not to attribute the observed rewarming cycles to cold-induced vasodilation, since amplitudes of up to 10°C were recorded at skin temperatures above 15°C and the rewarming was usually rapid.

When the combined results of foot exposure to water and foot exposure to air are inspected, it appears that the temperature differences between Indians and Whites were raised to the greatest magnitude under conditions of moderate rather than acute local cold exposure. This can be illustrated by comparing temperature values for the large toe during the local cold tests in air and in water (Table VII-1). Additional values are included from a study of general body cooling (Baker et al., 1966) carried out on Quechua Indians from the same area. Basically, Indians had a considerable advantage over Whites by maintaining decidedly warmer skin temperatures during the local air exposure and while the body was in a state of thermal comfort. At successively more acute local exposures (15 and 10°C water baths), however, the Indian's advantage decreased until at the most acute exposure (5°C water bath) it essentially disappeared. Other studies of hand and foot cooling in cold water for Quechua Indians (Hanna, 1965), Alakaluf Indians (Hammel, 1960), and Norwegian Lapps (Krog et al., 1960) have shown only slight or no differences between native groups and controls with respect to parameters measured. This lack of difference may be attributable to a local cold exposure that is too severe.

Table VII-1

Toe (Hallux) Temperatures (in °C) of Quechua Indians and Whites Under Various Conditions of Experimental Cold Exposure (All Adult Males)

Exposure Conditions	Indians	N	Whites	N	Temperature Difference
Local - Air at 0°C[1]					
Morning exposure	21.2	30	10.2	26	11.0***
Afternoon exposure	23.6	30	13.5	26	10.1***
Local - Water at 5°C[2]					
After 10 minutes	1.08	12	0.37	12	0.71*
After 30 minutes	0.63	12	0.34	12	0.29 N.S.
Local - Water at 10°C[2]					
After 10 minutes	1.81	12	0.24	12	1.57***
After 30 minutes	0.33	12	0.17	12	0.16 N.S.
Local - Water at 15°C[2]					
After 10 minutes	1.49	12	0.19	12	1.30***
After 30 minutes	0.51	12	0.08	12	0.43*
TBC - Air at 10°C[3]					
After 60 minutes	15.2	28	12.0	12	3.2 ***
After 120 minutes	13.1	28	10.9	12	2.2 **
TBC - Air at 15.5°C[3]					
After 60 minutes	21.0	28	17.1	4	3.9 **
After 120 minutes	18.1	28	15.9	4	2.2 *

$P < .05 = *$, $P < .01 = **$, $P < .001 = ***$

[1] At the end of a 60-minute local exposure of the foot to air.

[2] After 10 minutes and at the end of a 30-minute local exposure of the foot to water. Temperature values express the height of the toe temperature above that of the water to correct for slight differences in water temperatures.

[3] Baker et al., 1966b. After 60 minutes and at the end of a 120-minute total body cooling exposure (TBC) to air.

Under conditions of total body exposure where both local and general cooling took place, the Indian-White toe temperature differences were intermediate between the values for acute and moderate local cooling. Thus, even when the Quechua Indian is in a chilled state, he still is able to maintain peripheral skin temperatures at levels above the White. General cooling is discussed in greater detail in the following section.

Extremity Temperatures During Total Body Exposures to Cold

One of the most consistent patterns of difference during total body cooling between native subjects who are naturally cold-exposed and European or American White subjects is the higher extremity temperatures maintained by the native groups. The only exceptions, among the native groups that have been tested, are Australian Aborigines and Kalahari Bushmen, both desert dwellers who live under hot dry condtions during the day and cold conditions at night. Table VII-2 lists some of the studies performed on native groups by comparing their thermal and metabolic responses with White control subjects. Among each of the naturally cold-exposed native groups (excluding desert dwellers), metabolic rates and rectal temperatures varied with respect to White controls, while extremity skin temperatures were always higher for the native groups. This pattern is not uniform for all skin temperatures, since trunk skin temperatures of natives often equalled or dropped below values for Whites (Baker, et al., 1967; Elsner

Table VII-2

Comparisons of Thermal and Metabolic Responses of Native Groups and White Controls During Total Body Exposures to Moderate Cold.

Investigation	Native Group	Metabolic Rate	Rectal Temp.	Finger or Hand Temp.	Toe or Foot Temp.	[1]Duration of Test
Baker, 1966	Quechua Indians	N.T.	=	+	+	2 hrs.
Baker et al., 1967	Quechua Indians	+,=	+	+	+	2 hrs.
Elsner and Bolstad, 1963	Quechua Indians	=	-	+	+	8 hrs.
Hammel, 1960	Alakaluf Indians	+	=	N.T.	+	8 hrs.
Irving et al., 1960; Nelms, 1960, Elsner et al., 1960	Arctic Indians	=	-	+	+	7 hrs.
Adams and Covino, 1958	Eskimos	+	+	+	+	2 hrs.
Hart et al., 1962	Eskimos	+	-	+	+	8 hrs.
Lange Andersen et al., 1960; Nelms, 1960	Lapps	-	-	N.T.	+	8 hrs.
Hammel et al., 1962	Kalahari Bushmen	-	-	N.T.	=	8 hrs.
Ward et al., 1960	Kalahari Bushmen	+	=	-	-	8 hrs.
Hammel et al., 1959	Australian Aborigines	-	-	-	-	8 hrs.

N.T. Not tested or given.
= Native group equal to control group.
+ Native group greater than control group.
- Native group less than control group.

[1]During 2-hour tests, subjects were exposed nude at 10 to 17° C. During 7- and 8-hour tests, subjects were resting or sleeping with light blanket at 0 to 8° C.

1963; Elsner and Bolstad, 1963; Lange Andersen, 1963; Hammel, 1960; 1964; Nelms, 1960). The implication is that the temperature of extremities, and hence peripheral limb circulation, of most cold-accustomed natives is maintained at moderately high levels even when the body is in a state where heat loss may be exceeding heat production, -or at least where the two are in a precarious state of balance. It has been argued by some investigators (Rennie et al., 1962; Milan et al., 1963; Adams and Covino, 1958; Brown et al., 1954) that the elevated extremity temperatures of Eskimos might be produced by their high resting metabolic rates. But again this would not explain the high hand and foot temperatures of other native groups who are known not to have high metabolic rates. Carlson (1954; Carlson et al., 1953) has presented an interesting hypothesis that in the acclimatized individual there is a readjustment in peripheral circulation where extremities are kept warmer while the trunk surface temperatures decline slightly to better insulate the "core." This problem of circulatory distribution certainly deserves further study.

Sources of Adaptation to Local Cold Stress

From field observations of Quechua Indians, it appears that extremity chilling is experienced to a greater degree than general body chilling. The use of heavy wool clothing that covers the trunk and proximal parts of the limbs should protect most of the body against moderated cold during the day (Siple, 1949), and it was documented that little cold stress is experienced at night (Baker,

1966a). Some general chilling may occur during the early morning and early evening hours. Cold stress to the exposed parts of the body such as the hands, face, and feet can occur any time during the waking hours. The level of stress is seldom severe enough to cause frostbite (Calrson and Thursh, 1960), but temperatures are sufficiently low at any time of the year to produce mild trenchfoot or chilblain (Norman et al., 1960; Spealman, 1949). To the present author's knowledge, however, these conditions have never been observed among highland Quechua Indians. The most severe injury related to cold and wind chill is a slight chapping of the cheek pads of the face, and this is a condition that is most common in children.

