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MARSHALL Jr., Henry Crawford, 1929-
DEVELOPMENT OF HUMAN ADAPTATION TO COLD.

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DEVELOPMENT OF HUMAN ADAPTATION TO COLD

A

DISSERTATION

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by

Henry Marshall, B.A.

College, Alaska

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DEVELOPMENT OF HUMAN ADAPTATION TO COLD

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Chairman

APPROVED: ____________________ Date 5 Oct 69
Vice President for Research
and Advanced Study

ABSTRACT

In an effort to assess the development of the human adaptation to cold, children between the ages of 5 and 19 years were tested for peripheral skin temperature, thyroid function and peripheral nerve conduction velocity. Results of these tests were recorded according to age, sex, ethnic group and length of residence in interior Alaska.

Results showed an increase in skin temperature and nerve conduction velocity with age, and an increase in half relaxation time until puberty. Alaska Natives showed the highest skin temperatures, highest thyroid function measurements and highest nerve conduction velocities among the ethnic groups tested. The resident Caucasians showed the next highest results, and the non-resident Caucasians and Resident Negros showed the lowest values. Males showed a generally higher response to the tests than did females.

The change in test values with age is attributed to the inadequacy of clothing available for small children, development of more efficient temperature regulation with age and increase in body size with age. The higher responses found in males compared with females is attributed to larger body size and greater heat production capabilities, while the hierarchy of responses observed among the ethnic and residence groups tested, is attributed to differential cold adaptation between the groups, based upon their relative cold exposure experience.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

INTRODUCTION

A study of evolution has shown a pattern of increasing efficiency with which the young of a species are protected and nourished until they are able to fend for themselves. And whether the young are protected and nourished within an egg shell, or by a parent, the means by which the animal copes with the environment to which it is exposed as an adult are not present in the fetal stage of life, but follow a developmental process. This developmental pattern is especially evident in the temperature regulation of the newborn homeotherm, for, according to Hissa (1968 p 348), many of these cool according to Newton's Law, because insulation is totally lacking and the peripheral blood circulation is not regulated. It must be pointed out, however, that Hissa is referring here primarily to small rodents, and that many other newborn animals, such as seal pups, ducklings and caribou calves, have some insulation and vascular regulation at birth.

The development of temperature control from birth to adulthood has been described for white rats by Adolph (1957 p 93-103), for the opossum (Didelphis marsupialis virginiana) by Morrison and Petajan (1963 p 52-64) and for the Norwegian lemming (Lemmus lemmus L.) and the golden hamster (Mesocricetus auratus Waterhouse) by Hissa (1968 p 345-379). In each case the temperature regulating mechanism when present in the young lack the capacity which develops with age. In the case of the newborn human infant, a majority of investigators believe that they regulate their temperature by means of vasoconstriction and muscular movements, making the difference between infant and adult temperature regulation one of quantity rather than quality (Adamsons, 1966 p 599).

Various ethnic groups throughout the world have been shown to regulate their body temperatures in response to cold in different ways. For example, the Eskimos (Eagan and Evonuk, 1964 _in_ Folk, 1966 p 110) and the Ama, or diving women of Korea (Hong, 1963 _in_ Folk, 1966 p 113-114) respond to cold primarily by metabolic adjustment. When exposed to cold they raise their metabolic rate significantly above that of controls. The Australian Aborigines (Morrison, 1957 and Scholander, 1958 _in_ Folk, 1966 p 110-111) respond to cold in two ways, by tolerance of a mild hypothermia, _i.e._ they permit their core temperature to drop and allow extremities to cool; an adjustment of insulation. Through vasoconstriction they reduce bloodflow to the surface, thus providing a thicker tissue insulation over the more deeply situated arterial supply. This process also diverts more blood to the vital core area of the body. The Alacaluf Indians of South Chile respond to cold primarily by habituation. They have a high metabolic rate which does not change with cold exposure, and they can tolerate cold temperatures, without apparent discomfort, which cause white controls considerable distress, although the skin temperatures of both groups remain essentially the same (Elsner, 1963 _in_ Folk, 1966 p 113). Europeans and Americans also seem to respond to cold by habituation, which is manifested by an increased psychic tolerance to cold discomfort (Elsner, 1963 and Rodahl, 1965 _in_ Folk, 1966 p 110-113).

Since there is a homeothermic ontogeny, and since there is variation in temperature control responses among various ethnic groups, one is led to ask whether there is, in fact, a developmental process in human adaptation to cold; does it change with age, does it vary among ethnic groups and can differences be illustrated in terms of residence in extremely cold environments? These are the questions to which this study was directed. It may be noted here that the word "adaptation" as used in this study, means adjustment to a stressful environment. In a physiological sense the adjustment of an organism to a change in some physical dimension of the environment can be considered to be divided into several phases and to consist of multiple components. At any given time prior to the final equilibrium condition (acclimatized state if occurring under natural conditions, or acclimated state if artificially induced) the organism is undergoing changes which reflect the various modes of response to the stressor. Initially there is a reflex response to prevent sudden changes in an important internal state such as body temperature; among the reflex responses are shivering and vasoconstriction. The gradual attenuation of these responses during sustained cold exposure represents a transition into a state in which heat is supplied by other mechanisms. Adaptation at the cellular level can be considered to have occurred when activity has been adjusted to a new stable level under the changed ambient condition. Any of the responses comprising a reaction to cold could be considered in this light. The factors causing vasoconstriction converge upon the cells comprising the arteriolar wall. In the cold adapted individual the activity in these cells is adjusted to a new lower level. In transition to adaptation variation in their activity is greater, and at a higher mean level (Petajan, 1969 personal communication).

That cold is a stress is illustrated by survival tests used to define median lethal levels for this environmental extreme (Prosser, 1964 p 15). This is compatible with the observations of Boyd (1960), Bundesen and Falk (1926), Cryan and Becker (1952), Kutschenreuter (1959), Ortmann (1933), Spann (1957), Stuppler (1932), Tromp (1958) (all _in_ Tromp, 1963 p 572); and those of DeRudder (1952) and Keutzer (1957) (all _in_ Brezowsky, 1964 p 370-380) showing a higher mortality rate in humans during periods of cold weather. However, in both cases death may be influenced by secondary factors such as age, physical condition and illness.

In the past, most efforts to study the human response to cold have been conducted on polar expeditions. Such expeditions have been so well equipped, however, that members may have sustained little intensive cold exposure (Folk, 1966 p 101). On the other hand, residents in the Fairbanks, Alaska area, owing to familiarity with the climate and the requirements for lighter dress imposed by style and convenience, probably sustain more severe cold exposure than polar explorers.

Since the study was directed to the development of adaptive responses to cold, it was considered advisable to use developing humans as experimental subjects. The use of school children provided cold exposure information for age groups ranging from 5 to 20 years, and also provided indications as to whether differences exist between several ethnic groups and between groups having different periods of residence in Interior Alaska. Some of these children walk long distances to and from school at temperatures below -40°C. Very little down insulated or fur clothing is made for small children because of the expense involved. In addition, one cannot put the insulation thickness in a child's clothing that one puts into adult clothing without overburdening the child. For these two reasons small children are often inadequately dressed when compared with adults. Among young people of junior highschool and highschool age, style often prescribes rather light dress despite cold temperatures, thus resulting in increased cold exposure in these age groups (Figures 1 and 2). An added consideration is that the surface area to body mass ratio is greater in children of all ages than it is in most adults, thus contributing to a greater heat loss in children. This concept is based upon the surface law as written by Meeh (1879 in Kleiber, 1961 p 182) which is $S=kW^{2/3}$, and which was adjusted for humans by DuBois (1916 in Kleiber, 1961 p 182) to show $S=71.84W^{0.425} \times L^{0.725}$. In this formula S is the surface area in square centimeters, W is the body weight in kilograms and L is the body length in centimeters. The figure 71.84 is a constant term applicable to man, and by measuring surfaces and weights can be determined empirically. Since a child is not a small adult, but shows differences in shape with development (Nelson, 1954 p 17) the constant term 71.84 would have to be modified when dealing with children. Kleiber (1961 p 182) has condensed this formula into the following terms $k_1k_2 \times W^{2/3}$. Development of this formula is based on the observations that animals of similar shape have a surface area that is proportional to the two-thirds power of their weight (however, since all animals are not of a similar shape the constant differs with the shape of the animal). The oxygen consumption varies with approximately the two-thirds power of body weight, and consequently so does the heat production. In most mammals the core temperatures

Fig. 1. Dressed for recess 19 March 1968, temperature -15°C

Fig. 2. Dressed for recess 30 March 1968, temperature -6.1°C

are similar, and therefore their heat loss should vary as the two-thirds power of their body weight (Bartholomew, 1968 in Gordon, 1968 p 60-61).

Since the response of an organism to cold involves the circulatory system, the metabolic system, the endocrine system and the nervous system, the experimental approach to the problem of cold adaptation has been necessarily diverse. To use school children, however, the experiments would have to be quick and painless, and still provide data pertinent to several physiological parameters. The following measurements were selected to satisfy this requirement, and the rationale supporting this selection is outlined below: a.) peripheral skin temperatures, b.) capillary filling time, c.) a parameter of thyroid function and d.) peripheral nerve conduction velocity.

BACKGROUND AND SIGNIFICANCE OF PERIPHERAL SKIN TEMPERATURE MEASUREMENTS

The skin is richly supplied with sense organs and plays an important role in temperature regulation (Bullard, 1966 p 635-631; Prosser and Brown, 1961 p 257-259; Folk, 1966 p 103-104; Bard, 1961 p 536-538). It serves as a protective layer between the environment and the underlying parts of the body, and in this capacity it transmits the information necessary to enable the body to adapt itself rapidly to environmental changes (Tromp, 1963 p 209). Skin temperature represents the difference between the heat loss to the environment and that conveyed to the skin by the blood. If heat loss is maintained at a constant level, the surface temperature of the skin will then depend upon the rate of blood flow through the skin, if the temperature of the circulating blood reflects a constant core temperature (Abramson, 1967 p 51). Williams (1938 in Abramson, 1967 p 241) found that in the clothed individual the surface of the head and trunk play little part in thermoregulation in comparison with the extremities, which assume the primary role. In view of observations made by others, however, this statement seems a bit strong. Burton and Edholm (1955 p 140-141) report that when the face was heated to a temperature of 44°C the temperature of the hand was raised 10°C and the bloodflow increased fourfold. Sweat glands function in the dissipation of heat, and Kawahata (1939 in Kuno, 1957 p 69) found that the number of sweat glands per square centimeter of skin in the head is roughly the same as that in the upper extremities in subjects 20 years of age, and about one fourth as many as in the upper extremities at 35 years of age, Measurements in the trunk show there are more sweat glands here at all ages from 4 to 35 years, than there are in the upper extremities. Skin temperature is an estimate of the heat brought to the skin, and therefore an estimate of the local vascular response to the cold. Since digital temperatures, in an ecological sense, are limiting with respect to performance in the cold, they were chosen for study. Also they were quickly and easily determined (Petajan, 1969 personal communication).

Although measurements of skin temperature have been little used to determine the developmental aspects of cold adaptation in man, these methods have been instrumental in describing differences in adaptations between ethnic groups as well as in describing the basic human vascular response to cold. Hicks and O'Conner (1938, _in_ Hicks, 1964 p 408-409) used skin temperature measurements to show that the Australian Aborigines slept with a much colder surface than did White controls, and also that control of circulation was more localized in the Natives than in White controls. Scholander, _et al_. (1958, _in_ Hammel, 1964 p 417) used skin temperature measurements to show differences in surface temperatures between Australian Aborigines and White controls. Hammel, _et al_. (1962 _in_ Hammel, 1963 p 419-420) used skin temperature measurements to show differences in circulatory patterns between African Bushmen, Australian Aborigines and Europeans subjected to similar cold exposure, and in 1960 Hammel, _et al_. (_in_ Hammel, 1964 p 421) used skin temperature measurements to support findings that the Alacaluf Indians of Southern Chile responded to cold with a metabolic acclimatization. Skin temperature measurements have also been used by Irving, _et al_. (1960 p 638) in studies of the thermal responses of Arctic Indians; by Elsner and Bolstad (1963 _in_ Hammel, 1964 p 423-424) who showed higher hand and foot temperatures and lower rectal temperatures in Andean Indians exposed to cold, as compared to White controls; by Hart, _et al_. (1962 p 954-955) in a study of the thermal responses in coastal Eskimos; by Meehan (1955 _in_ Hammel, 1964 p 426) to compare racial variations in vascular response to cold between Eskimos, Alaskan Indians and Negros; by Irving and Miller (1962 p 451) to compare hand and face temperatures of Eskimo men, women and children with White controls and by Yoshimura and Iida (1952, _in_ Hammel, 1964 p 426) who made comparisons of peripheral vascular responses to cold between unaccustomed Japanese and three races living in Manchuria. All of these observations on surface temperature support the view that people who regularly expose their extremities to cold develop a response which appears to enable them to function better in their environment. These findings have been further supported by supplementary measurements of metabolic rate, muscular activity, rectal temperatures and hand calorimetry (Hart, et al. 1962 p 954-955; Hildes, et al., 1961 p 617-620; Miller and Irving, 1962 p 450-451). It should be emphasized, however, that while finger temperature discloses protective vascular response, it may not indicate the thermal requirement for that response. It shows the thermal sensitivity of finger blood flow.

Many studies involving measurements of peripheral skin temperatures as an indication of cold adaptation, have utilized thermocouples wired to finger tip pads (Hildes, et al., 1961 p 618; Eagan, 1963 p 947; Miller and Irving, 1962 p 541; Brown, et al., 1954 p 813; Brown and Page, 1952 p 222; Massey, 1959 p 616), but others also measured facial skin temperatures. Miller and Irving (1962 p 451) measured forehead and cheek temperatures, and Blair, et al. (1961, in Thauer, 1967 p 1936) measured nose, cheek and ear temperatures.

Although Froese and Burton (1957 in Thauer, 1965 p 1936) concluded, using the conductance method (based on heat loss and temperature gradient) that there was neither vasoconstriction or vasodilatation when cold or heat were applied to the head, Thron (1956 in Thauer, 1965 p 1936) using a calorimetric method to measure blood flow through the cheek, found a nearly linear relationship between blood flow and environmental temperature over a range of from +5°C to +42°C, and Blair (1961 _in_ Thauer, 1965 p 1936) concluded that on indirect cooling, vasoconstriction occurs in the nose and on indirect heating, vasoconstriction decreases in the ear and active vasodilatation occurs in the cheek.

It is noted by Greenfield (1963 p 1330) that the exposure of any part of the body to a change in temperature probably causes some alteration in all other parts. In view of this and of the foregoing observations, the possibility of finding some correlation between digit skin temperatures and facial skin temperatures seemed worth investigating, especially since the face is constantly exposed to the environment and might therefore be expected to manifest adaptive characteristics. It should be noted, however, that interpretation of results is complicated by the facial structure, and the effects of individual breathing habits.

BACKGROUND AND SIGNIFICANCE OF CAPILLARY FILLING TIME MEASUREMENTS

The danger of cold injury is reduced and the subjective tolerance to low environmental temperatures is improved by increasing the blood flow through the extremities (Thauer, 1965 p 1954). Since the efficiency of the flow to the extremities is based upon cardiac output, and the resistance of peripheral vessels (Thauer, 1965 p 1941-1943) a measure of the resistance pressure in the capillaries of the exposed face might be indicative of adaptation to cold. This capillary resistance may be measured indirectly by blanching the skin with a slight pressure and by timing the return to normal coloration (Landis and Pappenheimer, 1963 p 963; Greenfield, 1963 p 1328 and Bard, 1961 p 53). This method is admittedly undependable if one is attempting to quantify capillary pressure per se, but would appear to provide a reasonably good subjective representation of capillary condition based upon the time required for displaced blood to return to the surface. In using this method, however, especially on small children, one must take care that the pressure applied is not strong enough to damage the vessels.

BACKGROUND AND SIGNIFICANCE OF THYROID FUNCTION MEASUREMENTS

The main function of the thyroid gland is to synthesize thyroxine and to deliver a sufficient amount to the body. Iodine is essential for production of thyroxine (50-60 ug/day) and it reaches the thyroid in the form of iodide. Thyroid tissue has a special affinity for this element and can concentrate, collect and store it (Nelson, 1954 p 1234). It is well known that the thyroid gland exerts a great influence on metabolic rate through the production of heat (Bard, 1961 p 542; Nocenti, 1961 p 786; Adolph, 1968 p 100; Moore, 1966 p 714 and 723; Kleiber, 1961 p 234-235; Edman, 1964 p 541; Tromp, 1963 p 269; Pitt-Rivers and Tata, 1959 p 202) but the manner in which this is accomplished remains in disagreement (Wilson, et al. 1966 p 2; Nocenti, 1961 p 789-791). While there is general agreement that the thyroid plays an important role in control of metabolic rate. The function of the thyroid in response to cold exposure, is less clear, even though an influence of cold on the thyroid gland was noted as far back as 1894 by Smith (in Salvaneschi, et al., 1966 p 1240).

Tromp (1963 p 271-272) and Carlson (1964 p 214) note that cold produces increased activity in the thyroid gland, and Carlson (1964 p 215-216) notes that some thyroid hormone is essential to maintenance of thermal equilibrium. Moore (1966 p 723) supports these observations with the statement that normal man responds to cold by increasing thyroid hormone output as judged by an increase in basal metabolic rate (BMR), as do Ermans and Camus (1966 p 6-10) with findings that there was a marked increase in protein bound iodine (PBI) 125 and PBI 127 in the blood of 8 subjects who were exposed for 2 hours to 4°C, 24 hours after injection of I 125. On the other hand, there are many reports that fail to show changes in BMR in man in heat or cold (Nocenti, 1961 p 785), and Rodahl, Ingbar and Suzuki (in Suzuki, et al. 1966 p 430) all give negative reports regarding thyroid function changes with cold exposure. Bondy, et al. (in Carlson, 1964 p 215) reports that blood PBI is not increased in cold acclimated rats, while Héroux and Brauer (1965 p 597) showed that thyroxin requirements were twice as high in rats acclimated at 6°C as in controls acclimated at 23°C. Finally, Pitt-River and Tata (1959 p 202) advise that elevated output of thyroid hormones caused by low temperature stimulation of hypophysial thyrotrophin (TSH) release cannot elevate metabolic rate until after many hours have passed, while Ermans and Camus

(1966 p 6-10) report positive results in 8 subjects after exposure to 4°C for two hours, as noted above.

The discrepancies in results obtained in measurements of thyroid functions and metabolic rate in relation to cold exposure are numerous, and yet the majority of these probably stem from differences in animal species, differences in food intake where food contains iodine (Héroux and Brauer, 1965 p 603), differences in periods and degree of cold exposure, differences in time elapsed between radioiodine administration and cooling (Salvaneschi, et al., 1966 p 1241) and differences in physical activity (Rhodes, 1967 p 917-918); or when dealing with humans, differences in diet, body weight, body composition, ethnic group and differences in physical activity (Wilson, 1966 p 7, 16, 20, and p 9 in part VIII). In addition, one cannot discount differences between acclimated and acclimatized animals (Héroux and Brauer, 1965 p 597-605) or differences in photoperiod (Turner and Benedict, 1932 and Dempsey, 1943 in Tromp, 1963 p 272-273) as contributing to existing discrepancies in the literature.

In all of the forementioned work on humans, the number of subjects tested in one project was relatively small, the largest number being 9 It would seem that one way of overcoming some of the possible causes of the discrepancies listed above, would be to test a statistically large number of subjects in which these discrepancies would be absorbed. The laboratory techniques used by the forementioned investigators, however, are not well adapted to the testing of large numbers of subjects, especially when one is to be dealing with school children, where requirements for fast and painless testing are paramount.