It is clear from the present study and from other studies of Quechua Indian temperature responses that the highland native enjoys some measure of protection against local cold stress. The highland native suffers less discomfort, is able to maintain more limb mobility, and in all likelihood, is in less danger of cold injury to the lower extremity because of his elevated foot temperatures. It is still not certain, however, whether this thermal advantage is due to racial factors and natural selection or to the effects of a lifetime of cold exposure. There may be elements of both modes of adaptation in the responses of The Quechua Indian. For example the children who were tested in the present study responded with temperatures that were intermediate between those of the adult Indians and White subjects. This suggests a developmental factor in that their responses were apparently improving

with continued exposure. Yet the responses of the young Indian group were not consistently lower than the adult Indians, and furthermore, the correlations of skin temperatures with age were of a low order of magnitude. Sampling of younger natives might be a more productive design in order to shed more light on this problem in the future.

With regard to genetic adaptation, on theoretical and experimental grounds it seems likely, but there is still insufficient evidence to support the hypothesis that hereditary factors in the population are responsible for the elevated extremity temperatures. An hypothesis that may be untestable, but nevertheless theoretically valid (Baker, 1960; Prosser, 1964; Dobzhansky, 1968), is that the range of adaptability of extremity temperatures of the Andean Indian is set at higher levels than the non-cold-adapted individual, and yet the full expression of this thermal adaptation is dependent upon environmental conditions such as an extended period of cold exposure. Carefully controlled and time consuming investigations will be required to test this hypothesis.

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APPENDIX A

List of Abbreviations of Physical Characteristics

Stat . . . . . Stature (cm)

Wt . . . . . Weight (kg)

SA . . . . . Surface Area (m^2)

% Fat . . . . . Percent Fat

LBM . . . . . Lean Body Mass (kg)

SSF . . . . . Sum of 8 Skinfolds (mm)

Ft L . . . . . Foot Length (cm)

Ft B . . . . . Foot Breadth (cm)

Ft I . . . . . Foot Index (Breadth/Length x 100)

Met D . . . . . Metatarsal Depth (cm)

Heel B . . . . . Heel Breadth (cm)

Toe L . . . . . Hallux Length (cm)

Toe B . . . . . Hallux Breadth (cm)

Toe I . . . . . Hallux Index (Breadth/Length x 100)

Ft Vol . . . . . Foot Volume (ml)

APPENDIX B

Means and Standard Deviations of 10-Minute, 30-Minute, and 60-Minute Averages of Quechua Indian and U. S. White Skin Temperatures During a 60-Minute Foot Exposure to Air at 0°C.

MEANS AND STANDARD DEVIATIONS OF $\bar{X}$ TEMPERATURE (°C) VALUES:
FOOT COOLING IN AIR FOR INDIANS--RUN 1

	0		1st 10		2nd 10		3rd 10		4th 10		5th 10		6th 10	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Run 1, Toe 1														
Young	31.7	2.16	26.6	3.92	24.3	6.18	21.7	7.18	19.8	7.56	18.3	7.18	17.1	6.82
Adult	31.7	2.02	27.4	3.80	26.5	5.66	24.9	6.45	23.7	7.12	22.6	7.84	21.5	8.32
Combined	31.7	2.07	27.0	3.85	25.4	5.98	23.3	6.96	21.8	7.52	20.4	7.77	19.4	7.87
Run 1, Toe 5														
Young	33.2	1.95	27.6	3.75	24.9	6.16	22.3	7.07	20.1	7.58	18.2	7.09	16.6	6.59
Adult	32.9	2.08	28.0	4.00	26.7	5.59	24.6	6.54	22.9	7.56	21.7	8.28	20.8	8.72
Combined	33.1	2.01	27.8	3.85	25.8	5.90	23.4	6.84	21.5	7.64	19.9	7.85	18.7	7.97
Run 1, Dorsum														
Young	33.1	1.66	28.4	2.72	26.9	3.58	25.5	4.39	24.1	5.04	22.6	5.31	21.2	5.29
Adult	32.6	1.43	29.3	1.83	28.4	2.22	27.4	2.34	26.6	2.83	25.8	3.35	24.9	3.85
Combined	32.8	1.56	28.9	2.33	27.7	3.04	26.5	3.61	25.4	4.22	24.2	4.66	23.1	4.96

MEANS AND STANDARD DEVIATIONS OF $\bar{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR INDIANS--RUN-1 (cont.)

	Recovery		1st 30		2nd 30		60 min.	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Run 1, Toe 1								
Young	19.7	5.78	24.2	5.67	18.4	7.01	21.3	6.13
Adult	23.8	7.72	26.3	5.21	22.6	7.68	24.4	6.25
Combined	21.8	7.09	25.2	5.50	20.6	7.59	22.9	6.34
Run 1, Toe 5								
Young	19.4	5.80	24.9	5.51	18.3	6.97	21.6	6.00
Adult	23.3	7.93	26.4	5.24	21.8	8.13	24.1	6.54
Combined	21.4	7.19	25.7	5.38	20.1	7.73	22.9	6.36
Run 1, Dorsum								
Young	23.8	4.34	26.9	3.52	22.6	5.18	24.8	4.29
Adult	27.3	4.23	28.4	2.07	25.8	3.29	27.1	2.57
Combined	25.6	4.61	27.7	2.94	24.2	4.57	25.9	3.69

MEANS AND STANDARD DEVIATIONS OF $\bar{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR INDIANS--RUN-2

	0		1st 10		2nd 10		3rd 10		4th 10		5th 10		6th 10	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Run 2, Toe 1														
Young	32.9	1.42	29.0	3.13	28.3	4.89	26.6	6.24	25.1	7.26	23.8	7.89	22.6	8.29
Adult	32.4	2.53	28.8	3.74	28.4	5.04	27.7	5.96	26.4	6.86	25.4	7.39	24.2	8.01
Combined	32.7	2.06	28.9	3.42	28.4	4.93	27.1	6.08	25.8	7.03	24.6	7.62	23.4	8.12
Run 2, Toe 5														
Young	34.1	1.30	20.8	2.38	30.2	4.31	28.9	5.48	27.9	6.16	26.4	6.64	24.6	7.13
Adult	33.8	2.14	30.0	3.19	29.4	4.72	28.6	5.84	27.1	6.73	26.1	7.43	24.8	8.05
Combined	33.9	1.77	30.4	2.83	29.8	4.50	28.7	5.62	27.5	6.41	26.2	7.00	24.7	7.54
Run 2, Dorsum														
Young	34.1	0.63	29.9	1.33	29.2	1.66	28.2	2.14	27.4	3.53	26.5	4.03	25.4	4.25
Adult	33.5	2.14	30.1	2.21	29.4	2.38	29.1	3.06	28.3	3.39	27.7	3.86	26.9	4.16
Combined	33.8	1.26	30.0	1.81	29.3	2.26	28.7	2.97	27.9	3.47	27.1	3.96	26.2	4.24

MEANS AND STANDARD DEVIATIONS OF $\bar{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR INDIANS—RUN-2 (cont.)

	Recovery		1st 30		2nd 30		60 min.	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Run 2, Toe 1								
Young	24.5	7.21	27.9	4.69	23.[illegible]	7.74	25.9	6.12
Adult	26.0	7.36	28.3	4.7[illegible]	25.3	7.51	26.8	5.96
Combined	25.3	7.26	28.1	4.70	24.[illegible]	7.52	25.3	6.01
Run 2, Toe 5								
Young	26.3	6.71	29.9	3.99	26.3	6.49	28.1	5.14
Adult	26.4	7.41	29.3	4.51	26.0	7.33	27.7	5.81
Combined	26.3	7.01	29.7	4.24	21.6	6.87	27.9	5.45
Run 2, Dorsum								
Young	28.3	4.18	29.1	1.83	26.4	3.91	27.8	2.79
Adult	29.1	4.09	29.6	2.63	27.7	3.78	28.6	3.15
Combined	28.7	4.12	29.3	2.26	27.1	3.86	28.2	2.98

MEANS AND STANDARD DEVIATIONS OF $\overline{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR U.S. WHITES—RUN-1

	0		1st 10		2nd 10		3rd 10		4th 10		5th 10		6th 10	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Run 1, Toe 1														
Young	31.6	2,78	19.9	4.04	14.8	5.48	12.0	4.66	10.6	4.72	9.9	4.14	9.3	4.24
Adult	32.2	1.76	21.3	4.03	15.9	6.03	12.0	5.00	11.1	4.68	10.8	4.64	10.5	5.39
Combined	31.9	2.35	20.6	4.07	15.3	5.73	12.1	4.78	10.8	4.67	10.3	4.37	9.8	4.82
Run 1, Toe 5														
Young	32.6	2.21	20.2	4.57	15.1	6.05	13.2	5.66	11.4	5.32	9.8	4.53	8.6	4.07
Adult	33.3	1.64	21.1	4.77	16.2	6.26	13.2	5.09	12.9	5.49	12.4	5.56	10.6	4.06
Combined	32.9	1.97	20.6	4.65	15.6	6.12	13.2	5.34	12.2	5.41	11.1	5.18	9.6	4.14
Run 1, Dorcum														
Young	32.6	2.31	26.2	2.09	23.2	2.33	20.7	2.52	18.9	2.58	17.4	2.52	16.2	2.63
Adult	32.8	1.47	26.6	2.10	23.7	2.57	21.4	2.56	19.9	2.59	18.5	2.43	17.4	2.43
Combined	32.7	1.93	26.3	2.08	23.4	2.44	21.1	2.54	19.3	2.61	17.9	2.52	16.8	2.59

MEANS AND STANDARD DEVIATIONS OF $\overline{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR U.S. WHITES--RUN-1 (cont.)

	Recovery		1st 30		2nd 30		60 min.	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Run 1, Toe 1								
Young	17.3	5.48	15.[illegible]	4.44	9.9	4.01	12.7	3.[illegible]6
Adult	16.3	5.04	16.[illegible]	4.79	10.8	4.44	13.6	4.22
Combined	16.9	5.24	15.[illegible]	4.59	10.3	4.21	13.2	4.03
Run 1, Toe 5								
Young	15.2	4.07	16.1	5.02	9.9	2.77	13.0	4.58
Adult	16.8	3.07	16.8	4.93	12.0	4.60	14.4	4.35
Combined	16.0	3.67	16.4	4.94	10.9	4.[illegible]1	13.7	4.4[illegible]
Run 1, Dorsum								
Young	20.1	2.76	23.3	2.26	17.5	2.5[illegible]	[illegible]0.4	2.33
Adult	21.0	2.03	23.9	2.38	18.6	[illegible].3[illegible]	21.2	[illegible].29
Combined	20.6	2.46	23.6	2.32	64.4	[illegible].49	[illegible]0.[illegible]	2.[illegible]1

MEANS AND STANDARD DEVIATIONS OF $\overline{X}$ TEMPERATURE (°C.) VALUES
FOOT COOLING IN AIR FOR U.S. WHITES--RUN-2

	0		1st 10		2nd 10		3rd 10		4th 10		5th 10		6th 10	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Run 2, Toe 1														
Young	33.1	1.82	24.3	5.07	21.5	7.37	18.4	7.41	16.9	7.73	16.4	8.04	15.3	8.19
Adult	33.7	1.56	25.4	4.05	21.3	6.66	17.2	6.9	14.3	5.52	14.4	6.57	13.8	7.16
Combined	33.4	1.71	24.8	4.61	21.4	6.97	17.8	7.17	15.9	6.77	15.4	7.36	14.6	7.68
Run 2, Toe 5														
Young	34.1	1.47	24.7	5.17	21.5	7.55	18.4	7.37	16.3	8.11	14.7	8.07	14.4	7.57
Adult	34.6	1.22	25.5	5.11	21.0	7.73	18.6	7.73	16.1	7.55	16.8	8.00	16.1	7.36
Combined	34.3	1.36	25.1	5.11	21.3	7.57	18.5	7.57	17.2	7.82	15.7	8.03	15.2	7.44
Run 2, Dorcum														
Young	34.2	0.86	28.2	1.41	26.4	2.27	24.7	2.72	23.0	3.21	21.5	3.49	20.2	3.84
Adult	34.0	0.98	28.1	1.36	25.8	2.04	23.9	2.48	22.4	2.74	21.0	3.36	19.8	3.61
Combined	34.1	0.92	28.2	1.37	26.2	2.16	24.2	2.61	22.7	2.98	21.3	3.41	20.1	3.70

MEANS AND STANDARD DEVIATIONS OF $\bar{X}$ TEMPERATURE (°C.) VALUES:
FOOT COOLING IN AIR FOR U.S. WHITES--RUN-2 (cont.)

	Recovery		1st 30		2nd 30		60 min.	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Run 2, Toe 1								
Young	21.4	7.43	21.4	6.46	16.2	7.67	18.8	6.74
Adult	19.4	6.73	21.3	5.68	14.3	5.64	17.8	4.89
Combined	20.4	7.11	21.3	6.04	15.3	6.77	18.3	5.88
Run 2, Toe 5								
Young	20.6	6.88	21.6	6.39	15.1	7.72	18.3	6.81
Adult	20.7	6.82	21.7	6.39	17.0	7.07	19.3	6.19
Combined	20.7	6.78	21.6	6.33	16.0	7.40	18.8	6.46
Run 2, Dorsum								
Young	23.9	4.33	26.4	2.06	21.6	3.45	24.0	2.66
Adult	23.4	3.79	25.9	1.92	21.1	3.17	23.6	2.40
Combined	23.7	4.05	26.2	1.99	21.3	3.29	23.8	2.53

APPENDIX C

Correlation Coefficients Expressing Relationships Between 30-Minute and 60-Minute Average Skin Temperatures of the Foot of Quechua Indians and U.S. Whites.

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Young Indian Subjects (N = 29): Run 1

	Toe 1			Toe 5			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	-.10	-.13	-.12	.12	.10	.11	.05	.09	.08
Stature	-.11	-.10	-.11	.13	.13	.13	.12	.18	.16
Weight	-.08	-.06	-.07	.15	.17	.16	.09	.14	.13
Surface Area	-.10	-.08	-.09	.14	.15	.15	.11	.16	.15
Sum of Skinfolds	.15	.24	.20	.16	.19	.19	.29	.34	.32
Foot Length	-.15	-.14	-.15	.09	.09	.09	.10	.14	.13
Foot Breadth	-.03	-.04	-.04	.15	.14	.15	.13	.18	.16
Foot Index	.21	.18	.20	.19	.15	.17	.13	.19	.17
Metatarsal Depth	-.02	-.02	-.02	.15	.17	.17	.16	.21	.20
Heel Breadth	.03	.05	.04	.22	.25	.24	.20	.29	.26
Hallux Length	-.25	-.21	-.23	.12	.12	.12	.16	.17	.17
Hallux Breadth	.02	-.01	.00	.20	.28	.25	.07	.15	.12
Hallux Index	.36	.28	.33	.06	.16	.12	-.18	-.07	-.12
Foot Volume	-.04	-.04	-.04	.18	.17	.18	.11	.17	.15

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Young Indian Subjects (N = 29): Run 2