Prolonged tendon reflexes in hypothyroidism were first described in 1884 by William Ord (in Verdy, et al. 1968 p 169), however, the exact cause of the reflex changes is not known (Anderson, 1968 p 33). The reflex which most efficiently reflects this prolonged condition in hypothyroidism proved to be the Achilles tendon reflex (Anderson, 1968 p 33). Many devices have been used since that time in an effort to quantify results of the tendon reflex (Abraham, et al. 1966 p 828). Lambert, et al. in 1951 (in Abraham, et al. 1966 p 838) transmitted movement of the foot to a pedal electronically, and Lawson, (1958 in Abraham, et al. 1966 p 828) devised his Kinemometer which times the delay between stimulus and ankle jerk by means of a magnet attached to the sole of the foot. When the foot moves, the magnet generates a current in an adjacent coil which causes the results to be recorded on an electrocardiograph. Finally, in 1959, Gilson developed an apparatus which he called a Photomotograph. This device times the delay between the stimulus and the movement of the foot through the beam of a photoelectric cell and records the result on an electrocardiogram (Fogel, et al. 1963 p 1160; Sherman, et al. 1963 p 243-245)

Through studies made with this and similar equipment, it is now generally established that the tendon reflexes are shortened in the majority of thyrotoxic patients and prolonged in hypothyroid patients (Abraham, et al. 1966 p 828). Although the ankle jerk measurement is not as accurate as the PBI (Abraham, et al. 1966 p 832) or the radioactive iodine (RAI) test, it is a more accurate technique than BMR for measuring thyroid function (Fogel, et al. 1963 p 1168) and has the added advantage of not being influenced by diet (Sherman, _et al_. 1963 p 245) pregnancy, obesity, nervous agitation and a variety of pathological conditions (Fogel, _et al_. 1962 p 1167). It correlates well with the RAI (Fogel, _et al_. 1962 p 1162) and the PBI tests (Sherman, _et al_. 1963 p 243-245) and is considered an accurate test of the state of thyroid activity (Fogel, _et al_. 1962 p 1162). Among the various techniques used to measure the Achilles tendon reflex, a survey of the pertinent literature appears to favor the Photo-motograph as the most efficient and accurate method (Fogel, _et al_. 1962 p 1160-1168; Sherman _et al_. 1963 p 243-245; Petajan and Watts, 1962 p 240-250).

BACKGROUND AND SIGNIFICANCE OF NERVE CONDUCTION VELOCITY MEASUREMENTS

It has been assumed that an animal acclimated to one environment is different physiologically and biochemically from one acclimated to a different environment (Prosser, 1964 p 20) and we might add to this that the acclimated animal may differ physiologically from the acclimatized animal (Héroux and Brauer, 1965 p 597). Thus we would expect that an animal exposed to cold would develop measurable differences which would enable it to function better at lower temperatures than the non-adapted animal. From a behavioral point of view this is indeed the case, for the cold adapted fish can swim in ice water when it could not prior to adaptation, and the Eskimo can handle cold wet fish nets that would be beyond the tolerance of the non-adapted individual (Prosser, 1964 p 20). Scholander, et al. (1950 in Irving, 1964 p 373) kept several arctic glaucous gulls (*Larus hyperboreus*) outdoors through the winter at Pt. Barrow, Alaska in good health. One of these gulls which had been permitted inside of the warm laboratory, escaped onto the snow at -20°C, and when recaptured one minute later, was found to have frozen parts of its feet. During its time indoors it had lost its ability to withstand the cold. Since these subjective observations involve nervous adaptations (Prosser, 1964 p 20) one would expect to find changes in peripheral nerve conduction reflecting this condition.

Studies related to peripheral nerve conduction go back as far as the 1770's when the Italian physician Luigi Galvani and his wife Lucia, observed that the leg of a frog could be made to twitch if certain parts of the animal were touched simultaneously with the ends of two different pieces of metal joined together (Casey, 1962 p 263). In 1848 du Bois-Reymond (in Brazier, 1959 p 22) discovered the nerve action potential by improving upon the galvanometer used by Matteucci, who laid the groundwork for investigations in muscle electrophysiology. In 1852 von Helmholtz (in Johnson and Olsen, 1966 p 2) measured the conduction velocity of the median nerve in humans, obtaining results similar to those obtained today, but the physiologists had to wait for the invention of the cathode ray oscilloscope to obtain accurate and direct measurement of nerve responses (Katz, 1966 p 12).

The oscilloscope was first used for physiological investigations of nerve responses by Gasser and Erlanger in 1922 (Brazier, 1959 p 24) and in 1928 Gasser (in Wagman and Lesse, 1951 p 243) used it to show that the conduction velocity in the phrenic nerve of the dog was decreased by cooling. In 1948 Chatfield, et al. (in Hensel and Hildebrandt, 1964 p 58) found an increased resistence to cold along the nerves supplying the bare peripheral portion of the legs of the herring gull (Larus argentatus). When the birds were maintained in a cold environment, the metatarsal nerve, tested in vitro, conducted down to a significantly lower temperature than did the tibial segment. They also found that the temperature at which the maximum height of the compound action potential occurred was shifted to a lower level.

In 1965 Petajan and Daube found that when the arm and hand were immersed for 15 minutes daily in a 10°C water bath, median nerve conduction velocity in one subject progressively increased over a period of approximately 6 weeks. This was taken to indicate an adaptation to cold.

In 1967 (p 1295) Miller and Irving conducted studies on excised caudal nerves in muskrats from Alaska and Louisiana. They found that the conduction velocity was higher in the nerves of the Louisiana muskrats (Ondatra zibethicus rivalicus at temperatures higher than 5°C, and that this difference increased with increasing temperature. At temperatures of 15°C and below, however, the excitability of the nerves of Louisiana muskrats was significantly less than that of the Alaskan muskrats (Ondatra zibethicus zalophus).

Petajan (1968 p 130) studied changes in conduction velocity in rat ventral caudal nerves in vivo during cold exposure. He found that the most notable decreases in conduction velocity occurred at temperatures above 20°C, but that with continued exposure of the animals to cold, the nerve function returned to normal. He also studied the effects of cold upon digital nerves in normal human subjects, who exposed their hands to a 5°C bath for 15 minutes (Petajan, 1968 p 597). Results showed a uniform slowing of conduction velocity of 1.4 m/sec/degree in all subjects. In these subjects with a short exposure time, the recovery of nerve conduction velocity depended entirely upon the rate of finger rewarming, and in no case was conduction velocity at normal temperatures affected by the previous short experimental cold exposure. In similar tests performed on high altitude mountaineers after severe exposure to cold and high altitude, however, conduction velocity was not only decreased in those members who did not sustain freezing injury during the climb, but in those who sustained freezing injury there was a marked impairment of conduction velocity along with loss of pain, light touch and temperature sense. It is significant, from the standpoint of cold adaptation, that the loss of sensitivity to heat was greater than the loss of sensitivity to cold.

In summary then we see that skin temperature measurements are significant because digital temperatures are limiting with respect to performance, that measurements of reflex action as an indication of thyroid function are significant as a reflection of metabolic response and that nerve conduction velocity measurements are significant in that they reflect upon the organism's ability to perform motor and sensory functions. It has further been illustrated that the parameters of peripheral vascular changes, metabolic response and motor and sensory function all reflect the organism's degree of adaptation to its environment.

METHODS

To obtain experimental subjects 5 schools were selected, upon the recommendation of the school authorities, that would provide a broad cross section of different racial and economic groups. These consisted of Hunter, University Park and Adler elementary schools, Main Junior Highschool and Lathrop Highschool, all within the Fairbanks, School District. In addition, the school children of the Village of Old Crow, Yukon Territory, Canada were chosen. These children would provide not only a culturally and genetically more homogeneous group because of their isolated location, but would provide a group, for comparison with local children, which has had many generations of cold exposure experience. Testing was started on 25 October 1966.

Initially, at each school, but on different dates, skin temperatures and capillary filling times were taken on students selected at random as they arrived in the morning. All measurements were taken outdoors prior to the student entering the building. This system had two subsequent disadvantages. First the school bus service was improved and very few students walked to school any longer. Second, among those who did walk there was a great disparity in both exposure time and the amount of exercise indulged in *en route*, thus making comparisons difficult. In consequence, arrangements were made to perform these tests on members of outdoor physical education classes, or during recess periods, where both exposure time and activity could be more closely controlled.

The following information was obtained from the student on a portable tape recorder for transcription to a record book at a later time: name, age, sex, length of residence in Fairbanks in months, length of time outdoors just before the measurement was taken (exposure time), thumb temperature at the distal pad, forefinger temperature at the distal pad, little finger temperature at the distal pad, nose tip temperature, cheek temperature and capillary filling time. The name of the school, date, air temperature and wind velocity were also recorded, and wrist temperatures taken over the radial artery were included in later tests. Evaluation of winter dress was made as a subjective judgement of light, medium or heavy, based upon the opinion of the single observer. Verbal recordings were made with a Craig portable tape recorder, which was carried under the observer's parka to keep it from freezing. The microphone cord was extended through the neck of the parka.

Skin temperatures were taken with a Yellowsprings model 46-TUC thermometer equipped with a disk thermister 5 mm in diameter. The disk was mounted on the end of a piece of glass tubing. A spring loaded handle of glass tubing of a larger size rode over the piece holding the thermister (Figure 3). This arrangement permitted application of a constant pressure of 45 g, $\pm$ .5 g, against the skin. Periodic spot checks showed this pressure to hold constant throughout the entire testing period. When skin temperature measurements were repeated immediately the same results were obtained to within .2°C, however, the skin temperature normally showed a steady drop during cold exposure without exercise.

Capillary filling time was measured by having the subject place his forefinger on his cheek over the zygomatic bone, in the area just below

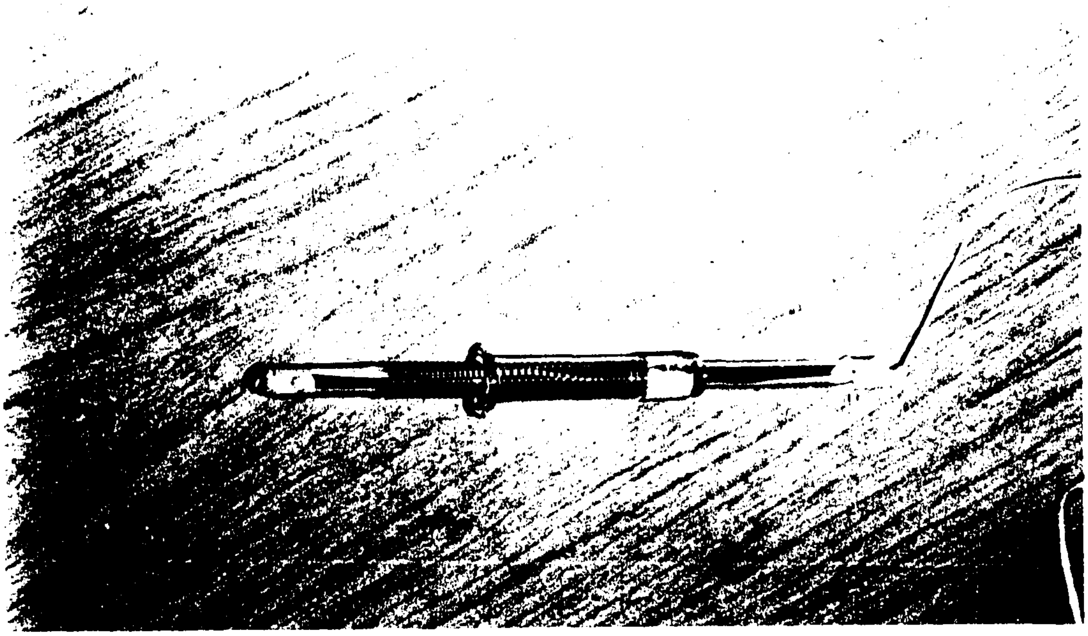

Fig. 3. The thermister for taking skin temperatures was secured to a spring loaded glass rod to assure constant pressure

the outer edge of the orbit. The subject applied firm pressure with his finger tip, squeezing the blood from this area. At a given signal the finger was removed, and the time required for the pressured area to regain normal coloration was recorded using a stop watch which measured the elapsed time to within one tenth of a second. Measurements, however, were probably only accurate to within $\pm$ .5 second since the return to normal coloration was a subjective observation and as such would tend to vary slightly.

It was recognized that the method described for obtaining peripheral skin temperature and capillary filling time measurements would be very difficult to correlate with age, sex, ethnic and residence groups because of variation in the outdoor air temperatures and wind velocities to which each group would be exposed. On the other hand, while use of an environmental room at a constant temperature would remedy this situation, it would not be an ideal solution to the problem. One purpose of this study was to obtain some indication of how young people respond to the environmental extremes to which they are naturally exposed in the Fairbanks area. Such information is not ideally obtained in an environmental room. Some of the skin temperature and capillary filling time measurements were taken at an outdoor air temperature of -44°C, and while parents will permit their children to be exposed to such temperatures under natural conditions out of doors, the children could not be deliberately exposed to such conditions in an environmental room. Use of an environmental room would further require the skin temperature and capillary filling time measurements to be taken outside of school hours on large numbers of children.

This would have involved timing, facility and transport problems which would have been incompatible with the scope of this study. One more important factor exists regarding the use of an environmental room. In cases where skin temperatures were taken simultaneously with nerve conduction measurements, but on the opposing hand, it was observed that finger temperatures differred considerably from those taken outdoors at air temperatures similar (-1.1 to 1.1°C) to that used in the environmental room. This may be an indication that some psychological factor influences results in the environmental room, or it may have been a result of anticipation of the nerve stimulation.

Air temperature was obtained using a Taylor mercury bulb thermometer. Temperature and wind velocity were obtained from the U.S. Weather Bureau for comparison, but the temperatures obtained at the site of observation are the ones which have been used.

An indication of thyroid function was obtained by measurement of the half relaxation time (HRT) of the myotatic stretch reflex of the triceps surea muscle, which is elicited by the blow of a reflex hammer. The reflex response was recorded from a Burdick Photomotograph model FM-1, which records the speed of the foot movement during the muscle relaxation phase after its reflex contraction. The HRT is measured in milliseconds, and the time parameters of the reflex were recorded graphically on moving tape on a standard electrocardiograph with a tape speed of 50 mm per second (Petajan and Watts, 1962 p 240-241). At this tape speed one scale division is equal to 20 milliseconds. The manner in which the HRT was measured is illustrated in Figure 4.

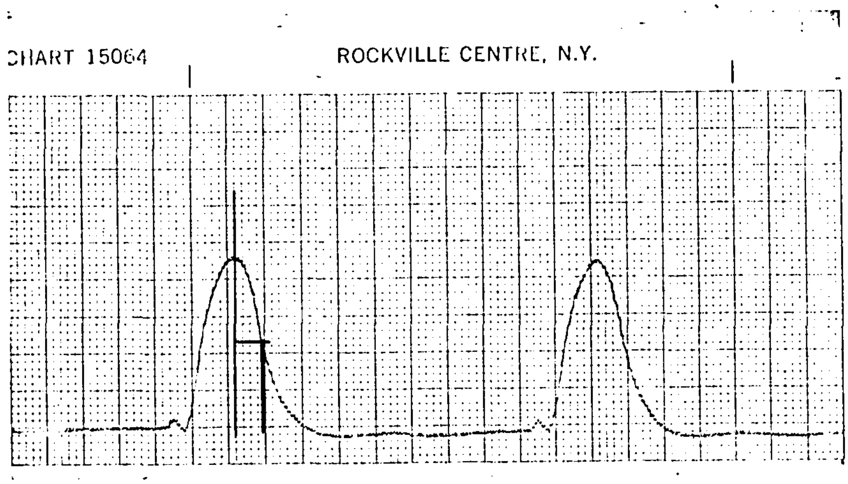

Figure 4. Method used in calculating HRT. (1) Extend base line across base of reflex curve, (2) From base-line measure height to highest point on reflex curve and drop a perpendicular line from this point to the baseline, (3) Divide this height by 2 and draw a horizontal line from this point to the descending portion of the reflex curve, (4) Drop a perpendicular from this point to the baseline, (5) The HRT is measured in m/sec from the interrupted baseline (caused by the strike of the hammer) along the baseline, to the perpendicular dropped in (4). This distance is measured with a Burdick phomotogram scale in which 1mm is equal to 20 m/sec. The first small peak in the diagram is caused by the hammer blow. From the base of the descending portion of the small peak to the highest portion of the large peak is the contraction phase of the reflex curve and from this point to the base line is the relaxation phase of the reflex curve.

There has been some question among investigators as to whether the contraction phase, or the relaxation phase of the Achilles reflex contributes most to the evaluation of thyroid function. Lawson (1958, _in_ Nuttall and Doe, 1964 p 272) has found the contraction phase more sensitive to thyroid activity, however, he also found this phase to be influenced by the administration of salicylates, adrenocorticotrophic hormone, (ACTH) cortisone, estrogens, thiourea compounds, perchlorates and bromides, while Goldberg (1962 _in_ Nuttall and Doe, 1964 p 286) found the contraction phase to be altered following an injection of 0.5 mg of epinephrine. On the other hand, Nuttall and Doe (1964 p 284) found the last part of the contraction phase and the first part of the relaxation phase to correlate best with thyroid function tests, and they further found this measurement to be less influenced by drugs than the contraction phase of the reflex alone.

Although there are a variety of methods by which to measure the Achilles reflex, the HRT was chosen for the following reasons: It included the contraction as well as part of the relaxation phase of the reflex, which, as indicated above, contributes to the overall accuracy; it is easy to measure with reasonable accuracy; it is considered to be one of the best measurements by a majority of investigators (Nuttall and Doe, 1964 p. 283-284) and using this method facilitates comparison with other work in this field.

It has been shown in Figure 4 that the measurement of HRT in this study, is actually a measurement to HRT, and includes all of the reflex activity beginning with the blow of the reflex hammer, through the contraction phase to the HRT. Although the nerve response is included in this measurement, this study was conducted using a relatively large number of presumably normal young subjects, and it was consequently felt that any nervous disorders of a nature which would effect the HRT measurement would be absorbed in the large sample. It may also be noted, in this regard, that Sherman, Goldberg and Larson (1963 in Nuttall and Doe, 1964 p 285) studied 21 patients with different neuromuscular disorders and found no significant alteration in reflex measurement except for 2 patients with severe paralysis agitans.

Results obtained using the HRT measurement and the photomotograph seldom varied more than 30 milliseconds in a single individual when good reflex responses were obtained. Measurements were made to the nearest 10 milliseconds using the Burdick photomotogram scale.

Photomotograms were obtained during indoor physical education classes. Measurements were taken at room temperature, but skin temperatures of the leg or ankle were not obtained. The subject was seated and gave his name, age and length of residence. His ethnic group and sex were noted on the ECG tape by an assistant. The subject's pulse was then counted over a 10 second interval. He was then required to remove his right shoe, and kneel on the chair with both knees, while grasping the back of the chair with both hands (Figure 5). The Achilles tendon was tapped and the reflex recorded on the ECG tape. Results were normally recorded as a mean of 5 reflex responses.

The warm up effect of exercise has been shown to decrease the HRT of subjects in good physical condition, presumably by increasing utilization

Fig. 5. Position assumed by subject for HRT measurements

of thyroid hormone, while in untrained subjects the HRT is unaffected (Petajan and Eagan, 1968 p 16). Consequently, measurements of HRT were taken after controlled exercise as well as in a resting state, to serve as an indication of the subject's state of physical conditioning. Because muscular efficiency (which is enhanced by physical training) effects heat production (Bard, 1961 p 541 and Zierler, 1961 p 986-988) it was anticipated that results of this comparison could be correlated with cold adaptation.

As noted above, cold has been shown to affect nerve function in the cooled extremities of birds and mammals. In consequence, it was felt that peripheral nerve conduction velocity would serve as an indicator of adaptation to cold. To assess this the conduction velocity of the median nerve of the forefinger was studied. This area was chosen because the fingers are known to function in temperature regulation, the fingers are often exposed to the prevailing environment and in the forefinger the median nerve runs close to the surface of the skin, permitting a closer approximation of its temperature using sensors attached to the skin. A Teca model J oscilloscope-stimulator apparatus was used to obtain the nerve response, and the results were recorded from the oscilloscope screen using a polaroid camera attachment. The hand was wired in the manner described by Petajan (1968 p 597) which is illustrated in Figure 6. In regard to this method, the question has arisen concerning whether or not the strength of the supramaximal stimulus could cause the stimulus peak to shift from its measured position, i.e. if the finger stimulating electrodes were placed 4.0 cm distance from each other, could the strength of

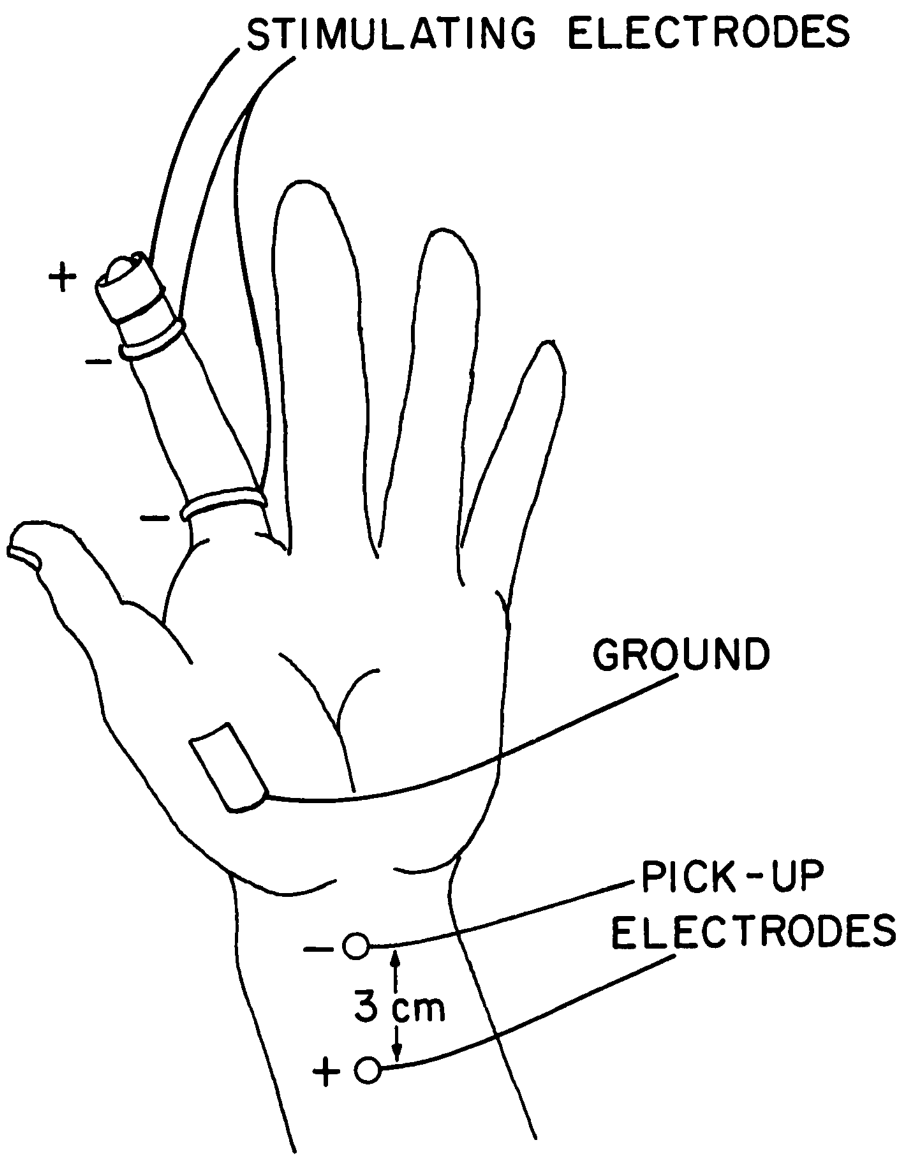

Fig. 6. Wiring diagram used to obtain median nerve conduction velocity measurements from the forefinger

the stimulus shift the stimulus peak so that it would be representing a distance of perhaps 3.5 cm between electrodes on the oscilloscope screen.

It is clear that where the field of a stimulus is great, the chance of displacement is great, and where the field is small the chance of displacement is small. In this case, the finger volume is small, the diameter of the electrodes is small (roughly 1mm) and the electrodes are close to the nerve. Under these conditions there is no reason to expect the nerve to be stimulated first at a point of lower intensity stimulation.

Because it would be difficult to conduct such studies under natural outdoor conditions, measurements were obtained from each subject at both room temperature and under a controlled temperature of 0°C in an environmental room (Figures 7 and 8). The equilibrium time in both cases was not less than 12 minutes, although at times it was as long as 20 minutes, when difficulty in eliminating electrical interference was encountered. For the environmental room phase, the subjects were dressed as they would be for normal outdoor activity, except that the hands were uncovered. The temperature of 0°C was chosen for the environmental room because the studies of Petajan and Daube (1965 p 49), Miller and Irving (1967 p 1295-1296) and Petajan (1968 p 597) indicate that this degree of stress would be sufficient to elicit a reasonably rapid nerve conduction response, i.e. within the equilibration time used. At the same time it would not cause the subject undue discomfort.

The skin temperature of the finger being studied was monitored concurrently with skin thermisters attached to a Yellowsprings model 46-TUC

Fig. 7. Subject prepared for median nerve conduction velocity measurements at room temperature

Fig. 8. Subject prepared for median nerve conduction velocity measurements in the environmental room

thermometer. In some instances facial skin temperatures at the cheek and skin temperatures from the forefinger, little finger, thumb and wrist of the other hand were monitored with thermocouple sensors connected by leads to a Leeds and Northrup Speedomax recorder.

Typical examples of the nerve responses obtained under the foregoing conditions are shown in Figures 9 and 10. As can be seen from the traces shown on the photograph, repeatability of the results is good. Where the trace was not distorted by mechanical, or electrical interference, the results were consistent to within 2 milliseconds. The method used to calculate the conduction velocity is shown in Figure 11.

While the methods outlined above were applicable to studies conducted in the Fairbanks area, in studies conducted at the Indian Village of Old Crow, in the Yukon Territory, lack of facilities required a bit of improvising. During the summer experiments, which were conducted during the period from 7 to 13 August 1968, the Village ice house was used as the controlled temperature environmental room. The temperature inside of this log structure varied only 2°C, i.e. between 5°C and 7°C during use. This permitted a cooling stress somewhat comparable to that achieved in our environmental room. Room temperature experiments were conducted in the office of the school principal, which was comparable to room temperatures used at Fairbanks.

During the winter testing at Old Crow (conducted between 28 January and 1 February 1969) the outdoor air temperature ranged between -34.4°C and -51.1°C which precluded any outdoor exposure of either equipment or uncovered extremities. In consequence, the cold portion of the testing

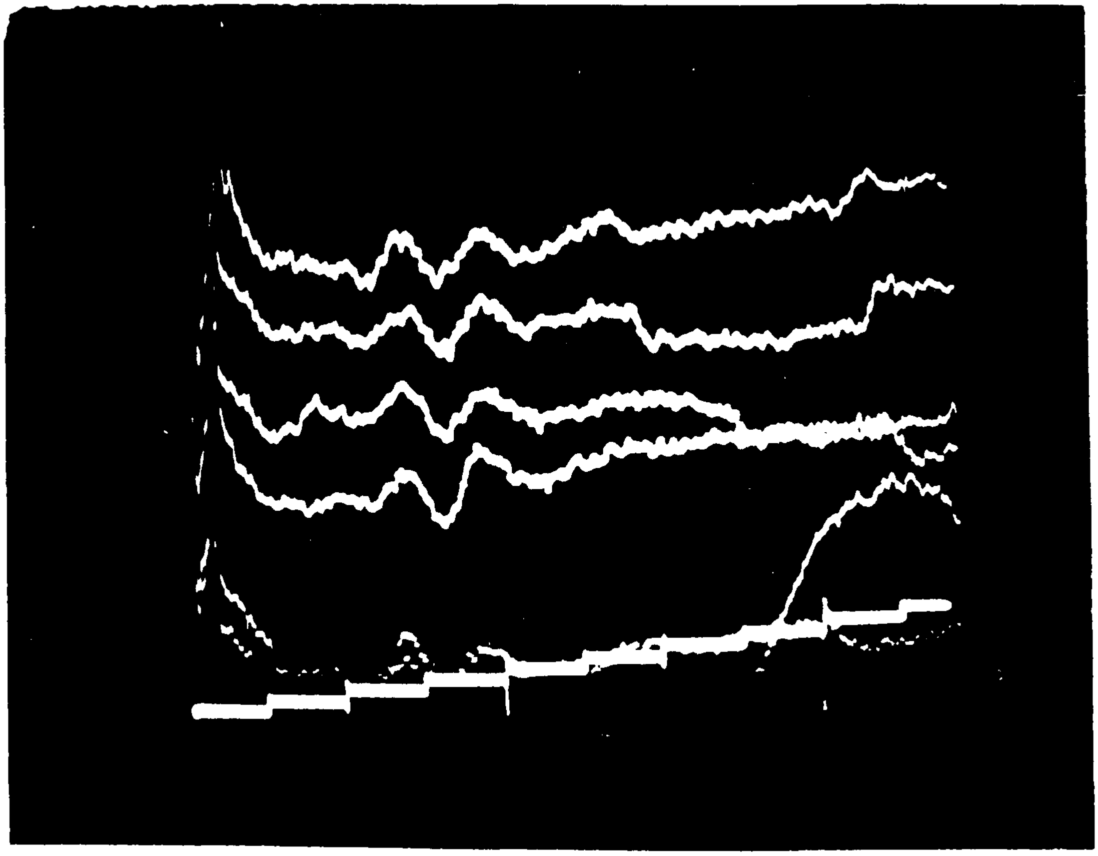

Fig. 9. Oscilloscope trace of median nerve in the forefinger obtained at room temperature

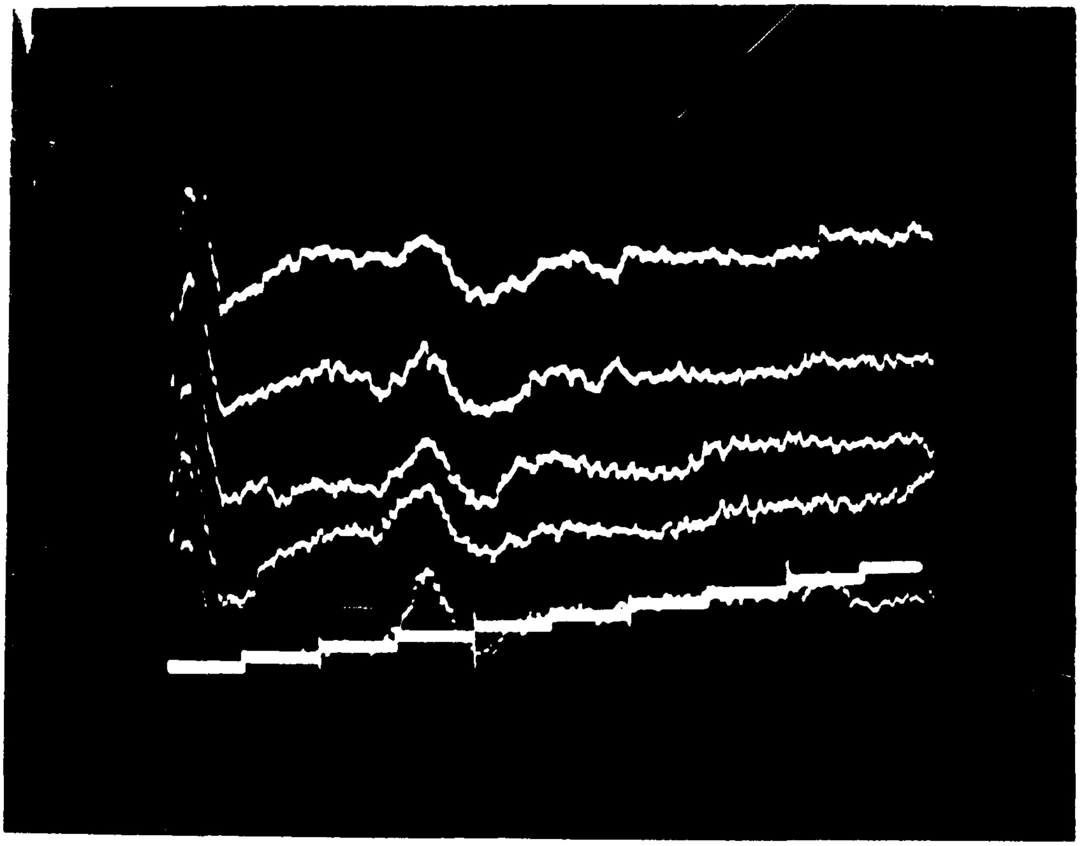

Fig. 10. Oscilloscope trace of median nerve in the forefinger obtained in the environmental room

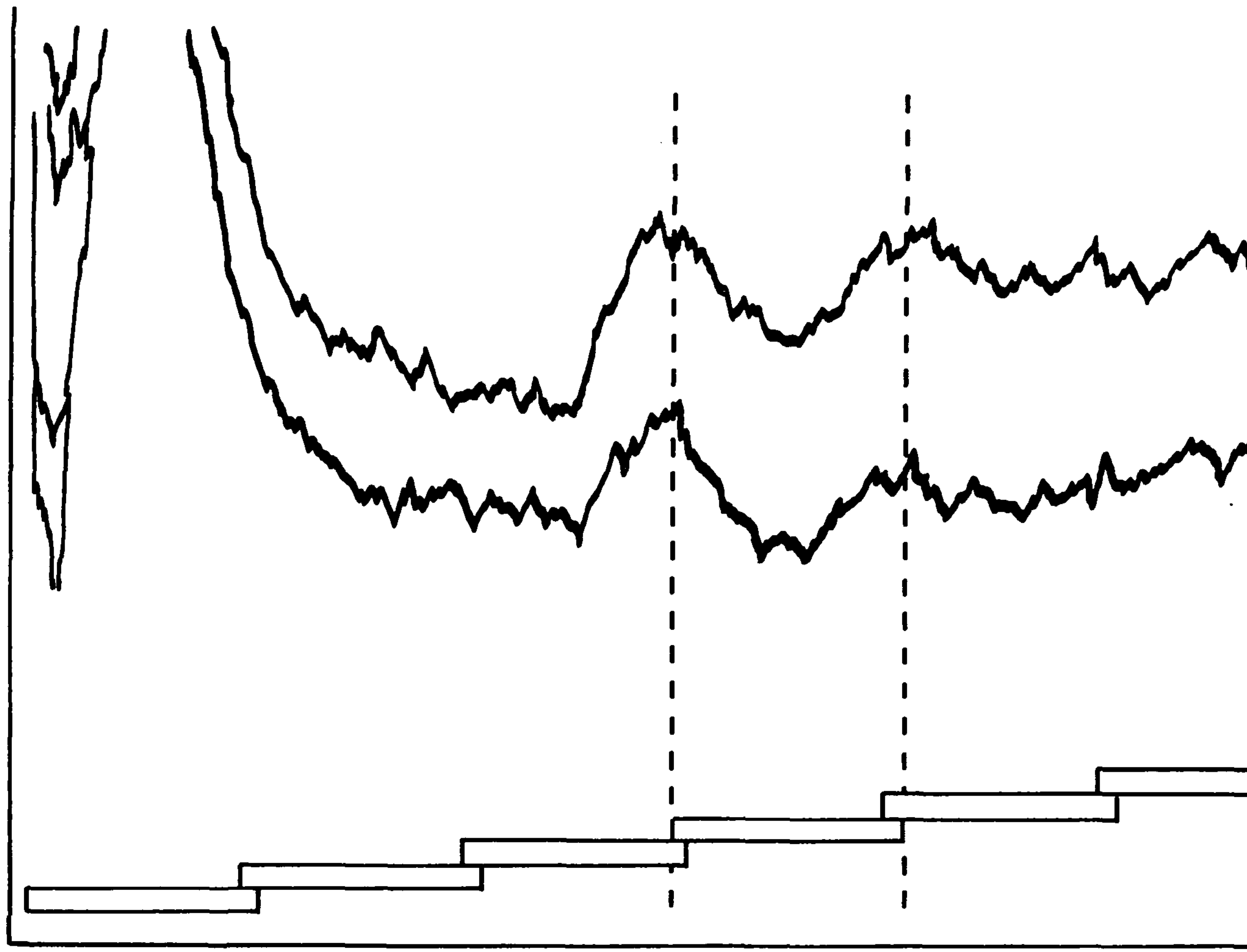

Fig. 11. Vertical lines are dropped from the 2 peaks to the calibration marks below (30 and 41 msec respectively). The difference between these 2 intercepts, i. e. 11 msec., is divided into the measured distance between the 2 electrodes on the finger (4.3 cm) giving a conduction velocity of 39.0 m/sec

was conducted in the following manner:

The subject was seated next to a window in the school building, with his hand wired as described. A thermister was taped to the skin of the forefinger being measured on the side facing the thumb, at the second joint over the median nerve. When prepared for stimulation the window was opened and the subject placed his hand outside, between blankets which were thrust into the remaining space to keep the cold from entering. The skin temperature, which dropped very rapidly, was monitored on the Yellow-springs thermometer by an assistant. On cold days the hand was kept outside until the skin temperature approached 20°C before stimulation of the nerve was started and the record taken, but even at this, the skin temperature dropped so rapidly that by the time the record was obtained the finger temperature sometimes approached 0°C. Due, however, to the discomfort of the subject and the consequent muscular movements, useable records were not generally obtained at finger temperatures below 8°C. Since it was felt that this method of cold exposure might differ enough from the exposure in the environmental room at 0°C to effect results, control experiments were conducted using this method at Fairbanks. Conduction velocities obtained at given finger temperatures using this method were not significantly different from those obtained in the environmental room at the same finger temperatures.

During the winter testing the school was again used for the room temperature measurements, and again, the room temperatures at Old Crow were similar to those used in Fairbanks.

In all measurements of nerve conduction velocity in which the subject was exposed to cold, blood pressure measurements were taken (from a sitting position) before and after exposure to assess the degree of cold pressor response.

RESULTS

Peripheral Skin Temperature Measurements

For measurements of peripheral skin temperature and capillary filling time, as well as for measurement of half relaxation time and nerve conduction velocity, an attempt was made to separate the experimental subjects into 3 basic groups according to physiological age. This breakdown included a childhood group, a puberal group and a post puberal, or young adult group. In the case of peripheral skin temperature and capillary filling time measurements, the chronological age breakdown reflecting these 3 basic groups was established initially at 6 through 9 years of age for the childhood group, 10 through 14 years of age for the puberal group and 15 through 19 years of age for the post puberal group. Although this breakdown gave statistical advantages to the relatively modest sample size of 355 subjects, it was not found to provide the best representation of the physiological age groups defined above. Nelson (1964 p 32) defines puberty for females as falling between the ages of 8 and 13, and puberty for males as falling between 10 and 14 years of age. The 5 through 9 year breakdown would consequently be expected to contain a few puberal females, and the 10 through 14 year age group could be expected to contain a significant number of prepuberal and puberal males and females. A subsequent chronological age breakdown was therefore established which was felt to be better representative of physiological age. In this breakdown a childhood group was comprised of subjects 6 through 8 years of age, a prepuberal group of subjects 9 through 11 years of age, a puberal group of subjects 12 through 14 years of age and a post puberal group of subjects 15 through 19 years of age.

As noted previously, results of peripheral skin temperature and capillary filling time measurements were very difficult to handle because for each age, sex, ethnic and residence group, there was a difference in the outdoor air temperature at which the measurements were taken. Direct comparison of peripheral skin temperatures and capillary filling times between these groups, consequently could not be made without some sort of adjustment for air temperature variation. To partially accomodate this problem, a selection of age and sex groups was made from meaurements obtained at fairly consistent temperatures, _i.e._ among the groups compared, the range of outdoor air temperature did not exceed 5°C. Comparisons of age groups resulting from this selection are shown in Tables 1A and 1B.

The small sample size, in each age group, which resulted from selection on the basis of temperature consistency, made testing for statistical significance a most improbable venture. Still, as shown in Table 1A a significant difference ($P<.05$) exists between the 12 through 14 and the 15 through 19 year age groups, and with a sample size of only 10 a $P<.2$ exists between the 6 through 8 and the 15 through 19 year age groups.

The value of the data lies perhaps not in statistical significance, but more in the consistent patterns observed between measurements comparing age groups exposed to reasonably consistent air temperatures and measurements comparing age groups exposed to wide variation in air temperature, which are shown in Tables 2A and 2B. In such a comparison it is seen that the relationships between age groups, with regard to finger temperature, are quite similar whether or not adjustment has been made for variation in outdoor air temperature. In each case the younger subjects show a lower finger temperature than the older subjects. This general pattern of increasing finger temperature with age also holds true for Negro and Alaska Native groups (Tables 3A and 3B). The only deviation from this pattern is seen during the puberal years among the resident ethnic groups and during the prepuberal years among the non-resident Caucasians, where the mean finger temperature drops to near the level of the 6 through 8 year age group, or in some cases below it. There is even a tendency for this characteristic to go against the temperature gradient, _i. e._ in Table 2 A the 6 through 8 year age group is exposed to a mean outdoor air temperature of -16.8°C and the 12 through 14 year group is exposed to a mean outdoor air temperature of -15.5°C, and yet the mean finger temperatures are almost the same (13.2 vs 13.7°C). In Table 4A the mean air temperature for the 12 through 14 year age group is higher than it is for the 9 through 11 year age group, and yet the mean finger temperature for the 12 through 14 year group is lower.

Although the sample size is again very small, further evidence showing the increase of finger temperature with age is observed in measurements

TABLE 1A. Winter Skin Temperature Measurements of Resident Caucasians, Temperature Range 5°C.

N	Age	Mean Air Temperature	Mean Face Temperature	Mean Finger Temperature	Std. Dev. Mean Finger Temperature
2	6-8	-26.1°C	10.8°C	7.1°C	1.2
2	9-11	-26.1°C	10.6°C	7.4°C	0.8
38	12-4	-25.9°C	10.3°C	10.5°C	5.1
				P>.05	
8	15-19	-26.3°C	10.4°C	16.0°C	7.3

TABLE 1B. Winter Skin Temperature Measurements of Resident Caucasians, Temperature Range 5°C.