	Toe 1			Toe 2			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	.05	-.03	.00	.26	.18	.21	.41*	.36	.39*
Stature	.08	-.01	.03	.27	.21	.24	.50**	.47**	.50**
Weight	.06	.01	.03	.19	.17	.18	.45*	.42*	.45*
Surface Area	.06	.00	.02	.22	.18	.20	.48**	.45*	.47**
Sum of Skinfolds	.23	.14	.18	.06	.07	.07	.02	.18	.13
Foot Length	.09	.00	.03	.27	.18	.22	.55**	.51**	.54**
Foot Breadth	.10	.02	.05	.28	.22	.24	.43*	.38*	.41*
Foot Index	.03	.04	.03	.13	.15	.15	-.07	-.15	-.13
Metatarsal Depth	.12	.07	.09	.28	.25	.27	.38*	.39*	.40*
Heel Breadth	.18	.11	.13	.23	.21	.22	.44*	.46*	.47**
Hallux Length	.01	-.04	-.02	.27	.21	.24	.48**	.46*	.48**
Hallux Breadth	.17	.11	.13	.21	.23	.23	.45*	.48**	.48**
Hallux Index	.21	.21	.21	-.13	-.01	-.05	-.14	-.08	-.10
Foot Volume	.14	.08	.11	.30	.27	.29	.49**	.47*	.49**

P<.05 = *, P<.01 = **

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Young White Subjects (N = 28): Run 1

	Toe 1			Toe 2			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	-.11	-.19	-.16	.00	-.11	-.05	-.19	-.19	-.19
Stature	-.11	-.25	-.19	-.03	-.19	-.11	-.12	-.16	-.14
Weight	.12	.05	.09	.27	.17	.23	.06	.09	.08
Surface Area	.03	-.07	-.02	.16	.03	.10	-.01	-.01	-.01
Sum of Skinfolds	.41*	.61**	.55**	.53**	.70**	.64**	.38*	.55**	.49**
Foot Length	-.16	-.23	-.21	-.05	-.15	-.10	-.13	-.17	-.16
Foot Breadth	-.05	-.14	-.10	.14	-.01	.08	-.08	-.06	-.07
Foot Index	.26	.20	.25	.42*	.30	.38*	.13	.27	.21
Metatarsal Depth	.18	.18	.20	.29	.19	.25	.15	.16	.16
Heel Breadth	.14	.10	.13	.30	.25	.29	.05	.03	.04
Hallux Length	-.15	-.21	-.19	-.01	-.10	-.05	-.17	-.18	-.18
Hallux Breadth	-.01	-.19	-.10	.09	-.09	.01	-.08	-.11	-.10
Foot Volume	.01	-.10	-.05	.13	.02	.08	-.02	-.04	-.03

P<.05 = *, P<.01 = **

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Young White Subjects (N = 28): Run 2

	Toe 1			Toe 5			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	-.17	-.25	-.23	-.07	-.13	-.11	-.30	-.22	-.26
Stature	-.15	-.24	-.21	-.04	-.09	-.07	-.22	-.17	-.20
Weight	-.23	-.23	-.21	-.06	-.14	-.11	-.30	-.22	-.26
Surface Area	-.21	-.24	-.24	-.06	-.12	-.10	-.28	-.21	-.24
Sum of Skinfolds	-.27	-.12	-.20	-.08	-.22	-.16	-.20	-.19	-.20
Foot Lenght	-.22	-.30	-.27	-.12	-.15	-.14	-.23	-.21	-.22
Foot Breadth	-.22	-.29	-.27	-.13	-.16	-.16	-.25	-.20	-.23
Foot Index	-.01	.04	.02	-.04	-.02	-.03	-.04	.03	.00
Metatarsal Depth	-.28	-.3-	-.30	-.13	-.25	-.20	-.30	-.29	-.30
Heel Breadth	-.09	-.04	-.07	.07	.05	.06	-.20	-.07	-.12
Hallux Length	-.24	-.29	-.28	-.14	-.16	-.16	-.23	-.20	-.22
Hallux Breadth	-.16	-.23	-.21	-.04	-.10	-.08	-.27	-.18	-.22
Hallux Index	.22	.22	.23	.21	.18	.20	.05	.14	.11
Foot Volume	-.19	-.26	-.24	-.06	-.14	-.11	-.19	-.17	-.18

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Adult Indian Subjects (N = 30): Run 1

	Toe 1			Toe 5			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	.02	-.11	-.06	-.05	-.14	-.11	.18	.07	.12
Stature	-.03	-.09	-.07	-.14	-.13	-.14	.16	.13	.14
Weight	.17	.21	.20	.13	.12	.13	.36*	.39*	.39*
Surface Area	.11	.11	.11	.03	.04	.04	.31	.32	.33
Percent F +	-.03	.09	.04	-.06	-.08	-.07	-.25	-.05	.13
Lean Body Mass	.17	.20	.20	.13	.13	.13	.38*	.39*	.40*
Sum of Skinfolds	-.03	.12	.06	-.01	-.03	-.02	-.20	.01	-.07
Foot Length	-.17	-.22	-.21	-.23	-.22	-.23	.13	.04	.08
Foot Breadth	-.09	-.19	-.15	-.18	-.17	-.18	.17	.08	.12
Foot index	.06	.00	.03	.03	.02	.02	.05	.05	.05
Metatarsal Depth	.10	.26	.20	.16	.24	.21	.22	.35	.31
Heel Breadth	.06	.05	.06	.02	.04	.03	.41*	.28	.34
Hallux Lenght	.00	.01	.01	-.04	-.10	-.08	.34	.17	.24
Hallux Breadth	.14	.08	.11	.10	.02	.06	.24	.21	.23
Hallux Index	.08	.04	.06	.08	.10	.09	-.19	-.03	.09
Foot Volume	-.01	.03	.02	-.20	-.14	-.16	.22	.24	.24

P<.05 = *

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Adult Indian Subjects (N = 30): Run 2

	Toe 1			Toe 5			Dorsum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	.02	.02	.02	-.21	-.08	-.13	-.06	.00	-.02
Stature	.02	.06	.04	-.18	-.11	-.14	.08	.11	.10
Weight	.21	.23	.23	-.06	.03	-.01	.12	.16	.14
Surface Area	.16	.19	.18	-.11	-.02	-.06	.12	.16	.14
Percent Fat	.15	.09	.11	.19	.10	.14	.05	.04	.04
Lean Body Mass	.20	.23	.22	-.08	.02	-.02	.12	.16	.14
Sum of Skinfolds	.09	-.01	.03	.13	.04	.07	-.03	-.03	-.03
Foot Length	-.40*	.30	-.35	-.45*	-.37*	-.40	-.23	.28	-.27
Foot Breadth	-.17	.00	-.07	-.37*	-.14	-.23	-.09	.01	-.03
Foot Index	.16	.24	.22	.00	.17	.11	.09	.23	.18
Metatarsal Depth	.01	-.02	-.01	.08	.06	.07	-.06	-.07	-.07
Heel Breadth	.02	-.06	-.03	-.08	-.07	-.07	-.10	-.12	-.12
Hallux Length	.20	.10	.14	.04	-.04	-.01	.12	.04	.07
Hallux Breadth	.13	.11	.12	.01	.06	.04	.07	.09	.08
Hallux Index	-.13	-.05	-.08	-.05	.06	.02	-.10	.00	-.04
Foot Volume	.09	.06	.07	-.10	-.09	-.10	.04	.04	.04

P<.05 = *

Correlation Coefficients of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Adult White Subjects (N = 26): Run 1