6	6-8	-19.8°C	17.1°C	14.3°C	9.2
7	9-11	-20.0°C	22.0°C	16.5°C	8.9
8	12-14	-21.1°C	12.6°C	11.9°C	4.7
4	15-19	-20.3°C	12.7°C	18.0°C	10.1

TABLE 2A. Winter Skin Temperature Measurements of Resident Caucasians, Temperature Range 32.2°C.

21	6-8	-16.8°C	14.9°C	13.2°C	7.6
27	9-11	-13.3°C	18.0°C	16.0°C	6.3
104	12-14	-15.5°C	14.2°C	13.7°C	5.8
53	15-19	-12.4°C	16.7°C	15.9°C	5.6

TABLE 2B. Winter Skin Temperature Measurements of Non-Resident Caucasians. Temperature Range 31.1°C.

5	6-8	-21.9°C	8.6°C	9.3°C	8.1
9	9-11	-23.4°C	11.4°C	8.2°C	4.0
11	12-14	-15.0°C	13.2°C	15.3°C	5.9
7	15-19	- 7.6°C	18.6°C	20.2°C	4.6

TABLE 3A. Winter Skin Temperature Measurements of Alaska Natives, Temperature Range 30.0°C.

N	Age	Mean Air Temperature	Mean Face Temperature	Mean Finger Temperature	Std. Dev. Mean Finger Temperature
2	6-8	-20.6°C	13.0°C	8.8°C	6.7
4	9-11	-25.1°C	17.0°C	17.2°C	4.7
10	12-14	-17.2°C	16.8°C	16.2°C	4.8
8	15-19	- 9.0°C	19.2°C	17.3°C	5.9

TABLE 3B. Winter Skin Temperature Measurements of Resident and Non-Resident Negros, Temperature Range 31.1°C.

1	6-8	-30.0°C	7.3°C	6.1°C	1.6
11	9-11	-18.4°C	16.6°C	13.2°C	6.4
5	12-14	-23.5°C	12.4°C	9.5°C	5.5
2	15-19	- 6.7°C	20.9°C	21.7°C	2.3

TABLE 4A. Winter Skin Temperature Measurements of Resident Caucasian Males, Temperature Range 32.2°C.

11	6-8	-17.2°C	14.7°C	13.0°C	7.0
17	9-11	-14.0°C	18.3°C	16.3°C	7.0
54	12-14	-12.1°C	15.6°C	15.0°C	5.6
38	15-19	-13.2°C	16.2°C	15.3°C	5.9

P<.05 (between 5.6 in Table 4A and 5.7 in Table 4B)

TABLE 4B. Winter Skin Temperature Measurements of Resident Caucasian Females, Temperature Range 32.2°C.

10	6-8	-15.8°C	15.1°C	13.5°C	8.6
10	9-11	-12.0°C	17.7°C	14.7°C	5.0
50	12-14	-18.8°C	12.6°C	12.3°C	5.7
15	15-19	- 9.1°C	17.8°C	17.2°C	4.7

of forefinger temperature obtained in the environmental room just prior to electrical stimulation of the nerve (Tables 5A and 5B). Here the air temperature was constant at 0°C ±.5°C, and the subjects were dressed similarly. The exposure time normally varied between 12 and 15 minutes, but in a few cases between 12 and 20 minutes. It should also be mentioned that in the environmental room, forefinger temperatures were taken at the second joint on the outside surface over the median nerve, while the outdoor finger temperature measurements were taken at the distal pad. Further, the hand was wired for nerve conduction velocity measurements as shown in Figure 6, and although the wires may have slightly restricted blood flow, all subjects were tested under the same circumstances. Although statistical significance is lacking, the persistence of the same age related finger temperature pattern is indicative of a real relationship between these two factors. It is noted in Table 5A that during the spring the low temperature pattern (which has been associated above with the puberal years) has shifted from the 12 through 14 year age group, as seen in Tables 1B, 2A, 3A, 3B, 4A and 4B to the 9 through 11 age group in Tables 1A, 2B and 5A, revealing that both patterns exist independent of air temperature.

Because of the small sample size among other groups, male *versus* female comparisons for the representative age groups could be made only for resident Caucasians. Results of this comparison are shown in Tables 4A, 4B, 5B and 6B. Male *versus* female comparisons were also made, without regard to age breakdown, within all ethnic groups, both resident and non-resident. When the finger temperatures which were taken over a wide

TABLE 5A. Environmental Room Measurements Comparing Seasonal Forefinger Temperatures in °C of Resident and non-resident Caucasians.

	Resident Caucasian Winter			Resident Caucasian Spring			Non-resident Caucasian Spring		
Age	N	Mean Forefinger Temperature	Std. Dev. Mean Forefinger Temperature	N	Mean Forefinger Temperature	Std. Dev. Mean Forefinger Temperature	N	Mean Forefinger Temperature	Std. Dev. Mean Forefinger Temperature
6-8	2	12.7	3.8	7	15.4	7.7	3	13.2	1.1
9-11	4	13.2	5.3	6	13.1	2.4	1	9.7	0.0
12-14	4	14.0	2.7	4	13.9	4.5	4	17.0	4.4
15-19	22	14.4	3.4	15	15.5	3.5	3	17.2	3.5

TABLE 5B. Environmental Room Measurements Comparing Forefinger Temperatures in °C of Resident Caucasian Males and Females, Seasons Combined.

	Resident Caucasian Males			Resident Caucasian Females		
Age	N	Mean Forefinger Temperature	Standard Deviation Mean Forefinger Temperature	N	Mean Forefinger Temperature	Standard Deviation Mean Forefinger Temperature
6-8	2	14.4	3.7	6	16.6	7.2
9-11	4	12.5	5.7	6	13.6	1.8
12-14	2	12.2	0.3	6	14.5	3.8
15-19	13	15.5	3.3	24	14.5	3.5

TABLE 6A. Winter Measurements Comparing Mean Finger Temperatures of Resident Caucasian Males and Females, Age Groups Combined.

Sex	N	Outdoor Air Temperature Range °C	Mean Outdoor Air Temperature °C	Mean Forefinger Temperature °C.	Mean Finger Temperature °C.	Standard Deviation Mean Finger Temperature
Male	17	-24.4 to -27.8	-26.6	12.7	13.5	7.0 } $P<.05$
Female	33	-24.4 to -27.8	-25.7	9.3	9.9	4.6
Male	19	-18.3 to -21.1	-20.6	14.9	15.4	7.6
Female	6	-18.3 to -21.1	-19.4	13.1	12.4	9.0
Male	20	-15.0 to -12.2	-12.7	15.8	15.7	6.4
Female	12	-15.0 to -12.2	-15.0	12.9	13.5	3.4

TABLE 6B. Winter Measurements Comparing Age Related Mean Finger Temperatures of Resident Caucasian Males and Females

Resident Caucasian Males

Age	N	Range Outdoor Air Temperature °C	Mean Outdoor Air Temperature °C	Mean Finger Temperature °C	Std. Dev. Mean Finger Temperature
6-8	1	-24.4 to -27.8	-26.1	6.2	0.0
9-11	1	-24.4 to -27.8	-26.1	6.9	0.0
12-14	9	-24.4 to -27.8	-26.6	12.8	5.9
15-19	6	-24.4 to -27.8	-26.8	16.7	8.3

Resident Caucasian Females

6-8	1	-24.4 to -27.8	-26.1	7.9	0.0
9-11	1	-24.4 to -27.8	-26.1	7.9	0.0
12-14	29	-24.4 to -27.8	-25.7	9.8	4.7
15-19	2	-24.4 to -27.8	-24.4	13.7	4.6

range of outdoor air temperatures were compared, no consistent temperature pattern could be detected between the sexes. There was, however, a significant difference in mean finger temperature observed in the 12 through 14 year age group (which consisted of a larger sample than the others) showing the males to have a higher mean finger temperature than the females (Tables 4A and 4B). When male versus female comparisons were made (without regard to age breakdown) under conditions where outdoor air temperature range was limited to not more than 5°C, a consistent pattern showing males with a higher mean finger temperature was seen in all temperature groupings, and a significant difference was observed in the -24.4°C to -27.8°C temperature grouping (Table 6A). When these subjects were broken down into the representative age groups (Tables 5B and 6B) the females showed a warmer mean finger temperature in the younger age groups. While the males showed a higher mean finger temperature in the older age groups. The drop in finger temperature previously shown in the prepuberal and puberal groups is not evident in Table 6B.

In attempting to establish comparisons between ethnic groups, the basic problem is again the small sample size of the minority ethnic groups and the wide range of outdoor air temperatures at which the measurements were taken. Because of this problem all comparisons between ethnic groups are made without regard for age breakdown. The finger temperatures, face temperatures and capillary filling times obtained over wide ranges of outdoor air temperatures are shown in Tables 7A and 7B. Those obtained where outdoor air temperature variation was limited to not more than 5°C are shown in Table 8. It is seen that when the winter and spring measurements are combined the Alaska Native has the highest finger temperature, the resident Negro has the next highest and the resident Caucasian the lowest. During the winter season, however, the Alaska Native retains the highest finger temperature, with the resident Caucasian showing the next highest and the resident Negro the lowest. This latter pattern is evident whether or not limitations are placed upon variation in the outdoor air temperature. Although the results shown in Table 7A are not statistically significant, a comparison of the mean finger temperatures between Alaska Natives and resident Negros in Table 7B gave a $P<.1$. In Table 8, where the outdoor air temperature range was from -24.4°C through -27.8°C, a comparison between the Alaska Natives and the resident Negros resulted in a $P<.05$, and a comparison between resident Caucasians and resident Negros resulted in a $P<.1$.

For a comparison of residents with non-residents, a resident classification was established if a subject had resided in Interior Alaska for a period of one complete calendar year or longer. If the subject had resided in Interior Alaska for less than one complete calendar year, he was classified as non-resident. Because the sample size was so small among the minority ethnic groups, a comparison was attempted only between resident and non-resident Caucasians. In comparing these two groups, under conditions of a wide outdoor air temperature range, a pattern was observed wherein during the winter the 6 through 8 and the 9 through 11 year age groups showed a higher mean finger temperature among the residents than the non-residents. This situation was reversed, however, in the 12 through 14 and 15 through 19 year age groups, where the non-residents

TABLE 7A. Comparison of Skin Temperatures Between Ethnic Groups, Temperature Range Not Restricted.

Ethnic Group	N	Mean Outdoor Air Temperature °C	Range Outdoor Air Temperature °C	Mean Face Temperature °C	Mean Finger Temperature °C	Std. Dev. Mean Finger Temperature °C
Res. Caucasian	241	-11.8	50.6	16.4	16.0	6.6
Res. Negro	24	-10.0	50.6	19.2	16.7	8.4
Alaska Native	27	-10.9	48.4	18.4	17.1	6.1

TABLE 7B. Winter Comparison of Skin Temperatures Between Ethnic Groups, Temperature Not Restricted.

Res. Caucasian	206	-14.4	32.2	15.4	14.5	6.1
Res. Negro	15	-20.6	23.9	15.6	12.4	6.8
Alaska Native	24	-13.9	30.0	17.3	16.1	5.5

TABLE 8. Winter Comparison of Skin Temperatures Between Ethnic Groups, Temperature Range Restricted

Res. Caucasian	25	-20.6	-18.3 to -21.1	14.7	13.7	4.6
Res. Negro	3	-21.1	-18.3 to -21.1	18.9	15.6	3.7
Alaska Native	2	-19.4	-18.3 to -21.1	22.5	17.7	5.6
Res. Caucasian	50	-26.1	-24.4 to -27.8	10.4	11.1	5.7
Res. Negro	6	-26.1	-24.4 to -27.8	11.3	6.6	2.7
Alaska Native	4	-27.2	-24.4 to -27.8	13.5	11.8	3.1
Res. Caucasian	20	-13.3	-15.0 to -12.2	16.7	14.9	5.5
Res. Negro	1	-15.0	-15.0 to -12.2	17.6	9.7	0.4
Alaska Native	5	-13.3	-15.0 to -12.2	17.2	16.9	5.7

showed the higher mean finger temperatures (Tables 2A and 2B).

It is readily observed that in Interior Alaska neither the air temperature, nor the the photo period is indicative of spring by the 21st of March. Because of this, a designation of spring which was more compatible with sub-arctic conditions had to be established. Since distinct physiological changes were seen to occur among some subjects beginning about the 18th of April, this date was chosen to represent the beginning of spring in this study

During the spring season, under conditions of a wide variation in outdoor air temperature, the non-residents showed a warmer mean finger temperature in all age groups (Table 9) but in records obtained during the spring in the environmental room, the winter pattern was seen, _i. e._ the residents showed a warmer mean finger temperature in the younger age groups, and the non-residents a warmer mean finger temperature in the older age groups.

During the course of this study, the opportunity was taken to test a small group of mixed subjects in the 15 through 19 year age group during both winter and spring. The results are shown in Figure 12. Six of these subjects were the same individuals in both the winter and the spring test and therefore acted as their own controls. All subjects were dressed similarly for the winter test, and similarly for the spring test. For example, during the spring test all wore either a light skirt and blouse, or a light shirt and trousers, with no jackets, caps, or gloves. In each case they were engaged in the same activity, and were exposed to the same outdoor air temperature for a similar period of time. During the winter

TABLE 9. Spring Comparison of Skin Temperatures Between Resident and Non-resident Caucasians.

N	Age	Mean Outdoor Air Temperature °C	Mean Face Temperature °C	Mean Forefinger Temperature °C	Mean Finger Temperature °C	Std. Dev. Mean Finger Temperature
Resident Caucasians						
5	6- 8	13.3	23.5	20.2	20.3	1.6
9	9-11	20.6	30.0	29.0	28.8	3.0
4	12-14	14.4	24.5	21.3	21.3	0.3
16	15-19	7.8	22.6	20.6	20.7	4.2
Non-resident Caucasians						
4	6- 8	13.3	23.2	21.1	21.1	3.1
2	9-11	14.4	29.9	28.6	30.3	2.0
3	12-14	13.9	23.6	24.1	24.3	7.3
7	15-19	7.8	23.2	24.2	23.9	4.3

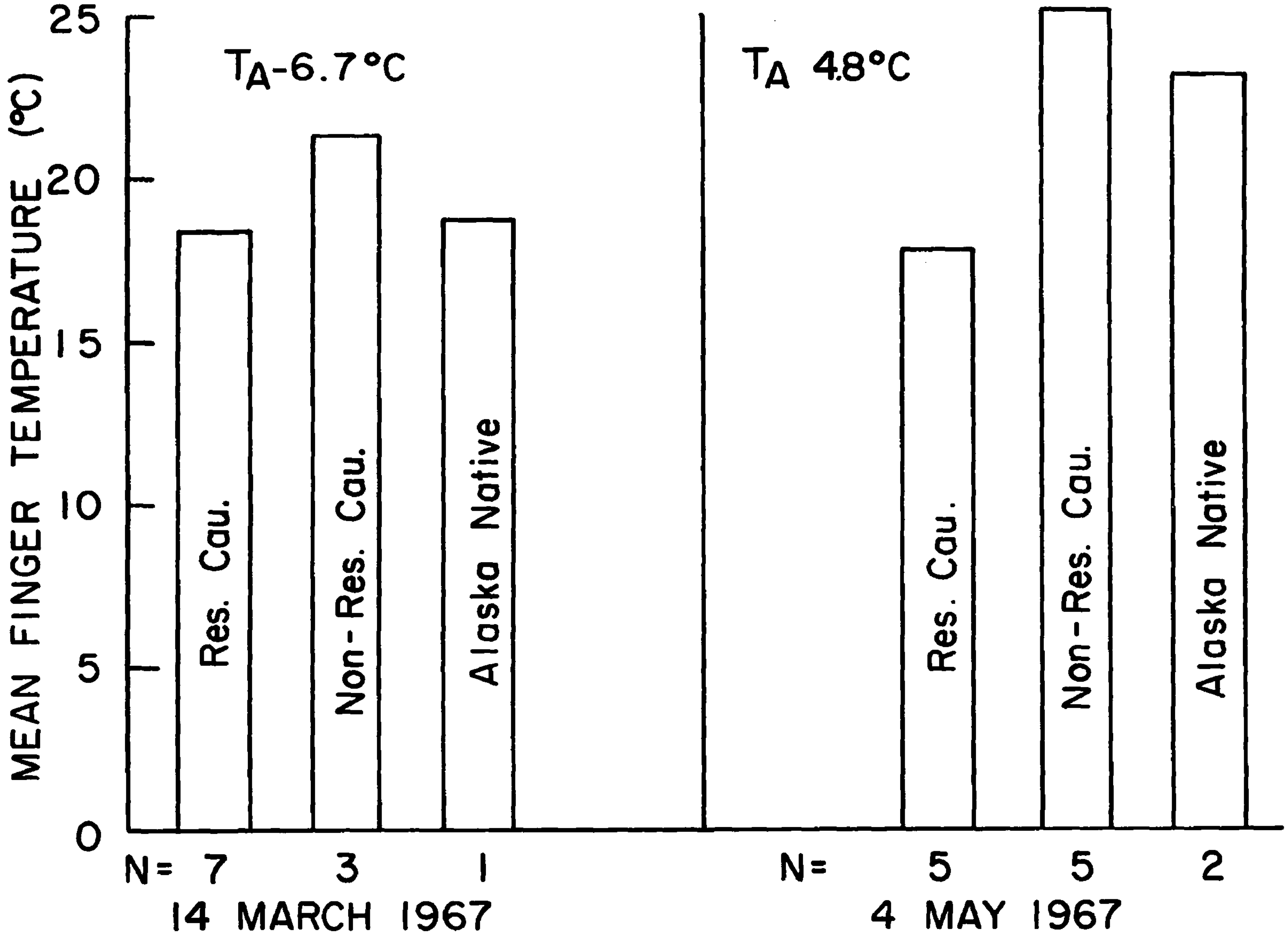

Fig. 12. Seasonal comparison of ethnic groups.

test the difference in mean finger temperature between residents and non-residents is not significant, but a highly significant difference ($P<.01$) was seen during the spring season.

Measurements of capillary filling time showed no consistent patterns, nor significant differences between any of the groups tested. The variations were large in this measurement as were the standard deviations, thus obviating their statistical value.

Where comparisons were made on the basis of age breakdown within major groupings, facial temperatures generally followed the same pattern as finger temperatures, however, the differences between age groups was not as evident in facial temperature measurements. Where ethnic groups were compared no consistent pattern was observed in the facial temperature measurements, but a tendency was observed to follow the finger temperature pattern.

In summary, the results show a rise in mean finger temperature with increasing age in all groups tested. There is evidence of a deviation from this pattern in the puberal, and in some cases the prepuberal age groups, where mean finger temperatures in these groups are low.

When the range of outdoor air temperature is limited to a variation of not more than 5°C, and all age groups are combined, consistent differences appear between males and females, with males showing the higher mean finger temperatures. When subjects are broken down into the representative age groups, the females show higher mean finger temperatures in the younger age groups and the males show the higher mean finger temperatures in the older age groups.

Differences between ethnic groups appear to have a seasonal basis. When spring and winter measurements are combined, the Alaska Native has the highest mean finger temperature, the resident Negro the next highest and the resident Caucasian the lowest. When winter measurements are recorded alone, however, the Alaska Native still has the highest mean finger temperature, but the resident Caucasian has the next highest and the resident Negro the lowest. The differences in these temperature measurements, however, are significant only during the winter between the Alaska Natives and Resident Negros.

Differences between resident and non-resident Caucasians appear to have both a seasonal and an age related basis. The younger age groups show a higher mean finger temperature among the residents than among the non-residents, but the older age groups show a higher mean finger temperature among the non-residents than among the residents. In the spring the difference between the residents and non-residents in the older age groups is greatly amplified with the non-residents showing a much higher mean finger temperature than the residents.

Since almost all measurements were taken in the field over a long time period, the great variation in outdoor air temperatures at which the measurements were taken made comparisons between groups difficult. For this reason, consistent patterns and significant differences between groups had to be supported by either similar results obtained in an environmental room, or similar results obtained from samples selected from a limited range of outdoor air temperatures.

Half Relaxation Time Measurements

Because of the small sample size in measurements of half relaxation time (HRT), as compared with peripheral skin temperature measurements, it was necessary to use the age group breakdown first described in order to obtain any sort of valid comparisons. In this breakdown the 5 through 9 year age group represented the childhood stage of life, the 10 through 14 year age group the puberal stage and the 15 through 19 year age group the post puberal stage.

The results of the half relaxation time (HRT) test, as an indicator of thyroid function, are shown in Figure 13 and Table 10. Resident Caucasian subjects showed a continuous increase in mean HRT with age. In the group which had exercised prior to testing, the difference between the 5 through 9 year age group and the 15 through 19 year age group was significant at the $P<.01$ level, the shorter HRT being manifested by the younger group. In the resident Caucasian group which was tested without having exercised, a similar pattern was seen, but the difference between the 5 through 9 year age group and the 15 through 19 year age group was not statistically significant ($P<.2$). In this case lack of statistical significance is probably influenced by the inadequate sample in the 5 through 9 year age group.

Among the Indian subjects from Old Crow, Yukon Territory, all of whom were tested without having exercised, the same pattern is evident. The statistical significance is a bit better, *i. e.* $P<.1$, however, an inadequate sample is again felt to contribute to the level of significance.

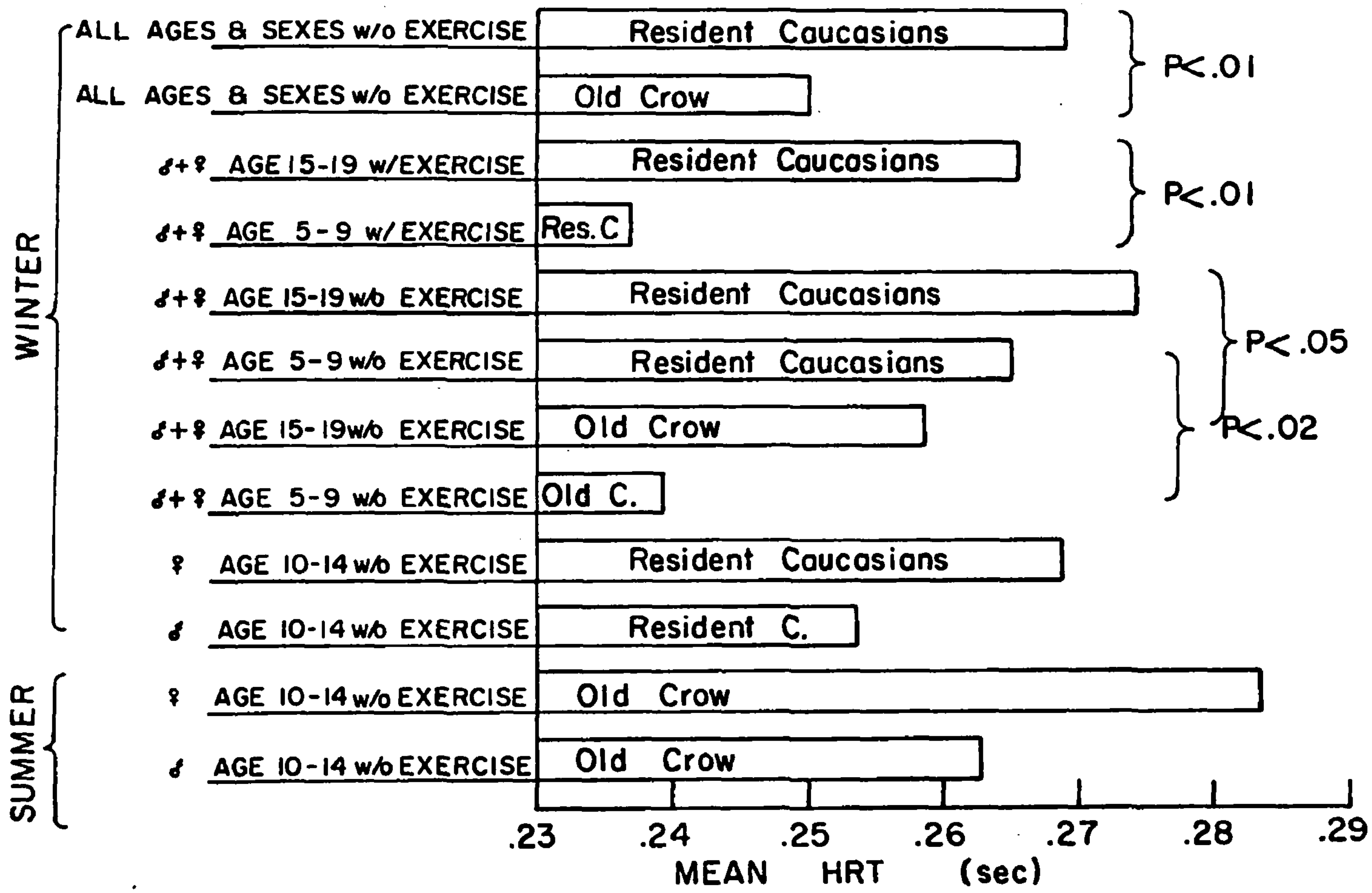

Fig. 13. Seasonal HRT comparison between male and female resident Caucasians and Old Crow Indians.

TABLE 10. Seasonal Mean HRT Comparisons Between Sexes and Ethnic Groups.

		Winter		Winter		Winter		Winter		Summer	
Age	Sex	Res. Cau After Exercise		Res. Cau. No Exercise		Old Crow Indian No Exercise		Non-res. Cau. No Exercise		Old Crow Indian No Exercise	
		N	Mean HRT(sec)	N	Mean HRT(sec)	N	Mean HRT(sec)	N	Mean HRT(sec)	N	Mean HRT(sec)
5- 9	M&F	31	.237	14	.265	14	.239			17	.250
5- 9	M	21	.239	6	.265	6	.234			6	.240
5- 9	F	10	.235	8	.265	8	.252			11	.256
10-14	M&F	48	.246	49	.263	12	.258			16	.275
10-14	M	28	.244	23	.254	3	.257			7	.263
10-14	F	20	.252	26	.269	9	.259			9	.283
15-19	M&F	19	.266	73	.275	8	.259			2	.295
15-19	M	14	.262	29	.275	7	.257			2	.295
15-19	F	5	.276	44	.273	1	.270			ø	ø
Combined Ages											
	M&F			141	.269	35	.251	20	.271		
	M			57	.266	19	.257	7	.270		
	F			84	.271	16	.246	13	.271		

The non-resident Caucasians showed virtually no difference in HRT between age groups.

Differences in the HRT between males and females are indicated in both the resident Caucasian group and the Old Crow Indian group, ($P<.1$), with males showing a shorter HRT than females. This difference, however, is most conspicuous in the 10 through 14 year age group, which encompasses the major portion of puberal males and females. It is interesting that among the Old Crow Indians the difference between sexes was conspicuous only during the summer period, while in the resident Caucasian group a sexual difference is indicated during the winter. With the present sample, however, one can only speculate as to what the resident Caucasian response would be during the summer season.

Differences between resident and non-resident Caucasians were not observed in a comparison of the group totals, nor in a breakdown of male and female subjects. Regrettably, the sample size for non-residents was not large enough to permit a breakdown and comparison by age groups.

Significant differences were observed in winter measurements between the two ethnic groups studied (resident Caucasians and Old Crow Indians) where neither group had exercised prior to testing. When all ages and the two sexes were combined for both groups, the HRT for the Old Crow Indians was significantly shorter, $P<.01$, than it was for the resident Caucasian group. This pattern persisted in comparisons of the 15 through 19 year old age group ($P<.05$), and in the 5 through 9 year age group ($P<.02$), but again the puberal group, 10 through 14 years of age, was unique in that significant differences between the two ethnic groups could not be detected.

Because a statistical number of resident and non-resident Caucasian subjects have not been tested during the summer, a comparison between ethnic groups on a seasonal basis is not possible. Among the Old Crow Indians, however, although the samples are not large enough to afford statistical significance, there seems to be a consistent trend toward an increased HRT during the summer. This trend is especially evident in females in the 10 through 14 year age group. There were not enough subjects of either sex in the 15 through 19 year age group to permit seasonal comparisons, but the trend observed in the small male sample in this age group may suggest that significant differences exist in this area.

Exercise was observed to shorten the HRT in all age groups tested; however, only resident Caucasians were tested immediately after controlled exercise. The pattern of a shortened HRT with exercise held true for males and females in each age group, except for the females in the 15 through 19 year age group. These subjects showed a shorter HRT in the non-exercise group than in the group tested after exercise. In regard to the effects of exercise, it is also interesting to note that even with exercise the resident Caucasians in the 15 through 19 year age group, did not come close to acquiring the shortened HRT that was manifested by the Old Crow Indians in the same age group without exercise.

Results obtained from taking the 10 second pulse rate prior to testing for HRT were not significantly different between any of the groups compared, nor were any consistent patterns observed within these groups. For such a measurement to be useful, it is felt that a tighter control of individual activity would be necessary than is readily obtainable in large physical education classes.

In summary, the results show that age, sex, exercise and ethnic group influence HRT, and that season may influence it. In all comparisons the Old Crow Indian group manifests a higher thyroid activity (as indicated by shorter HRT) than the Caucasians. The younger children manifest a shorter HRT than the older children. In almost all cases the male manifests a shorter HRT than the females.

Peripheral Nerve Conduction Velocity Measurements

Results of peripheral nerve conduction velocity measurements show that there is a consistent increase in nerve conduction velocity with age, among resident Caucasians and among Old Crow Indians. This increase in conduction velocity with age is seen both when measurements are taken at room temperature (25.0 $\pm$ 1.5°C) and when measurements are taken in an environmental room at 0°C $\pm$ .5°C. This correlation is highly significant, and is illustrated in Figures 14 through 17. In no case is the significance of the regression line slope less than $P<.01$. Each point on each graph represents an individual subject, and it can be seen that in each example that there is a slight drop in conduction velocity in the 12 through 14 year age groups. In the non-resident Caucasian group the sample is too small to permit correlation between nerve conduction velocity and age. It can be seen, however, from the distribution of points in Figures 18 and 19 that there is a trend in this direction, and that the highest mean nerve conduction velocity exists at 14 years of age,

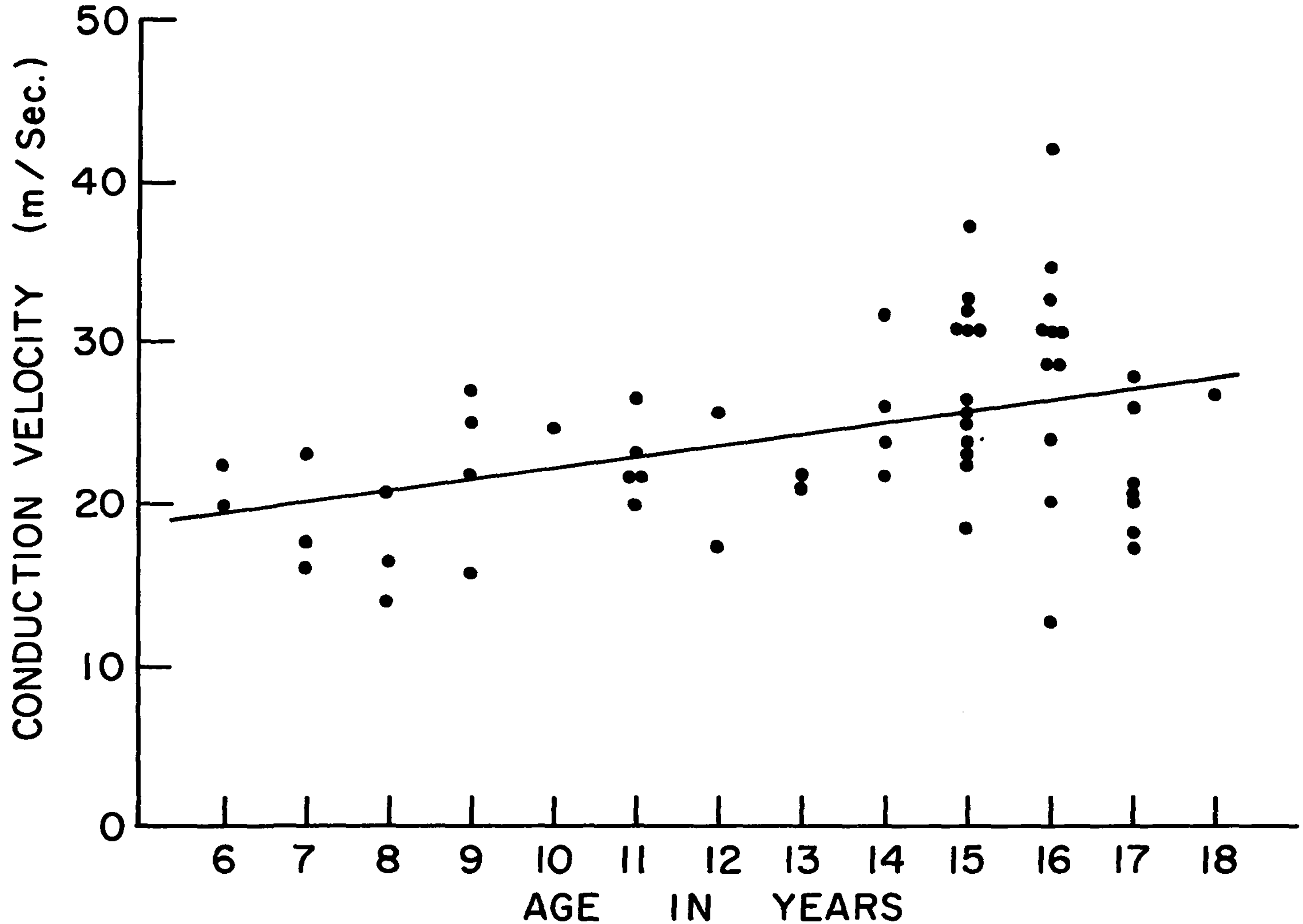

Fig. 14. Environmental room measurements of resident Caucasians, spring and winter combined. $\tilde{y}$ = 14.8 + .73 (X), N=57, correlation coefficient = .4156, P<.005.

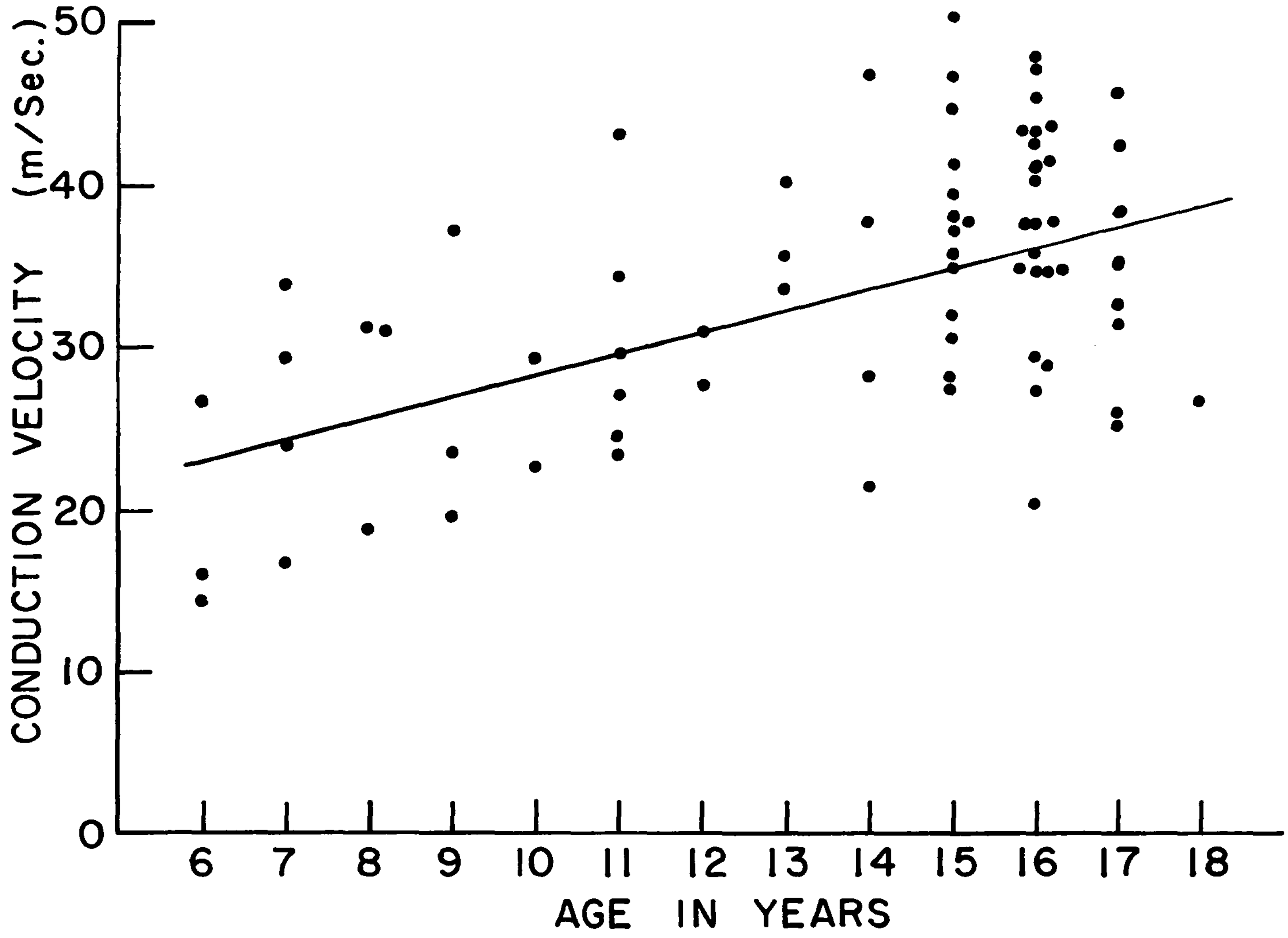

Fig. 15. Room temperature measurements of resident Caucasians, spring and winter combined.
$\bar{y}$ = 15.4 + 1.3 (X), N=77, correlation coefficient = .5432, P<.005.

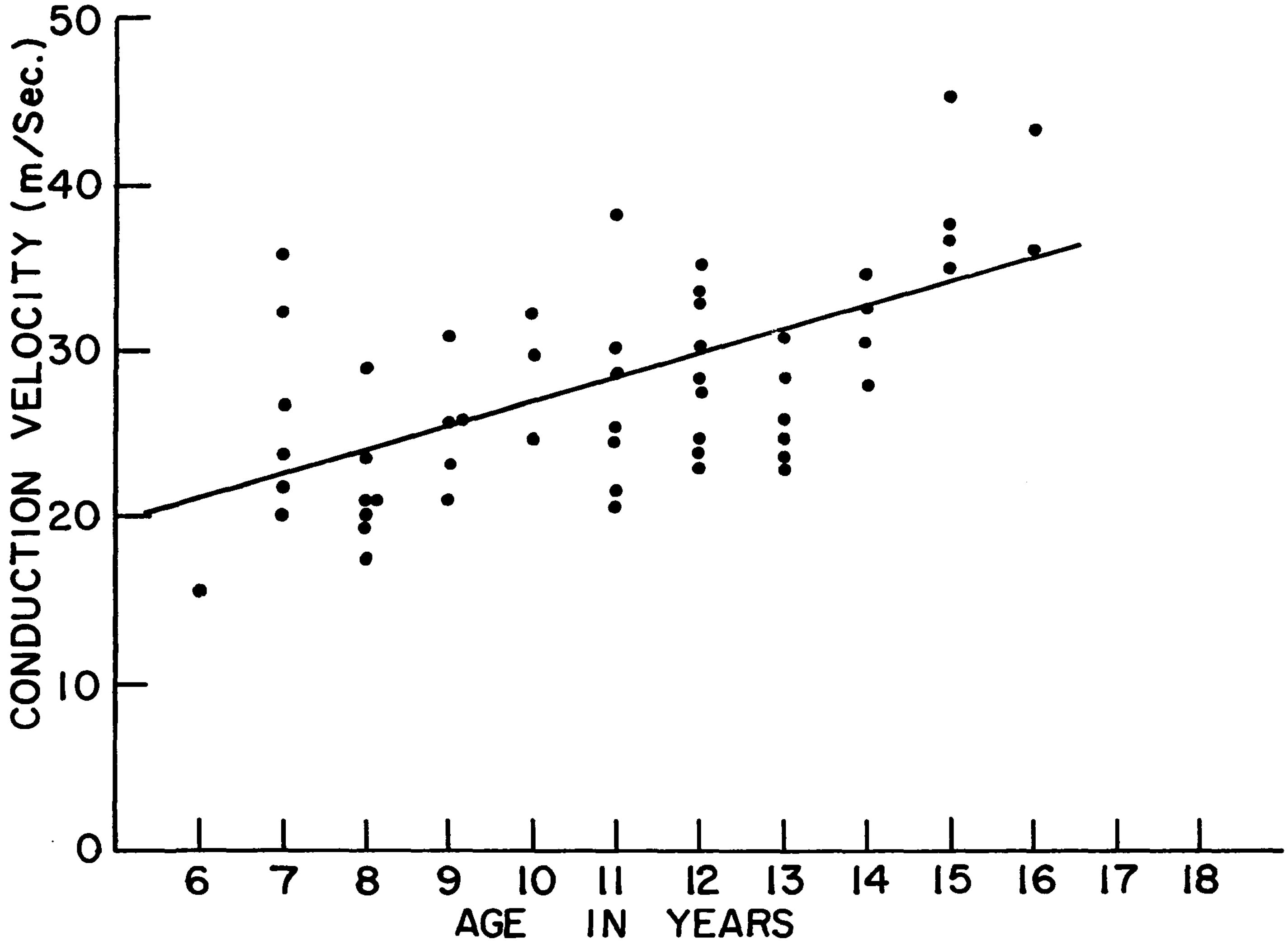

Fig. 16. Cold exposure measurements of Old Crow Indians, summer and winter combined.
$\tilde{y} = 13.0 + 1.4\ (X)$, N=54, correlation coefficient = .5824, $P < .005$.