	Toe 1			Toe 5			Dorsum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	-.05	.02	-.02	-.03	.20	.09	-.34	-.26	-.31
Stature	.00	-.08	-.04	-.09	-.06	-.08	-.14	-.12	-.14
Weight	.42*	.26	.37	.42*	.21	.35	.15	.14	.15
Surface Area	.36	.18	.30	.32	.15	.26	.07	.06	.07
Percent Fat	.42*	.35	.42*	.48*	.33	.44*	.06	.17	.12
Lean Body Mass	.30	.13	.24	.26	.08	.19	.16	.07	.12
Sum of Skinfolds	.44*	.36	.44*	.49**	.33	.45*	.07	.18	.13
Foot Length	.15	-.25	-.04	.00	-.26	-.14	.21	.03	.13
Foot Breadth	.19	-.15	.03	.08	.00	.04	.30	.22	.28
Foot Index	.01	.10	.06	.06	.24	.16	.06	.16	.11
Metatarsal Depth	.01	-.20	-.10	-.02	-.10	-.07	.19	.09	.15
Heel Breadth	.54**	.21	.42*	.54**	.22	.42*	.30	.25	.29
Hallux Length	.00	-.22	-.12	-.01	-.07	-.04	.04	-.15	-.05
Hallux Breadth	-.13	-.24	-.20	-.24	-.09	-.19	.02	.04	.03
Hallux Index	-.09	.07	-.02	-.15	.00	-.09	-.03	.16	.07
Foot Volume	.43*	-.04	.22	.31	.10	.23	.41*	.32	.38*

P<.05 = *, P<.01 = **

Correlation Coefficiants of Associations Between Mean Foot Temperatures in Air and Physical Characteristics for Adult White Subjects (N = 26): Run 2

	Toe 1			Toe 5			Dorcum		
	1st 30	2nd 30	60	1st 30	2nd 30	60	1st 30	2nd 30	60
Age	.22	.01	.14	.20	.02	.12	.06	-.10	-.04
Stature	-.28	-.10	-.22	-.18	.02	-.08	-.37	-.16	-.25
Weight	.38*	.20	.34	.46*	.20	.35	.24	.12	.17
Surface Area	.22	.14	.21	.33	.17	.06	.03	.04	
Percent Fat	.42*	.21	.36	.50**	.19	.37	.32	.16	.23
Lean Body Mass	.25	.15	.23	.29	.14	.23	.11	.05	.08
Sum of Skinfolds	.45*	.22	.39*	.51**	.19	.39*	.34	.17	.25
Foot Length	.15	-.12	.02	-.02	.03	.01	.18	.04	.10
Foot Breadth	.21	.04	.14	.14	.24	.21	.19	.10	.14
Foot Index	.01	.14	.08	.11	.17	.16	-.03	.04	.01
Metatarsal Depth	-.15	-.26	-.24	-.14	-.23	-.20	-.04	-.13	-.10
Heel Breadth	.26	.22	.27	.27	.30	.31	.07	.16	.13
Hallux Length	-.12	-.09	-.12	-.17	-.19	-.20	-.08	-.15	-.13
Hallux Breadth	-.19	-.25	-.26	-.28	-.13	-.22	-.18	-.25	-.24
Hallux Index	.01	-.07	-.04	-.01	.09	.05	-.02	.00	-.01
Foot Volume	.23	-.03	.12	.16	.17	.16	.19	.11	.15

P<.05 = *, P<.01 = **

APPENDIX J

Food Requirements of High Altitude Peruvian Natives

E. Picon-Reategui

FOOD REQUIREMENTS OF HIGH ALTITUDE PERUVIAN NATIVES

by

Emilio Picon-Reategui
Instituto de Biologia Andina, Faculdad de
Medicina, Universidad San Marcos
and
The Pennsylvania State University

Every individual needs a daily supply of food in order to maintain health and well being. The amount of food required by a person is related to his body weight, physical activity level, physiological status, sex and a number of climatic variables. It has not, however, been established whether altitude is also a variable which is related to daily food requirements.

The FAO "Committee of experts" (1) suggested that the most satisfactory method to predict caloric requirements is an extrapolation based on a "reference man or woman". They have described a "reference man" of 65 kilos whose caloric requirements are 3,200 Kcal a day. The "reference man" of FAO differs in many aspects from the average Peruvian high altitude man. The specified weight of the FAO "reference man" is 9 kilos greater than most high altitude Peruvian averages and the presupposed degree of physical activity is probably less than the average in the Peruvian high altitude populations, where high levels of exercise are the rule rather than the exception. The average high altutude native adult male has a mean weight of 56 kilos and expends 10 to 12 hours daily in agricultural or pastoral labor, carried out in traditional fashion. He is outdoors daily for 12 to 14 hours and

must walk on very rough terrain. According to FAO's "reference man" this man should need a caloric intake of at least 2800 Kcal a day.

Several investigators (2-4) agree that the Peruvian high altitude natives at present have a high carbohydrate, low fat and low animal protein diet. However, they disagree as to caloric intake. The Instituto de Nutricion of Peru carried out several studies in the 1950's (2) on food consumption in various communities in the Peruvian Andes. These studies reported such a low daily caloric intake (about 1200 Kcal) that it would barely cover basal requirements. Since the weight-height relationships reported for the adult populations in the Peruvian Andes falls within the $\pm$ 10 percent range of U. S. standards (5), and relative body composition does not differ from that of sea level natives (6), it could be postulated from nutritional survey data that a high altitude environment conditions a low caloric expenditure. However, studies of oxygen consumption at high altitude show that the basal oxygen consumption per unit of surface area of high altitude males is comparable to that of sea level residents (7). These facts make it difficult to understand how high altitude residents could maintain their weight and normal body composition if caloric intakes were as low as the surveys indicated.

In two more recent studies on food consumption, the first carried out by Mazess and Baker (3) on a pastoralist population of the Southern Peruvian Andes at 4000 m of altitude, and the other

by Picon-Reategui (4) on a mining population of the Central Peruvian Andes at an altitude of 4540 m, a daily average caloric intake of 2700 and 3680 Kcal respectively were reported. These figures agree more closely with those predicted for these populations, using the "reference man" of FAO.

Dietary surveys have their pitfalls even in the hands of the most skilled investigator and survey results must be interpreted very cautiously, particularly when they were conducted by governmental agencies. Because of native attitudes toward the government, dietary habits may be changed during the course of the survey, either by augmented caloric intake and altered food variety in order to please the investigator, or by lowering intake in order to qualify for supplementary aid. These suppositions suggested that only a controlled experiment could provide accurate data about the amount of native food needed by high altitude natives to maintain their normal body weight, physical activity and well being. Data from a controlled experiment thus can contribute to our understanding of the action of altitude on food requirements. Therefore a series of balance studies were undertaken in the same population as that studied by Mazess and Baker (3) in the town of Nunoa at an altitude of 4000 m.

Methods

Six native adult males were selected from the Nunoa population to participate in the experiment. For the duration of the experiment the test subjects lived in the lab at Nunoa. Table I shows the physical characteristics of these subjects, and Table II shows

the weather data during the time of the experiment. The subjects chosen were as a group considerably shorter and lighter in weight than the average for Nunoa adult males. The weather conditions were near the average yearly conditions.