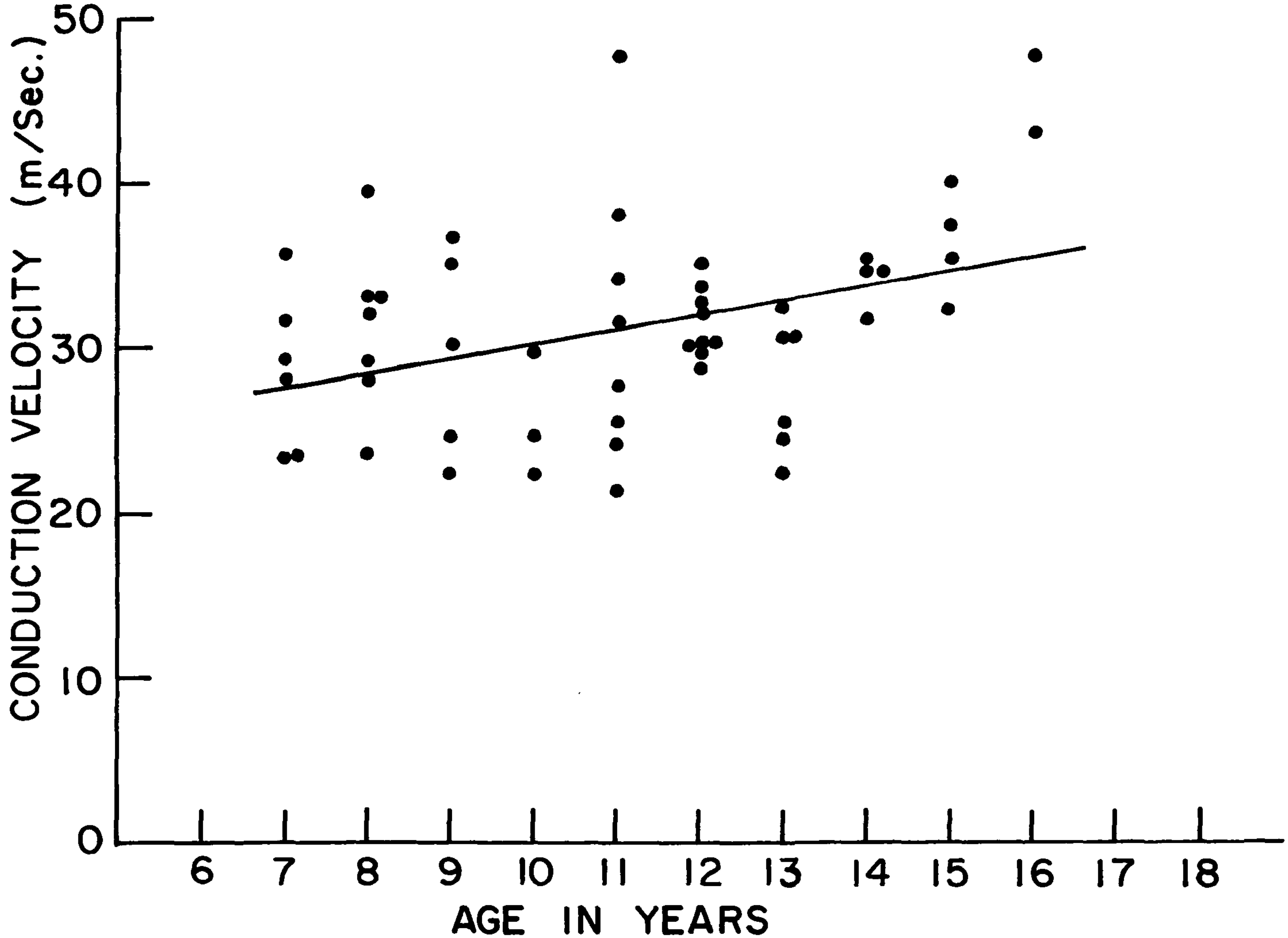

Fig. 17. Room temperature measurements of Old Crow Indians, summer and winter combined. $\tilde{y} = 21.8 + .85\ (X)$, N=54, correlation coefficient = .3701, P<.01.

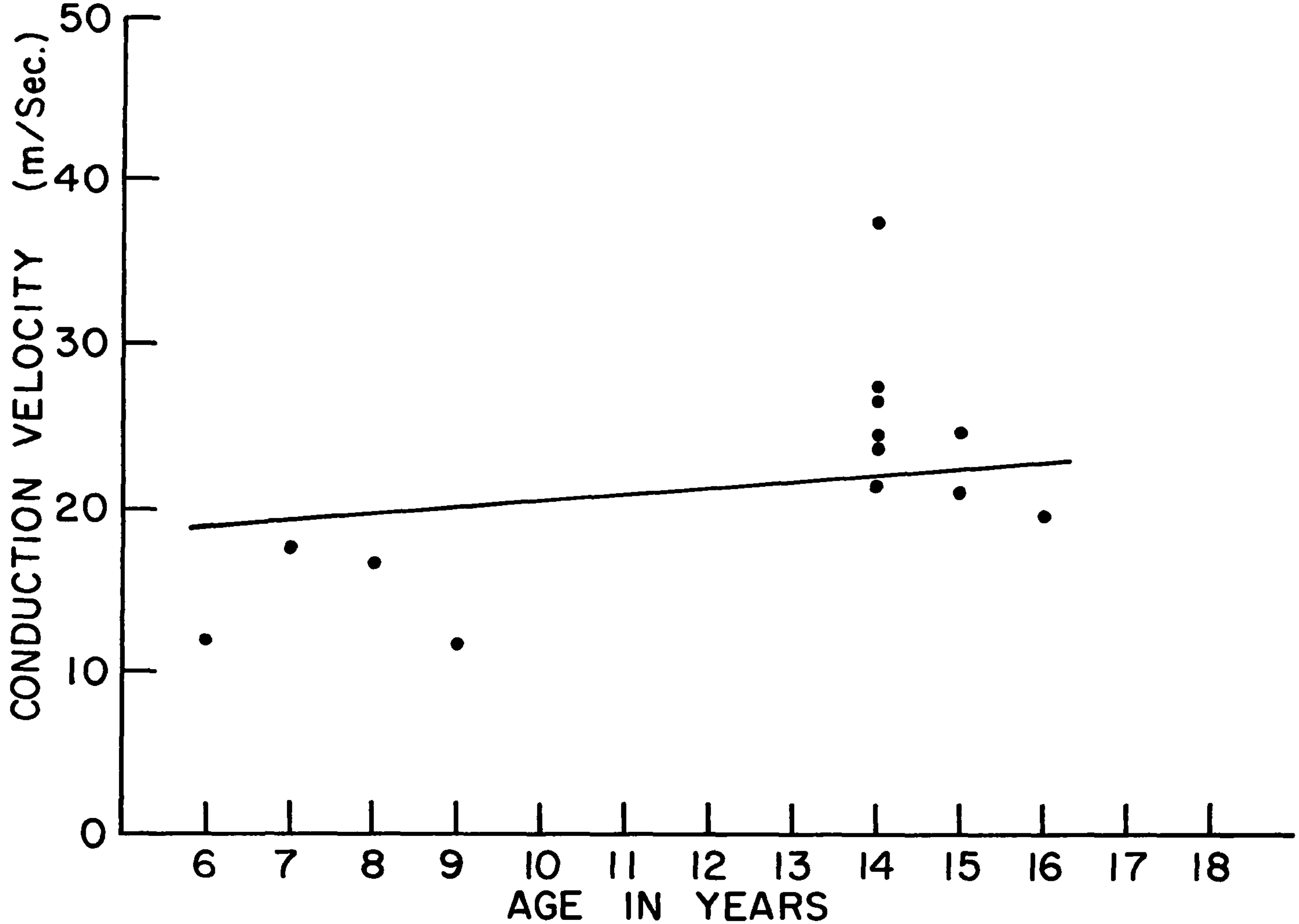

Fig. 18. Environmental room measurements of non-resident Caucasians, spring and winter combined. $\tilde{y}$ = 16.2 + .4 (X), N=15, correlation coefficient = .3867.

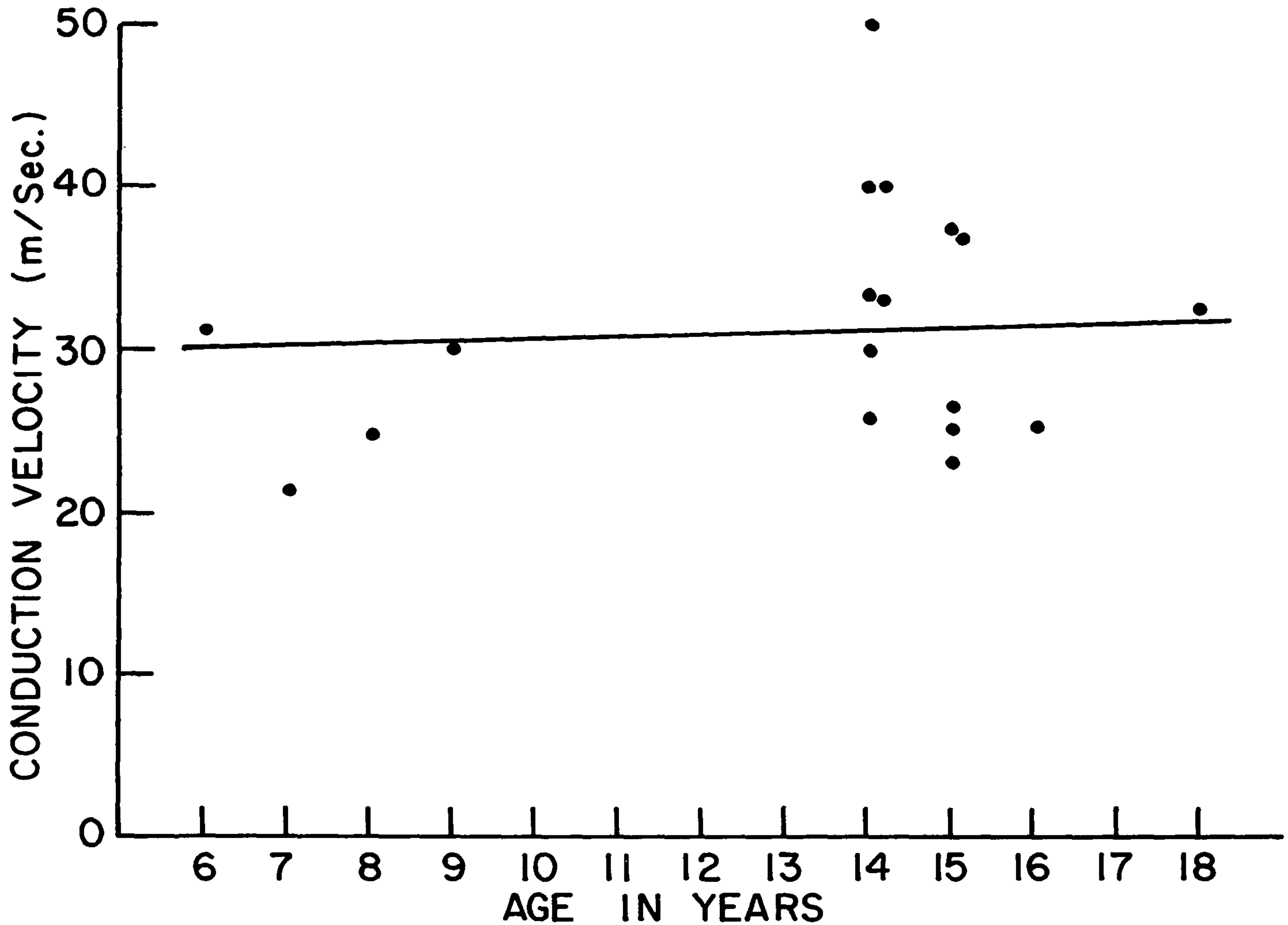

Fig. 19. Room temperature measurements of non-resident Caucasians, spring and winter combined. $\tilde{y}$ = 29.3 + .14 (X), N=20, correlation coefficient = .0860.

which is representative of the puberal years. This pattern is the same both in the environmental room measurements and in the room temperature measurements, although it is more distinct in the environmental room.

Nerve conduction velocity has been found to decrease as finger skin temperature decreases (Petajan, 1968 p 597). This relationship is illustrated in Figure 20 which shows that in the cooled digits of the Old Crow Indians there is a significant correlation ($P<.005$) between nerve conduction velocity and finger temperature during the winter. The same pattern exists during the summer season, but the correlation is not significant, ($P<.1$). Although the correlation is not significant probably due to the small sample size, this same pattern is seen in the non-resident Caucasians, but is almost completely absent in the resident Caucasian group (Figures 21 and 22).

A comparison of nerve conduction velocity between Old Crow Indians, resident Caucasians and non-resident Caucasians is shown in Table 11. During the winter, at room temperature, there were no significant differences observed between the 3 groups tested. The comparison between the resident and non-resident Caucasians, however, resulted in a t value of 1.9818, with 75 degrees of freedom (a t value of 1.984 results in a $P<.05$). When the same comparisons were made during the spring, at room temperature, both the resident and non-resident Caucasians showed a significantly higher mean nerve conduction velocity than the Old Crow Indians, with values of $P<.05$ and $P<.01$ respectively.

When the same tests were conducted in the environmental room, the Old Crow Indians showed a significantly higher mean nerve conduction

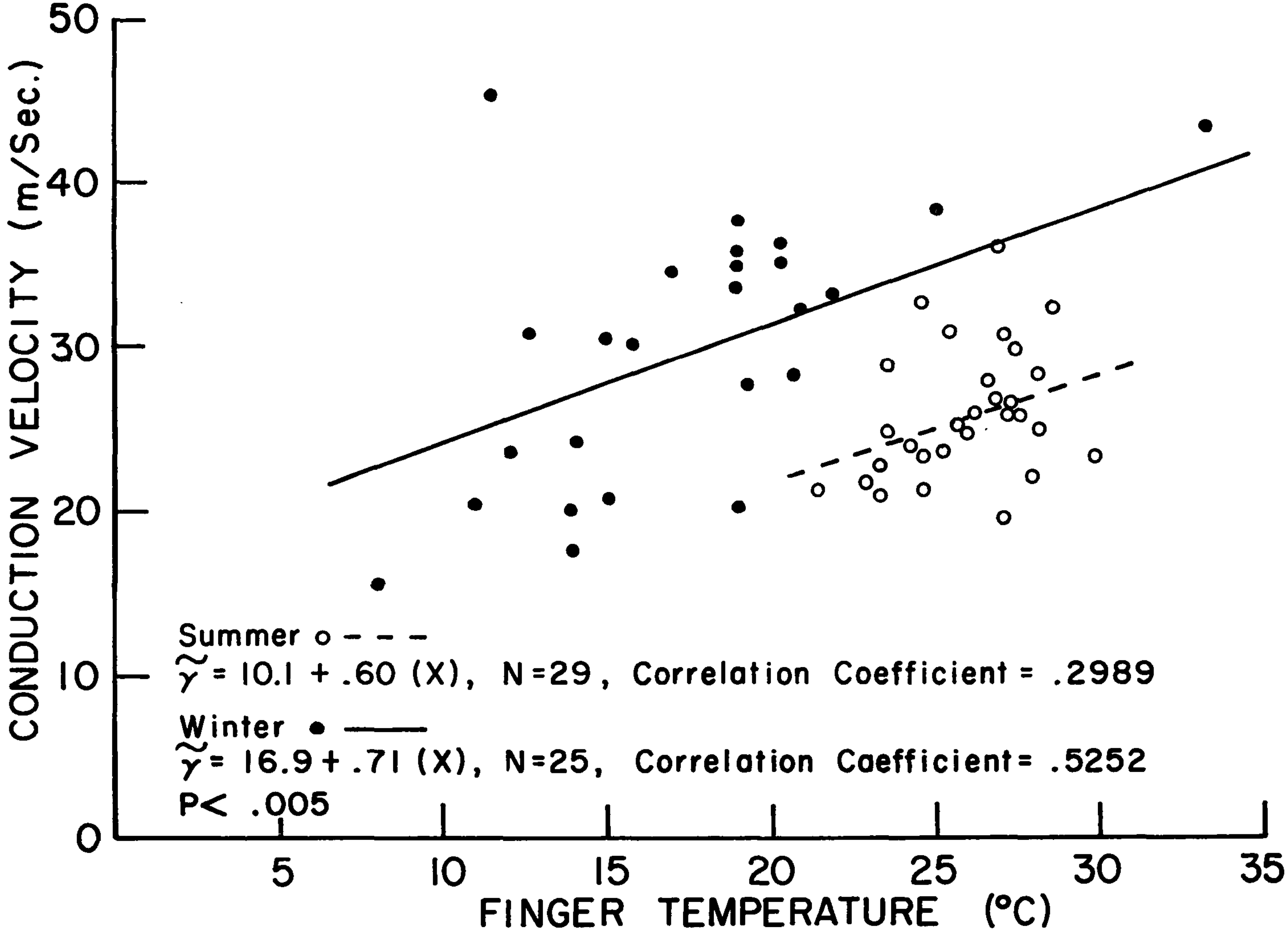

Fig. 20. Cold exposure measurements of Old Crow Indians.

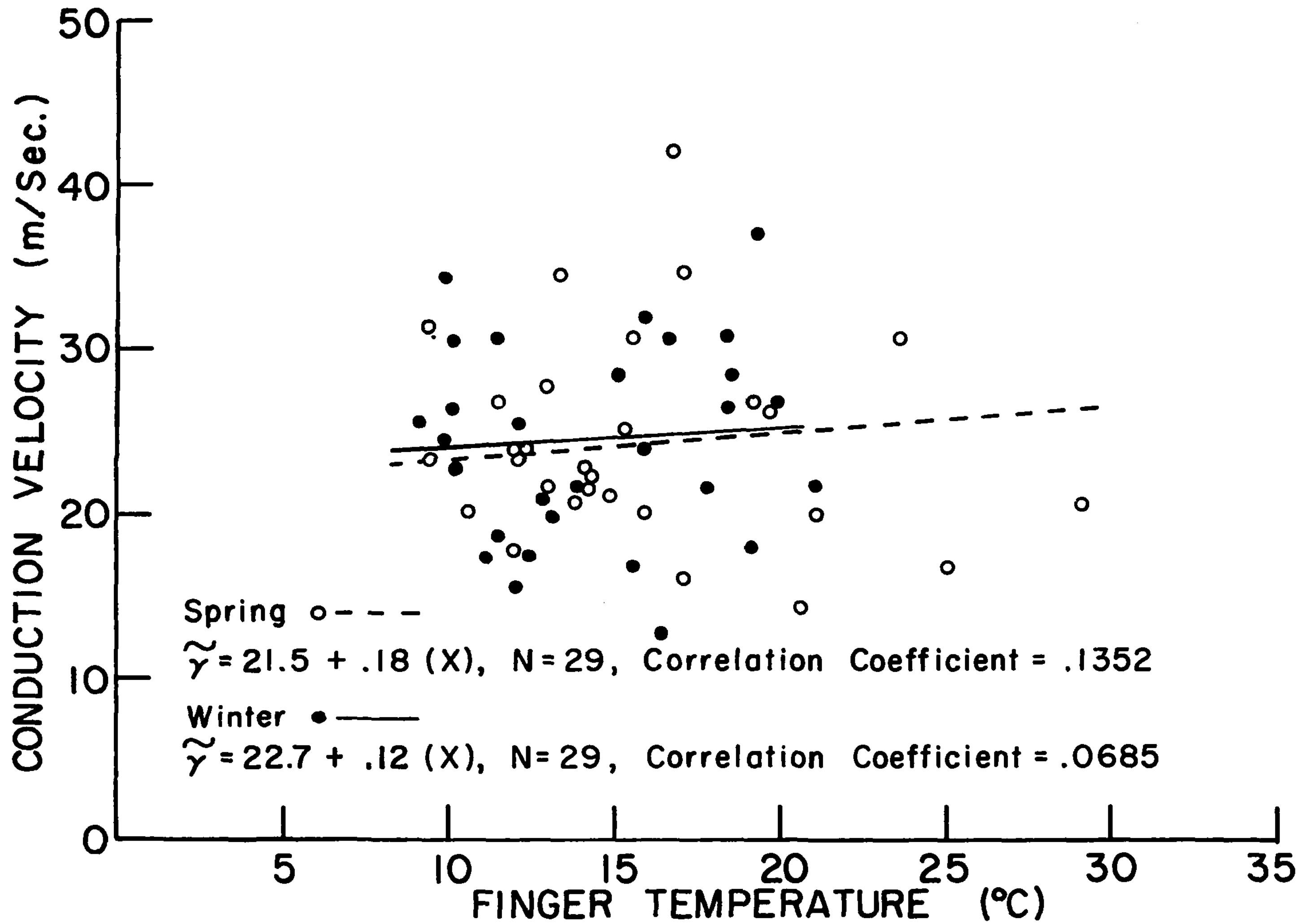

Fig. 21. Environmental room measurements of resident Caucasians.

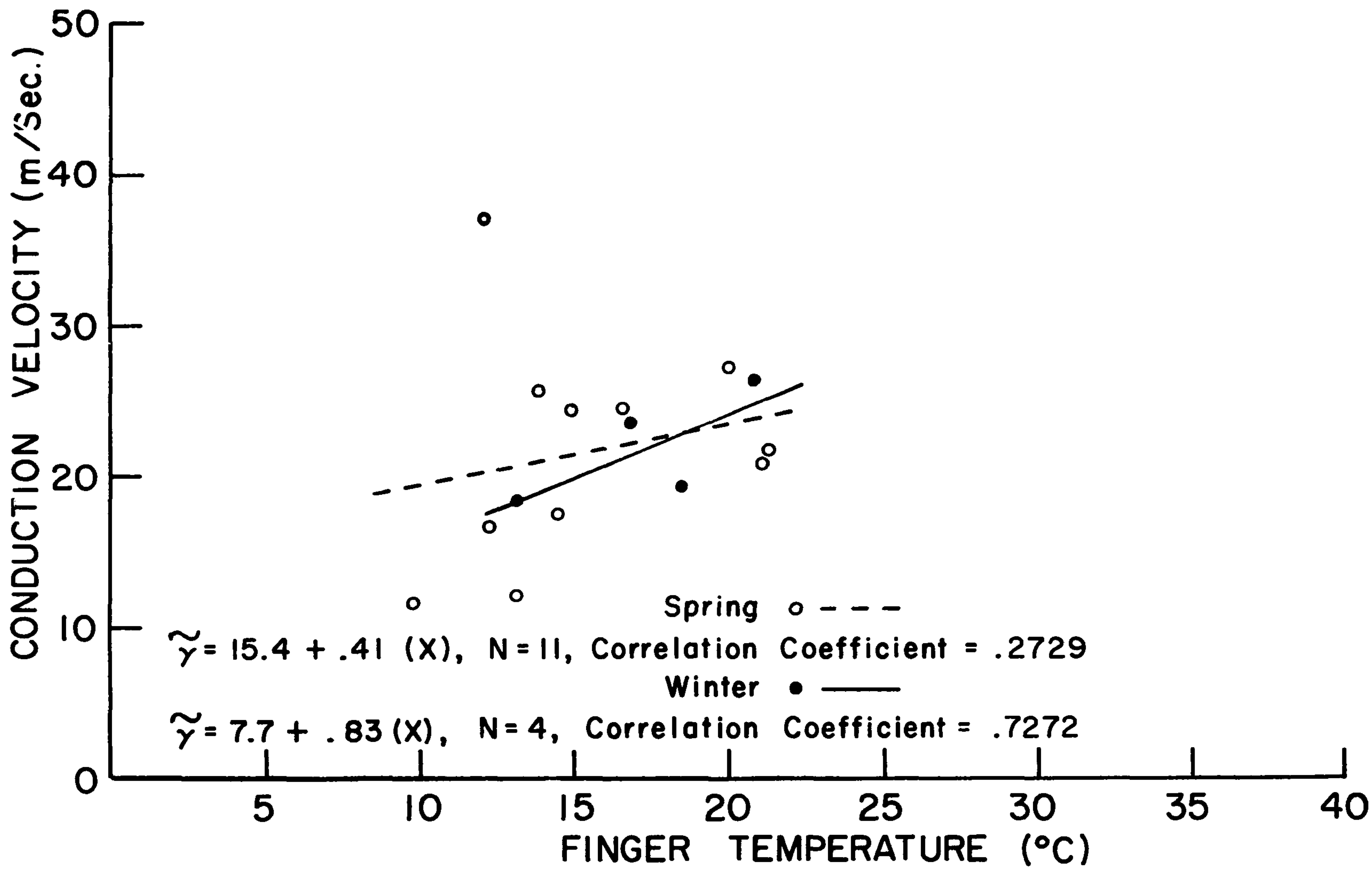

Fig. 22. Environmental room measurements of non-resident Caucasians.

TABLE 11. Seasonal Comparisons of Mean Nerve Conduction Velocity and Mean Finger Temperature in °C. Between Resident and Non-resident Caucasians and Old Crow Indians.

Ethnic Group	Mean Conduction Velocity	N	Std. Dev. Mean Conduction Velocity	Mean Finger Temperature	N	Std. Dev. Mean Finger Temperature
			Room Temperature Winter			
Res. Cau.	32.73	64	8.32	29.04	64	2.48
Old Crow Indian	31.95	27	6.37	29.04	27	3.97
Non-res. Cau.	27.90	13	6.14	29.12	14	2.13
			Room Temperature Spring			
Res. Cau.	34.44	15	8.58} P<.05	28.59	15	2.43
Old Crow Indians	30.16	30	5.74} P<.01	30.15	30	2.53
Non-res. Cau.	38.73	6	6.42	28.68	6	3.02
			Cold Exposure Winter			
Res. Cau.	24.40	29	6.05} P<.01	14.08	32	3.44} P<.01
Old Crow Indians	29.82	27	7.58	18.15	27	5.59
Non-Res. Cau.	22.05	4	3.70	14.51	6	4.99
			Cold Exposure Spring			
Res. Cau.	24.34	28	6.01	15.17	31	4.27} P<.01
Old Crow Indian	25.61	29	4.00} P<.05	26.00	29	2.00} P<.01
Non-res. Cau.	21.74	10	7.64	14.77	10	3.58

velocity than the resident Caucasians (P<.01) during the winter, and although the non-resident Caucasians showed the lowest mean nerve conduction velocity of the group, a comparison with the Old Crow Indian group was not significant because of the small sample size. During the Spring tests in the environmental room the Old Crow Indians were found to have a significantly higher mean nerve conduction velocity than the non-resident Caucasians (P<.05).

Disregarding statistical significance for a moment, it can be seen that for tests conducted in the environmental room there is a consistent pattern for winter and spring wherein the Old Crow Indians have the highest mean nerve conduction velocity, the resident Caucasians the next highest and the non-resident Caucasians the lowest. It is recognized that this observation could have occurred by chance, but the consistency of the pattern indicates, at least, that further study may be justified. This pattern is also generally reflected in the mean finger temperatures of the 3 groups. When the tests were conducted at room temperature, supposedly in the absence of temperature stress, only a seasonal effect on nerve conduction velocity would be expected. Under these circumstances the winter measurements showed the non-resident Caucasian to again have the lowest mean nerve conduction velocity, with that of the resident Caucasian and the Old Crow Indian being about the same. In the spring, however, the non-resident Caucasian had the highest mean nerve conduction velocity and the Old Crow Indians the lowest. The patterns found in the nerve conduction velocity measurements obtained at room temperature are not reflected in the finger temperature measurements. The narrow range of nerve conduction velocities obtained at room temperature may indicate that conduction velocity is not greatly influenced by finger temperatures within what might be considered a given comfort range. It should be mentioned that a comparison of spring season measurements might be influenced by the fact that the measurements of the Old Crow Indians were actually obtained during the summer rather than the spring.

No significant differences in peripheral conduction velocity were observed between males and females except in the winter measurements of the resident Caucasian group obtained at room temperature (Table 12). Among both the Old Crow Indians and the resident Caucasians, however, the males showed a higher mean nerve conduction velocity than the females in all parameters tested. There were not enough males in the non-resident Caucasian group to permit a comparison with females.

Peripheral nerve conduction velocities were plotted for all resident Caucasians by month in Figure 23. The results for measurements taken in the environmental room paralleled those taken at room temperature, but were in a lower conduction velocity range. In both cases there was a significant slope to the regression line showing a drop in conduction velocity as winter progressed into summer. In the interest of clarity it should be emphasized that each point in Figure 23 represents an actual nerve conduction velocity measurement for a given individual, while the comparisons illustrated in Table 11 are based on mean nerve conduction velocities for a given group.

Finger temperatures did not follow the same seasonal pattern found in nerve conduction measurements. Under conditions of cold exposure

TABLE 12. Comparison of Mean Seasonal Nerve Conduction Velocities Between Males and Females Among Resident Caucasians and Old Crow Indians.

	Conduction Velocity		Finger Temperature °C		Conduction Velocity		Finger Temperature °C	
	Female	Male	Female	Male	Female	Male	Female	Male
EXPOSED TO COLD								
Resident Caucasians	Spring				Winter			
N	23	6	23	6	15	14	15	14
Std. Dev.	4.7	10.1	4.6	3.7	7.0	5.0	3.4	3.9
Mean	24.0	26.7	15.4	15.2	23.4	25.5	14.2	14.4
Old Crow Indians	Summer				Winter			
N	17	12	17	12	15	12	15	12
Std. Dev.	3.5	4.8	1.6	2.5	6.7	8.6	4.8	6.6
Mean	25.2	26.2	26.2	25.7	28.6	31.4	17.5	19.0
ROOM TEMPERATURE								
Resident Caucasians	Spring				Winter			
N	10	5	10	5	41	23	41	23
Std. Dev.	7.8	9.9	2.7	1.3	8.1	8.1	2.3	2.9
Mean	32.7	38.0	28.0	29.7	31.2	35.6	29.2	28.8
Old Crow Indians	Summer				Winter			
N	17	13	17	13	15	12	15	12
Std. Dev.	5.0	6.7	2.8	2.2	7.1	5.6	4.9	2.4
Mean	29.6	30.9	29.8	30.6	31.5	32.6	27.7	31.0

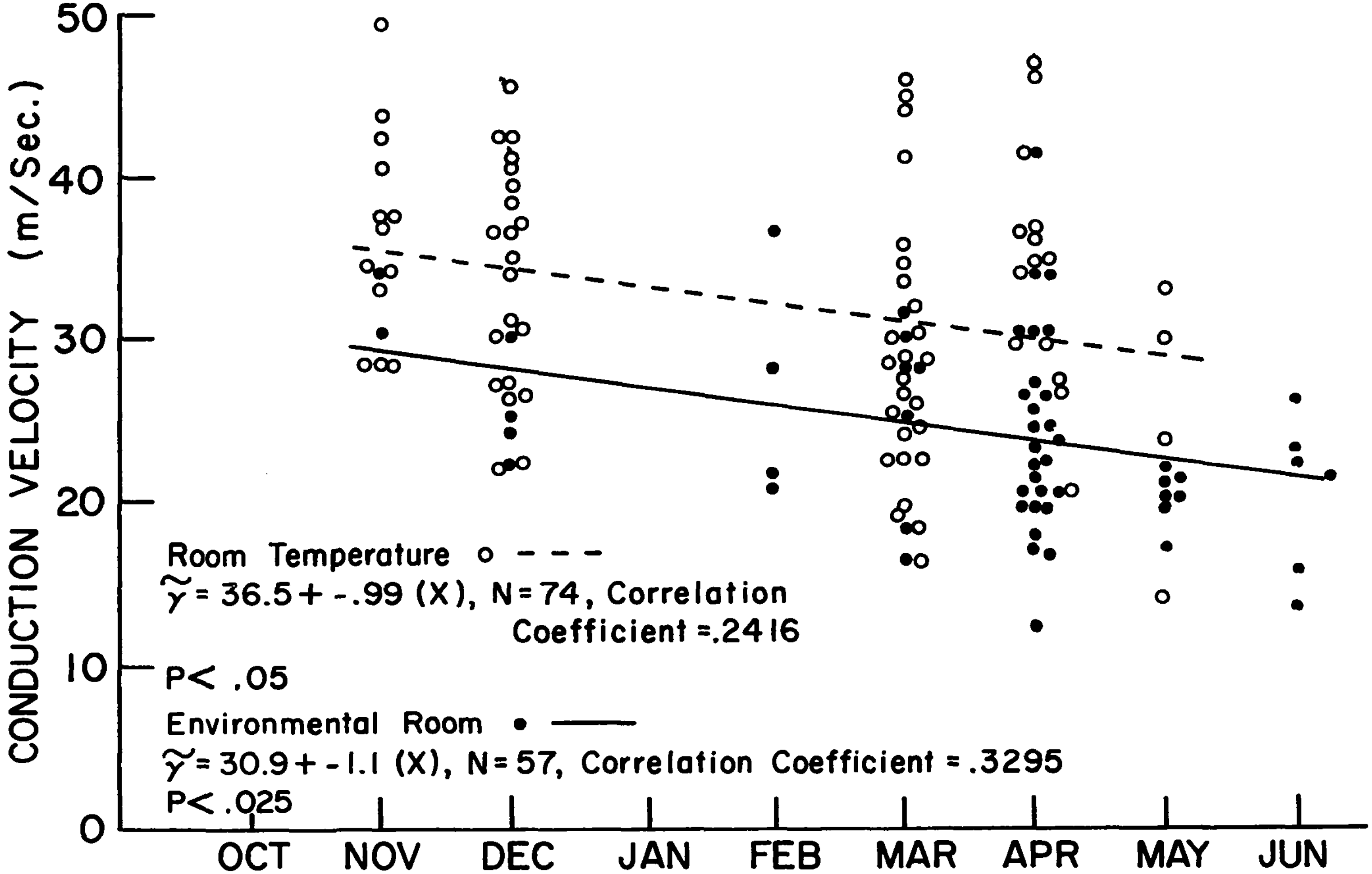

Fig. 23. Monthly nerve conduction velocity measurements of resident Caucasians.

finger temperatures increased slightly in the spring, however the increase was not significant. Comparisons of finger temperatures with conduction velocity at room temperature were not very rewarding since the finger temperatures were clustered primarily within a 5°C temperature range for all groups studied. This range was between 25 and 30°C for the resident and non-resident Caucasians and between 29 and 34°C for the Old Crow Indians. Within these narrow temperature ranges the nerve conduction velocity ranged between 18 and 50 meters per second.

Blood pressure measurements, which were taken in conjunction with nerve conduction velocity measurements, showed an increase in both diastolic and systolic pressure with exposure to cold in the environmental room. There were, however, no significant differences between residence groups, ethnic groups, or between males and females, and no significant differences in seasonal response could be detected between these groups.

In summary then, it is seen that there is an increase in nerve conduction velocity with age in the resident Caucasians and the Old Crow Indians. There is also a tendency in this direction observed in the small sample of non-resident Caucasians.

There is a parallel relationship between the peripheral nerve conduction velocity and finger temperature in the cooled digits of the Old Crow Indians and the non-resident Caucasians, but this pattern could not be detected in the resident Caucasian group. Finger temperatures obtained at room temperature occurred within a temperature range too narrow to be useful for comparisons with nerve conduction velocity.

When the digits were cooled, a pattern is shown wherein the Old Crow

Indians have the highest mean nerve conduction velocity, the resident Caucasians the next highest and the non-resident Caucasians the lowest. When the digits were not cooled, the non-resident Caucasians again showed the lowest mean nerve conduction velocity in the winter, but the highest mean nerve conduction velocity of the 3 groups in the spring.

Males were found to show a slightly higher mean nerve conduction velocity than the females.

And finally, a seasonal drop in peripheral nerve conduction velocity is seen among resident Caucasians, as winter progresses into spring.

A graphic summary of the foregoing results is presented in Figures 24, 25 and 26. It can be seen that although the 3 tests, finger temperature, HRT and peripheral nerve conduction velocity, are expressed by different scales of measurement. The changes in the 3 tests with age are consistent. These results can then be said to support one another. Figure 24 shows that there is an increase in mean finger temperature, mean HRT and mean nerve conduction velocity with age. Figure 25 shows that among the ethnic groups studied, the Alaska Native, or Old Crow Indian has the highest mean finger temperature, the highest indication of thyroid function (lowest HRT) and the highest mean peripheral nerve conduction velocity of the groups studied. The resident Caucasian is next highest in these 3 areas and the resident Negro lowest in the finger temperature test. The non-resident Caucasian is lowest in tests of HRT and peripheral nerve conduction velocity, however there was not a sufficent sample of resident Negros to permit comparison in these areas. Figure 26 shows that the males studied have a higher mean finger temperature, a higher

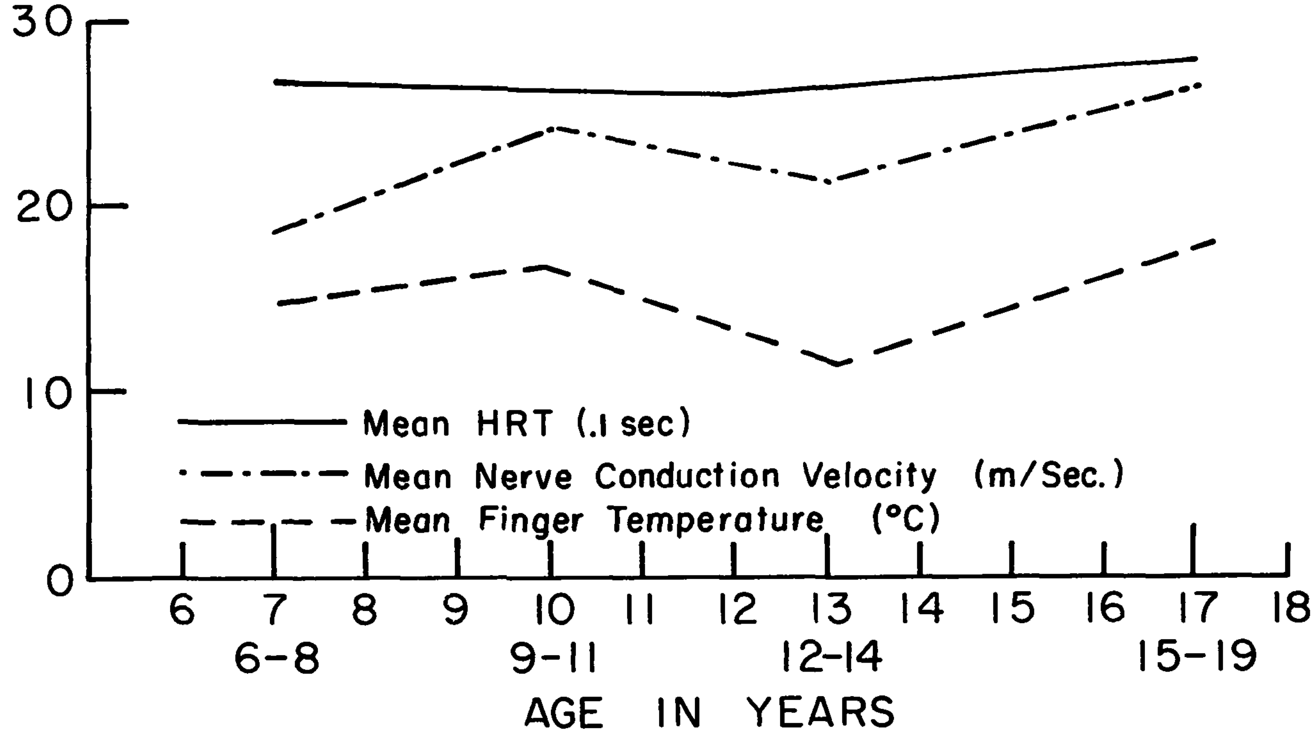

Fig. 24. Winter measurements of resident Caucasians showing changes in mean finger temperatures, mean HRT and mean nerve conduction velocity with age.