Since our interest focused on nutrition requirements within the context of a native diet, some homes in the community were visited, prior to the experiment, in order to inquire how the menus were prepared, what kinds of foodstuffs were used and the proportions included in the daily diet. Data was also collected on how often these foodstuffs were consumed in a week, and the amount of individual servings. Once these data were known, the caloric requirements for the experimental group was predicted using FAO standards (2,687.0 $\pm$ 52.1 Kcal per day per man) and sufficient amounts of native foodstuffs, to be consumed in ten days by seven persons, were purchased in the local market. The meals were prepared by a cook hired from the native community. For each meal, she received the amount of foodstuffs necessary to cover the food requirements of seven persons. The prepared food was divided into seven equal portions, one portion was saved for food analysis (8) while each of the six subjects received one of the remaining six portions. The subjects ate their meals under the supervision of two responsible persons, one of whom was the principal investigator. All food and liquid consumed (the entire portions) and all excreta were weighed. The chemical analyses of the food and excreta were carried out at sea level in the laboratory at Lima. During the experiment, the subjects were allowed "normal" activity of their choice.

The balance studies were carried out in two sequential periods of four days each. During the second period, the subjects were allowed to chew coca leaves, ad libitum. The amount chewed by each subject was recorded.

Results

Table III shows the mean food intake per 24 hours for each person, during the two periods. It will be noted that in this "typical' native diet eighty-six percent of the total caloric intake was obtained from carbohydrates, 8.1 percent by proteins, and 5.6 percent by fats. No attempt was made to determine whether this food pattern is purely a result of socioeconomic factors or whether it has partly evolved because carbohydrates are easily digested with less oxygen utilized in their metabolism. Since the subjects increased an average of 610 g in body weight during the first period (Table VI), 25.4 grams of carbohydrates (101.6 Kcal) were cut from the daily diet during the second period.

Protein intake for both periods was about 1 gram per kilo of body weight, however, only 17.5 percent of the total protein intake was of animal origin. Mean $\pm$ S.E. apparent nitrogen absorption was 76.0 $\pm$ 2.3 and 74.0 $\pm$ 1.0 percent for the first and second periods respectively. Mean $\pm$ S.E. nitrogen balance was +4.7 $\pm$ 3.3 g for the first period and +6.7 $\pm$ 2.9 for the second. However, it must be pointed out that no allowance was made for the nitrogen excreted via the skin.

Table IV shows the average energy balance per day, during the two periods. Heat production was calculated from insensible water (9). The subjects were in negative energy balance during the entire experiment. This was probably due to the fact that food

digestibility was not taken into account, and also because physical activity was not individualized for each subject based on predicted caloric requirements. Energy balance was even more in the negative during the second period, which may be explained, in part, because the subjects received fewer calories than in the first period, and also because heat production increased during the second period. Basal skin temperatures taken at the end of each period showed that energy liberated via the skin was also greater during the second period (Table V). Since we did not note an increase in physical activity and environmental temperature was 1.1° C higher in this period than in the first one, it is possible that the increase in heat production was caused by the cocaine or other products extracted from the coca leaves. According to Goodman and Gilman (10) cocaine augments heat production by increasing muscular activity. There is also the possibility that cocaine has a direct action on the heat regulating center. However, vasoconstriction which commonly accompanies cocaine use might decrease heat loss. No evidence for vasoconstriction was found as a result of coca chewing in the present study since skin temperatures were higher at the end of the coca chewing period than during the first period.

In spite of the negative energy balance, the subjects added 610 grams in body weight during the first period, as shown by Table VI. During the second period, they lost 290 grams in body weight. Table VII shows that during the first period, the subjects retained 240.6 grams of water per day, or 962.4 grams during the entire period. During the first period, they also retained 4.7 grams of nitrogen and 82.7 grams of ash, while burning 250.6 grams

of fat. Table VIII shows that during the second period 82.0 grams of water were given off per day, i.e., 328.2 grams during the entire period. During this period, 479.6 grams of fat were burned and 6.7 grams of nitrogen and 60.5 grams of ash were retained.

Discussions and Conclusions

An evaluation of these results suggests that at least among young Quechua males living on a native diet at 4000 meters of altitude basic caloric and protein requirements do not differ substantially from those found in the other populations which were incorporated in the model suggested by FAO's "reference man". If there is a deviation from this model it would probably be in the direction of higher caloric requirements rather than lower. In the present study, although there was some weight gain over the entire eight day period this appears to have been the product of water retention and the actual caloric balance calculated by this method shows a caloric deficiency.

Although our data indicated a positive nitrogen balance on an intake averaging only slightly over 53 grams per day, it should be remembered the excretion of both nitrogen and minerals through the skin was not measured and they were probably enough so that the group was near nitrogen balance. Such a balance, of course, suggests that the native diet normally provides an adequate quantity and quality of protein for adults.

The comparison of the balances with and without coca chewing did not show conclusive differences. There is the suggestion that heat production and water loss during coca chewing is greater but from our data no definite conclusions seem warranted.

In conclusion we believe that this pilot study demonstrates the need for additional controlled experimental studies on high altitude populations. Some significant differences in dietary requirements from low altitude situations may exist but clearly the early nutritional surveys on high altitude Peruvian populations either contained methodological errors or dealt with unusual populations in a transitory state of starvation.

This pilot study indicates clearly the need for more detailed studies on the various segments of high altitude populations. Using the experimental approach dietary requirement studies on the various segments of the high altitude populations such as children, adolescents, women in normal and pregnant conditions are required. Further analysis on the effects of coca chewing are certainly needed and finally new dietary surveys are called for on communities of varying altitudes and socio-economic conditions.

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TABLE 1

Physical Characteristics of the Subjects

Subject	Age (yr)	Stature (cm)	Body Weight (Kg)	Skinfolds		Hemoglobin (g/100 ml)	Hematocrit (per cent)
				Upperarm (mm)	Subscapular (mm)		
AL	28	144.7	49.10	4.2	8.0	17.9	52.8
TB	24	155.7	52.08	3.7	7.1	17.9	50.5
MM	22	164.9	56.28	7.0	10.1	18.4	53.1
AP	23	153.4	50.33	3.2	8.0	17.9	50.5
TC	26	154.4	46.60	5.1	5.9	18.4	52.6
SH	24	153.9	52.63	5.0	7.7	17.4	51.7
Mean	24.5	154.5	51.17	4.7	7.8	18.0	51.9
±SE	0.9	2.6	1.35	0.5	0.6	0.2	0.5

TABLE 2

Weather Data During the Experiment

Date	Environmental Temperature			Clouds at 9:30 A.M.	Wind Velocity 9:30 A.M.	Precipitation
	Max. (°C)	Min. (°C)	Average (°C)	(per cent)	(per cent)	(inches)
Nov. 22	17.8	2.2	10.0	35		0.04
Nov. 23	20.0	2.2	11.1	20	1.0	—
Nov. 24	17.8	1.1	9.4	35	2.5	—
Nov. 25	21.1	2.2	11.7	—	1.5	—
Nov. 26	20.0	2.2	11.1	70	3.0	—
Nov. 27	17.8	4.4	11.1	45	6.0	0.03
Nov. 28	19.4	2.2	10.8	50	2.0	0.79
Nov. 29	18.9	3.9	11.4	30	—	Trace

TABLE 3

Food Intake Per 24 Hours

Subject	Protein (g)	Fat (g)	Carbohydrate (g)	Ash (g)	Fiber (g)	Water (g)	Kcal
			First Period				
AL	53.1	16.7	581.2	33.4	15.2	3,164.5	2,694.8
TB	53.1	16.7	581.3	33.4	15.2	3,230.0	2,687.6
MM	53.4	16.8	583.8	33.6	15.2	3,339.3	2,708.4
AP	53.3	16.7	581.7	33.5	15.2	3,229.6	2,698.6
TC	53.4	16.8	584.3	33.6	15.2	3,181.1	2,710.2
SH	53.4	16.8	584.4	33.6	15.2	3,181.8	2,710.8
Mean	53.3	16.8	582.8	33.5	15.2	3,221.0	2,701.7
±SE	0.06	0.02	0.6	0.04	0.0	26.1	3.9
			Second Period				
AL	53.6	16.3	556.0	29.8	13.8	2,958.3	2,584.9
TB	54.2	16.5	561.1	31.6	13.9	2,960.7	2,609.2
MM	54.0	16.4	558.1	30.0	13.9	2,964.1	2,595.9
AP	54.1	16.5	556.2	29.8	13.8	2,952.4	2,589.6
TC	53.6	16.4	557.3	29.6	13.9	2,969.3	2,591.3
SH	53.6	16.2	555.7	29.8	13.8	2,955.0	2,583.5
Mean	53.8	16.4	557.4	30.1	13.8	2,960.0	2,592.4
±SE	0.1	0.05	0.8	0.3	0.02	2.5	3.8

TABLE 4

Mean Daily Energy Balance

Subject	Energy Requirement (Kcal)	Energy of Diet (Kcal)	Energy Lost in Excreta (Kcal)	Available Energy (Kcal)	Heat Production (Kcal)	Energy Balance (Kcal)
			First Period			
AL	2,606.0	2,784.2	241.9	2,542.3	2,781.6	- 239.2
TB	2,723.0	2,784.4	188.3	2,598.6	3,227.4	- 628.8
MM	2,884.0	2,797.2	210.3	2,586.9	3,217.0	-1,030.2
AP	2,655.0	2,787.1	252.0	2,567.0	2,945.1	- 378.1
TC	2,512.0	2,798.9	296.3	2,502.6	3,156.2	- 653.6
SH	2,742.0	2,799.5	312.4	2,487.1	2,644.0	- 157.0
Mean	2,687.0	2,791.9	250.2	2,547.4	3,061.9	- 515.5
±SE	52.1	3.0	47.9	18.5	142.7	131.7
			Second Period			
AL	2,642.0	2,682.0	221.9	2,460.1	3,256.4	- 796.2
TB	2,710.0	2,707.4	260.4	2,447.0	3,923.8	-1,476.8
MM	2,911.0	2,693.8	236.6	2,457.2	3,883.0	-1,425.8
AP	2,685.0	2,687.8	258.1	2,429.7	3,447.3	-1,017.6
TC	2,553.0	2,688.6	262.6	2,426.1	3,302.8	- 876.8
SH	2,761.0	2,680.8	318.2	2,383.2	3,133.8	- 750.6
Mean	2,710.3	2,690.1	259.6	2,433.9	3,491.2	-1,057.3
±SE	49.3	4.0	13.4	11.6	136.7	130.1

TABLE 5

Resting Temperatures at the End of the First and Second Periods

Site	Period	Subjects						Mean	±SE
		AL (°C)	TB (°C)	MM (°C)	AP (°C)	TC (°C)	SH (°C)	(°C)	
Upperarm	1	31.0	30.5	31.8	31.6	31.0	31.2	31.2	0.2
	2	31.3	31.6	33.3	31.8	32.4	32.4	32.1	0.3
Chest	1	32.1	32.6	32.7	32.8	32.6	32.0	32.5	0.1
	2	33.0	32.6	33.8	33.2	32.5	33.2	33.0	0.2
Back	1	31.4	31.5	31.6	32.3	31.4	32.4	31.8	0.2
	2	32.2	32.4	33.2	32.1	33.6	32.8	32.7	0.2
Thigh	1	30.5	31.5	31.3	31.6	30.8	30.2	31.0	0.2
	2	31.9	31.8	32.4	31.3	32.0	31.8	31.9	0.2
Calf	1	30.7	30.3	29.9	30.9	29.9	30.1	30.3	0.2
	2	30.1	30.8	31.3	30.3	31.9	30.8	30.9	0.3
Mean Skin	1	31.4	31.5	31.1	32.0	31.1	31.4	31.4	0.1
	2	32.0	32.0	32.6	31.8	32.3	32.4	32.2	0.1
Oral	1	36.1	36.3	37.0	36.5	36.2	37.0	36.5	0.2
	2	36.3	36.2	36.8	36.7	36.8	36.8	36.6	0.1
Rectal	2	36.4	36.3	36.6	36.7	36.7	36.3	36.5	0.1

TABLE 6

Body Weight at the Beginning of the Experiment and at the End of the First and Second Periods

Subject	Beginning	I	II
AL	49.10	49.95	49.42
TB	52.08	51.82	51.16
MM	56.28	56.98	57.23
AP	50.33	51.15	51.31
TC	46.60	47.63	47.18
SH	52.63	53.15	52.62
Mean	51.17	51.78	51.49
±SE	1.35	1.29	1.38

TABLE 7

Mean Daily Water Balance During the First Period

Subject	Water of Food and Water Drunk (g)	Water of Oxidation (g)	Preformed Water (g)	Total Water Available (g)	Water of Urine (g)	Water of Stool (g)	Insensible Water Loss (g)	Total Water Loss (g)	Water Balance (g)
AL	3,164.5	373.8	-68.2	3,470.1	2,021.9	157.8	1,151.0	3,336.6	+133.4
TE	3,230.0	422.9	8.4	3,661.3	2,167.0	88.5	1,335.5	3,591.0	+ 70.2
MA	3,339.3	467.0	9.4	3,815.7	1,767.3	96.1	1,496.7	3,360.2	+455.5
AP	3,229.6	390.8	27.8	3,648.2	1,869.4	200.0	1,218.7	3,279.0	+369.1
TC	3,181.1	415.3	-14.3	3,582.1	1,757.4	197.6	1,306.0	3,262.0	+320.2
SH	3,181.8	358.4	-59.0	3,481.2	2,076.3	215.6	1,094.1	3,386.0	+ 95.2
Mean	3,221.0	404.7	-16.0	3,609.8	1,942.9	159.3	1,267.0	3,369.1	+240.6
±SE	26.1	15.9	16.0	52.9	70.0	22.6	59.1	48.4	66.0

TABLE 8

Mean Daily Water Balance Durin· the Second Period

Subject	Water of Food and water Drunk (g)	Water of Oxidation (g)	Preformed Water (g)	Total Water Avail-able (g)	Water of Urine (g)	Water of Stool ( )	Insensible Water Loss (g)	Water of Coca Residue (g)	Total Water Loss (g)	Water Balance (g)
AL	2,958.3	424.0	-41.0	3,341.4	1,791.0	17.8	1,347.4	69.5	3,485.8	-144.4
TB	2,960.7	499.2	-11.0	3,448.8	1,685.4	16.4	1,623.6	67.0	3,540.1	- 91.4
MM	2,964.1	494.2	- 6.7	3,451.6	1,547.2	19.4	1,606.8	62.0	3,320.3	+131.3
AP	2,952.4	445.1	- 6.8	3,390.6	1,723.2	17.2	1,426.5	57.7	3,379.2	+ 11.4
TC	2,969.3	429.8	-73.1	3,326.0	1,902.2	22.0	1,366.7	104.6	3,593.2	-267.4
SH	2,955.0	409.4	23.2	3,387.6	1,920.1	24.7	1,296.8	55.3	3,519.5	-131.8
Mean	2,960.0	450.3	-19.2	3,391.0	1,778.2	18.1	1,444.6	69.4	3,473.0	- 82.0
±SE	2.5	15.4	13.6	21.4	61.4	2.0	56.6	7.8	42.2	56.3

APPENDIX K

Effect of Coca Chewing on Metabolic Balance in Peruvian High Altitude Natives

E. Picon Reategui

EFFECT OF COCA CHEWING ON METABOLIC BALANCE IN PERUVIAN HIGH-ALTITUDE NATIVES

A significant number of residents at high altitude in Peru chew coca leaves. This habit is well known to lay people, as well as to scientists from Peru and abroad. Nobody knows for sure what effects coca may have on the physiology and nutrition of those who have the habit. Although the leaves are not swallowed, coca chewing must not be overlooked in physiological and nutritional studies carried out in this area. Body water is one of the many body constituents whose physiology may be altered by coca chewing, as well as by altitude. A comparison of fluid volumes in sea-level natives and comparable individuals who resided at 4,540 m (1) showed that only sucrose space was significantly greater in the altitude natives. However, there are no sutdies showing how body fluids are maintained in those exposed for a long term to a high altitude enviornment and what synergistic or other effect, if any, the habit of chewing coca leaves could have on the physiology of body fluids. The present pilot experiment may establish a basis for future studies on the effect of factors, other than altitude, which may act on the nutrition and physiology of highland natives.

METHODS

Six native adult males from the Nuñoa population participated in the experiment. The studies were carried out in two sequential periods of four days each. For the duration of the experiment, they lived in the labratory of Nuñoa (altitude 4,000 m). Table 1 shows the physical characteristics of the subjects. As a group, they were shorter and lighter in weight than the average, for Nuñoa adult males. Table 2 shows the weather data during the time of the experiment. The weather conditions were near

average yearly conditions. Established food habits were not changed. Native foods were prepared by a female cook hired from the native community. Daily caloric intake were 2,702 and 2,592 kcal during the control and experimental period, respectively. The caloric intake agrees with that predicted from FAO's "reference man". Protein intake was about one gram per kg body weight, however, only 17.5 percent was of animal origin. In this 'typical' native diet pattern, 86 percent of the total caloric intake was obtained form carbohydrates, 8 percent from proteins and 6 percent from fat. Since the subjects were increasing in body weight during the control period, 25.4 g of carbohydrates were cut from the daily diet during the second period. During the second period only, were they allowed to chew coca leaves. Water was drunk ad-libitum during both periods. All food and liquid consumed, as well as all excreta were weighed to the nearest gram. All the food prepared was divided daily in seven equal portions, one of them was saved for food analysis (2). All the excreta, as well as the coca residue were also saved for chemical analysis (2).

Every day after voiding, the fasting subjects were weighed nude using a Plima balance. Water balance was calculated by the method of Wiley and New burgh (3).

RESULTS AND DISCUSSIONS

Table 3 shows the amount of water available to the body. It can be seen that the amount of water secured from food ingested and water drunk was lower during the period when they were chewing coca leaves. Thus, there was a lower amount of water available to the body, in spite of the larger amount produced by oxidation during this period. Oxidation of body fat may be responsible for the different amount of metabolic water produced during the two periods of study. According to our calculations, an excess of 229 g of fat was burned when the subjects were chewing coca leaves than during

TABLE I

Physical Characteristics of the Subjects

		Mean ± SE
Age (yr)		24.5 ± 0.9
Stature (cm)		154.5 ± 2.6
Body weight (Kg)		51.2 ± 1.4
Skinfolds (mm)	Upperarm	4.7 ± 0.5
	Subscapular	7.8 ± 0.6
Hemoglobin (g/100ml)		18.0 ± 0.2
Hematocrit (percent)		51.9 ± 0.5

TABLE II

Weather Data During the Experiment

		First period Mean ± SE	Second period Mean ± SE	Diff.	t
Environmental Temperature (°C)	Max.	19.2 ± 0.8	19.0 ± 0.5	0.2	0.21
	Min.	1.9 ± 0.3	3.2 ± 0.6	1.3	2.03
	Average	10.6 ± 0.5	11.1 ± 0.1	0.5	0.94
Wind velocity at 9:30 A.M. (mph)		1.7 ± 0.4	3.7 ± 1.2	2.0	1.56

the control period. On the contrary, an excess of 102 g of carbohydrates and 16 g of proteins were oxidized during the control period. This may account for the excess of 182 g of metabolic water produced during the second period, (245, -56 and -6 g of water from fat, carbohydrates and proteins, respectively).

TABLE 3

Water Available to the Body

Source of Water	First period Mean ± SE	Second period Mean ± SE	Diff.	t	P
Food and water drunk	12,884±104 (88.8%)	11,840±10 (86.8%)	1,044	10.13	.01
Oxidation	1,619±64 (11.2%)	1,801±62 (13.2%)	182	5.06	.01
Preformed	-64±64	-77±54	13	0.16	NS
Total Available	14,439±211	13,564±86	875	5.47	.01

An average of 962 g of water was retained during the first period (Table 4). However, body weight increased by only 610 g. Since the subjects were in nitrogen balance, it suggests that some body fat was also burned during this period. There is no explanation for the water retained, although transient changes in water retention are commonly observed. Since there was no change in the type of food consumed, the water retention may have been related to the discipline imposed by the experiment or a slightly negative water balance at the time the experiment began. It may also have been due to the elimination of coca chewing.

TABLE 4

Water Loss During the First and Second Period

Channel of loss	First period Mean ± SE	Second period Mean ± SE	Diff.	t	P
Urine	7,772±280 (57.7%)	7,113±246 (51.2%)	661	2.02	NS
Stool	637±90 (4.7%)	723±80 (5.2%)	86	1.56	NS
Insensible	5,068±236 (36.7%)	5,778±226 (41.6%)	710	5.42	.01
Coca residue	No Saliva Losses	277±30 (2.0%)	---	----	--
Total loss	13,477±194	13,892±169	415	1.80	NS
Balance	962±264	-328±225	1,290	5.35	.01

A negative balance of 328 g of water was produced during the period when the subjects were chewing coca leaves. Body weight loss averaged only 293 g. An increase in insensible water loss may account for this negative water balance. A tendency to excrete less water in the urine was recorded when they were chewing coca leaves, which may possibly be interpreted as a physiological response of the kidneys in their attempt to maintain body fluids constant. Some water was also lost in the coca leaves residue.

A direct relationship between skin temperature and the amount of insensible water loss has been reported (5). Table 5 shows an increase in skin temperatures in the readings reocrded at the end of the period when they were chewing coca leaves. According to Ritchie et al. (6) cocaine augments heat production by increasing muscular activity, and

possibly also by a direct action on the heat regulating center.

TABLE 5

Mean Resting Temperatures at the End of the First and Second Period

Site	First (°C±SE)	Second (°C±SE)	Diff.	t	P
Upperarm	31.2±0.2	32.1±0.3	1.0	4.37	.01
Chest	32.5±0.1	33.0±0.2	0.6	2.61	.05
Back	31.8±0.2	32.7±0.2	1.0	2.87	.05
Thigh	31.0±0.2	31.9±0.2	0.9	3.02	.05
Calf	30.3±0.2	30.9±0.3	0.6	1.40	NS
Oral	36.5±0.2	36.6±0.1	0.1	0.62	NS
Rectal	--------	36.5±0.1	---	----	

SUMMARY

It is interesting that withholding coca produced a positive water balance and chewing coca produced a negative water balance. Part of the explanation for the differences observed was increased insensible water loss assoicated with higher skin temperatures when chewing coca. Higher skin temperatures imply either elevated heat production or greater blood flow though the skin. It is also possible that cocaine may have some direct action on the kidney because urinary excretion of water was reduced when chewing coca. These changes in fluid balance appear provocative and further studies on the effects of coca chewing should be conducted to explain the results obtained and the overall effects of coca on nutrition and water balance.

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