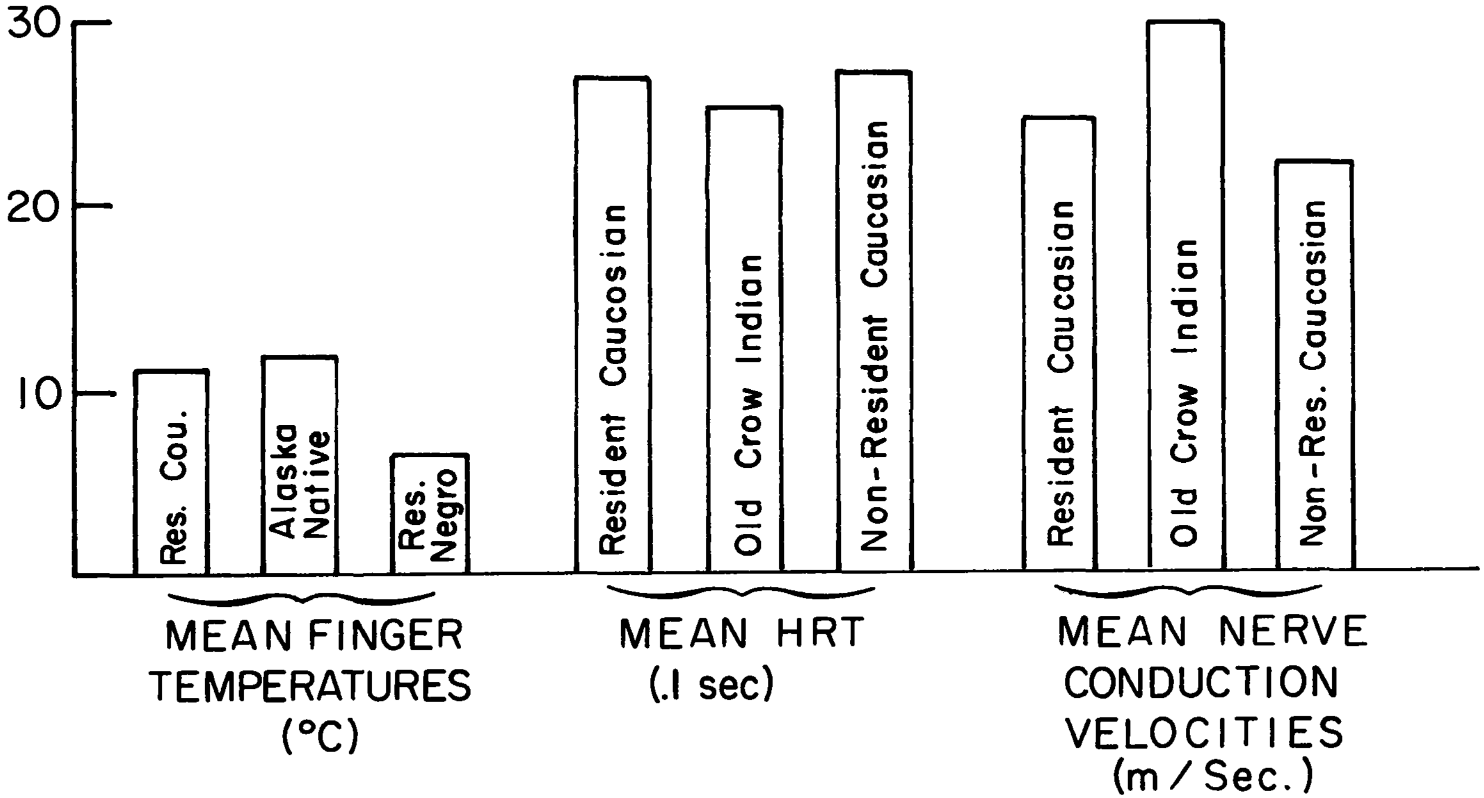

Fig. 25. Winter comparisons of mean finger temperature, mean HRT and mean nerve conduction velocities between ethnic and residence groups.

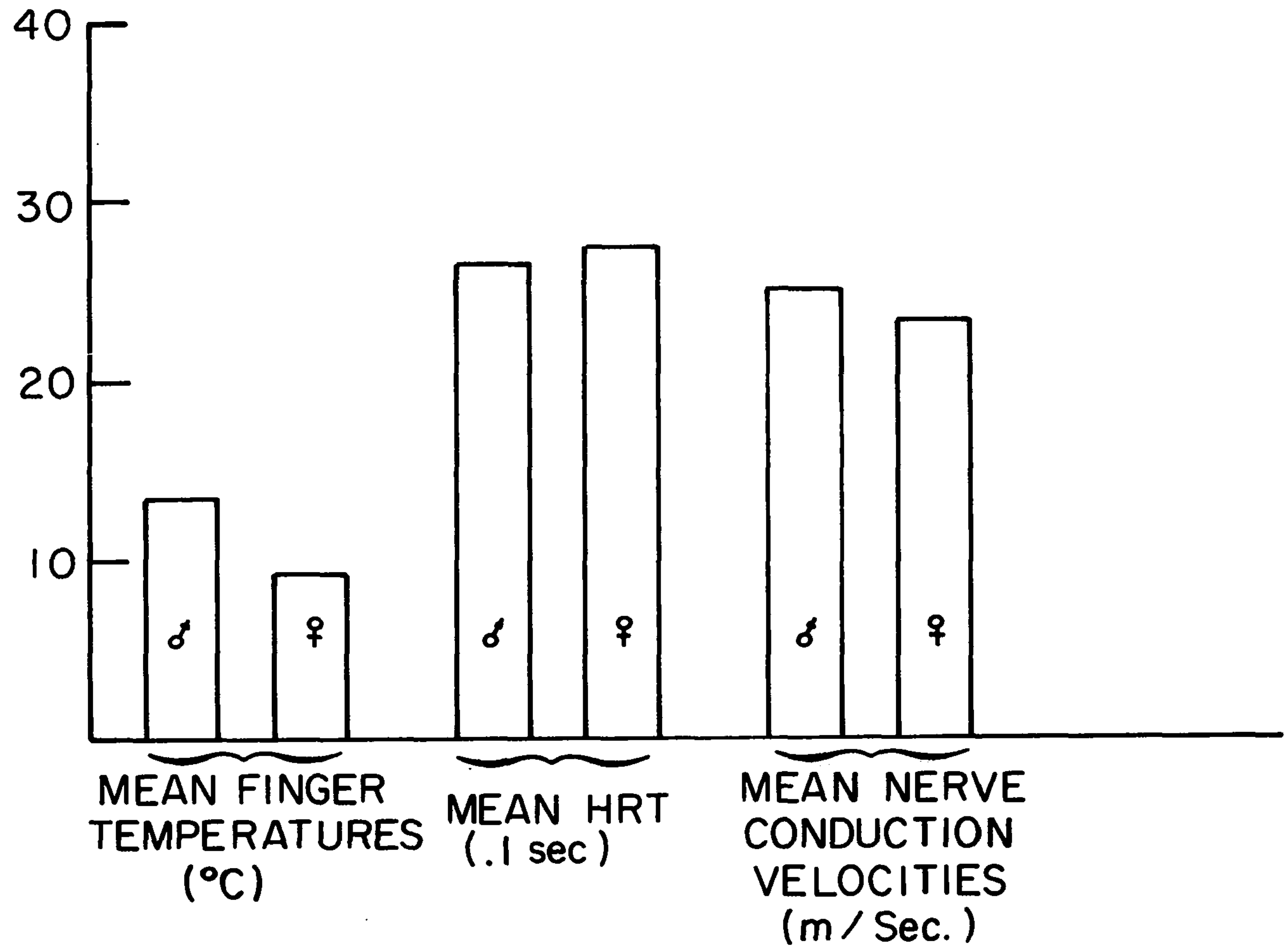

Fig. 26. Winter comparison of mean finger temperatures, mean HRT and mean nerve conduction velocities between male and female resident Caucasians.

indication of thyroid function and a higher mean peripheral nerve conduction velocity than the females.

The mean finger temperatures illustrated for the resident Caucasians in these graphs were obtained from data taken within an outdoor temperature range between 4°C and 5°C.

DISCUSSION

The experimental results have shown an increase in mean finger temperature with age. This is compatible with the observation that infants show a weaker thermoregulatory response than adults (Adamsons, 1966 p 599) (Bard, 1961 p 526) and that body temperature in children of school age is poorly controlled. This is based on the observation that exercise, emotion and cold exposure all may cause variations in body temperature much greater than would be caused in the adult (Bard, 1961 p 526; Tromp, 1963 p 229). The higher surface area to body mass ratio in small children, resulting from smaller body size, causes more rapid cooling. This also supports the observation of increasing finger temperature with age.

These observations pose 2 questions. The first relates to the deep body temperature of the child, which is similar to that of the adult (DuBois, 1948 in Bard, 1961 p 529). In extremely cold environments how does the child maintain this body temperature when, according to the surface law, he has a greater heat loss (Bartholomew, 1968 in Gordon, 1968 p 60-61) than the adult and, as noted earlier, inferior clothing? The second question relates to the subjective observation that the small child has a superior ability to manipulate his digits at finger temperatures of from 1° to 4°C when compared with the older child, or adult. This is demonstrated by his ability to work the buckles on his boots and pick up small objects from the ground. How can this ability be reconciled with a lower mean finger temperature?

Before going futher, it must be emphasized that these are questions which, at this time, can only be answered speculatively. Related data may be used, however, to add support to such speculations.

Although the small child faces some disadvantages when exposed to low temperatures, he appears, at the same time, to enjoy certain mechanisms which compensate for these disadvantages. Bruck, et al. (1958, 1960 in Abramson, 1967 p 395) found that in cooling premature infants, or normal babies immediately after birth, a rise in metabolic rate and a maximal vasoconstriction was produced. It was suggested by these authors that these well developed responses enable the baby to compensate somewhat for its greater heat loss and thinner sub-cutaneous fat layer. Hillier and Margolis (personal communication in Abramson, 1967 p 393) found that there was a much higher resting blood flow in the forearm of children up to 12 years of age, than there was in the adult. Finally, Spurr, et al. (1955 p 552-553) showed that when fingers were cooled in a cold bath, the vasodilatation cycles (often referred to as the Lewis hunting reaction) appeared earlier in children with a mean age of 6.5 years than it did in those with a mean age of 9.3 years, or in adults with a mean age of 24.4 years. In addition, the cycles showed a much greater magnitude in the younger children and appeared with a greater frequency.

Taking the view that these responses alone might not be sufficient to compensate for rapid heat loss, one might speculate that in addition, the thermostatic adjustment for peripheral tissue might be set a few degrees lower in the small child. Such a situation could be related to the degree of myelinization of the temperature control centers of the brain at this early age, as reported by Adolph (1957 p 102) for rats. On the other hand it might be an adaptive mechanism that would help compensate for small body size by setting the peripheral skin temperature limits at a more economical level. If one adds to this the possibility of a maximal vaso constrictor response, increase in metabolic rate (as described for infants by Bruck, et al. (1958, 1960 in Abramson, 1967 p 395), rapid onset of vasodilatation cycles, greater magnitude and frequency of vasodilatation cycles and increased blood flow to the extremities it would not be difficult to see how the child might compensate for the disadvantages of small body size and inferior clothing. It is also possible that while the child's clothing may be inferior to that of the adult, it may be quite adequate for the temperatures to which the child is exposed.

In attempting to reconcile the subjectively observed superior finger dexterity in small children with their low finger temperatures, the problem becomes more speculative. Miller (1966 p 67) found that the excised phrenic nerve in beavers, which is a deeply situated nerve not normally exposed to cold, did not conduct at temperatures as low as did the excised caudal nerves in beavers (Castor canadensis), which is naturally exposed to cold. This observation was similar to that of Chatfield, et al. (in Hensel and Hildebrandt, 1964 p 58) who found that the cold resistence in the metatarsal nerve segment in the leg of the herring gull (Larus argentatus), was greater than that in the nerve segment from the warmer tibial portion of the leg. On the basis of these observations one could speculate that this type of nervous adaptation might be present in small children, again as compensation for small digit size. Under such conditions a superior dexterity at lower finger temperatures might be expected. A greater subcutaneous fat layer and a thinner corneum may also contribute to finger dexterity in the small child (Petajan, 1969 personal communication).

Although the results showed a general increase in mean finger temperature with age, a break in this pattern was observed during the puberal years. During this time the mean finger temperature dropped to the level of that of the 6 through 8 year age group, or in some cases below it. Nelson (1964 p 165-166) describes the puberal growth period as a dangerous period in which the body focuses its resources upon the demands of growth, and in consequence resistance to disease is lowered. It is a period during which adequate nutrition is of greatest importance. Under such circumstances it is not unlikely that resistence to environmental stress would also suffer, and to some extent be manifested in the lower finger temperatures observed during this period. It seems probable that protein is especially important in northern areas. Heat can be released by the specific dynamic action of food, and a tendency toward an increased intake of protein, which has the highest specific dynamic action, has been observed in exposure to cold (Bard, 1961 p 542). Issekutz, et al. (1962 in Edman, 1964 p 538) have noted the deleterious effects of protein deficiency when combined with cold exposure. They feel that protein not only contributes to energy production, but to enzyme and hormone synthesis, and further, that carbohydrates and fats function more efficiently in nitrogen equilibrium. Nelson (1964 p 166) stresses the importance of adequate protein in the diet of adolescents and that because of the demands for protein, incurred by the rapid growth during this period, the child can readily go into a negative nitrogen balance. Under these conditions it would seem possible that protein deficiency (caused by increased demand) could account for a reduction in heat production and a decrease in finger temperature. This same argument might apply to the increase in thyroid activity observed during this period (Nelson, 1964 p 168). Since the effect of thyroid hormone at this stage is primarily anabolic (Nelson, 1964 p 168) its thermogenic aspect might be subordinated.

It was noted that in the non-resident group, the drop in mean finger temperature occurred earlier than it did in the resident group, i. e. in the 9 through 11 year age group, rather than in the 12 through 14 year age group. This may be related to the observation that in the younger age groups the residents showed a higher finger temperature than did the non-residents. Barnett and Coleman (1960 in Barnett and Mount, 1967 p 451) have observed that cold exposure delays the onset of estrous in mice. If this is the case in humans, it may be an indication that a portion, or the whole, of the maturation process in northern latitudes is a bit behind those in more temperate latitudes. Such a situation could theoretically result from the body's conflicting claims on available energy between that required for heat production and that required for anabolism (Barnett and Mount, 1967 p 443). It is conceivable that the extra energy required for heat production in cold climates might detract enough from the anabolic process to slow the maturation process.

In comparing differences in finger temperature between males and females, two patterns are seen. One is an overall pattern wherein males show a higher mean finger temperature than females. The other is a pattern wherein females show a higher mean finger temperature in the younger age groups and the males a higher mean finger temperature in the older age groups. These differences can be associated with many aspects of development, but where the emphasis should lie is speculative. The differences may be partially explained on the basis of body size. Boys are generally larger than girls from birth to the prepubescent period (the period preceeding the first secondary sex changes of adolescence). During this period the girls pass the boys in size, with the peak of physical difference occurring at about 13 years of age. During the 13th year the boys rapidly catch up and pass the girls in body size (Nelson, 1964 p 31-32). Under these circumstances the surface law would place the heat loss advantage with the girls during the prepubescent period (which in girls can preceed 8 years of age) Nelson (1964 p 31), but with the boys during the subsequent growth period. There are other factors associated with growth, that support the observed differences in mean finger temperature between males and females. The greater muscle mass in males from adolescence onward (Nelson, 1964 p 32) would tend to provide the male with additional heat production, since it is known that tonic muscular activity produces heat upon exposure to cold (Bard, 1961 p 542). Also associated with growth are the hormonal responses of adolescence. This study has shown a greater thyroid activity in males than in females from the puberal period to adulthood. This is supported by Nelson's (1964 p 31) notation that the basal metabolic rate is a bit higher in males during this period. Since thyroxine is a calorigenic hormone (Moore, 1966 p 723) this would place a heat production advantage with the males. Of the increase in sex hormones characteristic of adolescence (Nelson, 1964 p 31) the androgens dominate in the males and the estrogens in the female (Moore, 1966 p 744-745). The androgens are strongly anabolic in nature and have a pyrogenic effect, while estrogens are mildly anabolic with no reference to pyrogenic effect (Netter, 1965 p 90 and 225). The puberal male consequently has a further heat production advantage over the female from the standpoint of hormonal activity. Although the females possess an insulative advantage in the accumulation of a greater fat deposit during this period (Nelson, 1964 p 32) it does not seem to match the males heat production advantage as far as reflected in mean finger temperature measurements.

There is another factor worthy of mention which perhaps reflects upon the results of the HRT measurements. Inactivity results in depression of metabolism (Nelson, 1964 p 170) and it may be that the higher HRT and the lower mean finger temperatures seen in females of the 15 through 19 year age group are the result of inactivity. This would tend to be supported by the work of Petajan and Eagan (1968 p 16) who found that with exercise the HRT is shortened in subjects in good physical condition, by the work of Rhodes (1967 p 918) who found an increased utilization of thyroid hormone in exercised rats and by the work of Francis and Tipton (1969 p 91) who found a faster quadricep reflex time in subjects after a weight training program. A pattern reflecting on these observations may be seen in Table 10, where the resident Caucasian females show a slightly higher HRT after exercise than they did without exercise.

Results of winter skin temperature measurements between ethnic groups, which show the Alaska Native to have the highest mean finger temperature, the resident Caucasian the next highest and the resident Negro the lowest, are considered to represent degrees of adaptation to a cold climate. These results are compatible with those of Irving, et al. (1960 p 635-644) and Miller and Irving (1962 p 449) who obtained similar results when comparing arctic Eskimos and Indians with White controls. They are directly comparable with the results of Meehan (1955 in Hammel, 1964 p 426) who found that when immersed in ice water, the fingers of the adult Alaskan Eskimos and Indians showed the highest skin temperature, the Whites the next highest and the Negros the lowest. These observations correspond with the environmental history of the three groups when one considers that the Negro has been most recently removed from a tropical or semi-tropical climate, the Caucasians from a temperate climate while the arctic Indians and Eskimos have been long associated with an arctic or sub-arctic climate (Kroeber, 1948 p 133). Applying the surface law, adaptations to temperature presumably developed in these environments, may be reflected in the morphology of the groups considered. In general, the tall, slim body of the nilotic Negro may be said to encourage heat dissipation, the shorter close knit body of the Eskimo may be considered to be designed for heat conservation and the intermediate build of the average Caucasian may be indicative of temperate climate adaptation (Coon, Garn & Birdsell, 1950 in Baker, 1962 p 261-2). These general morphological descriptions are supported in Table 80, page 343-345 of the Biological Handbook on Growth which shows the body surface areas of various nationalities and subgroups of man.

It was noted that when spring and winter measurements of finger temperature were evaluated together the Alaska Native still showed the highest. This same general pattern was also evident in the spring season, where non-resident Caucasians showed a higher mean finger temperature than resident Caucasians. This response may only be explained by speculation at the present time, yet the existence of physiological clocks and physiological memory is well documented (Jungmann and Halhuber, 1964 p 272-273; Folk, 1966 p 43-74; Tromp, 1963 p 369). Further, we know that when the environment changes, these physiological clocks require resetting (Folk, 1966 p 74; Tromp, 1963 p 370). In the case of the non-resident Caucasian then, one may speculate that since he has not yet been in the Fairbanks area for a complete calendar year, his physiological clock, or memory, is still pretty much geared to the air temperature and photoperiod of a more southerly climate.

Seasonal changes in physiological response are well known (Hammel, 1964 p 428; Massey 1959 p 616; Hampton, 1969 p 9; Girling, 1967 p 13-27) and, as noted previously, differences among ethnic groups in response to cold are also well known. It is therefore not unreasonable to suspect that there would be seasonal differences in response to cold between ethnic and residence groups. In this light the higher mean finger temperatures seen in the non-resident Caucasians during the spring, could be interpreted as reflecting a premature warm season adjustment in peripheral temperature control. Girling (1966 p 13-27) conducted a study of seasonal responses to cold on adult male subjects in Toronto, Canada, where the mean monthly temperature during the winter never dropped below -12.2°C. He found that there was a minimum value in heat production in April and a maximum value in August. From his temperature chart it is seen that in Toronto, April is the time when the first consistent temperature rise of the warm season occurs. The low values in heat production are found in April, but the rise to the higher summer values in heat production also begin in April. Since the low values in heat production are interpreted as a maximum adaptation to cold, it would seem that the non-resident Caucasians in Alaska would exhibit a similar pattern until they became physiologically adjusted to the annual cycles in this area. On the other hand, since the consistent rise toward summer temperatures does not occur in the Fairbanks area until mid to late May, *i. e.* about one month later, the resident Caucasian would not be expected to show a physiological adjustment to higher temperature until then.

Since the Negro adaptation to the opposite extreme of a tropical, or semi-tropical climate is still relatively close in time, it may be that a partial adjustment to the cold climate of the Fairbanks area requires a longer time period than it does for the Caucasian. This concept is supported by the findings that even among the acclimatized Caucasians, the finger temperatures are not as high as those of the arctic Eskimos when exposed to cold (Miller and Irving, 1962 p 449).

Further consideration of data obtained in the present study, and associated data, appear to give evidence of another pattern emerging in regard to cold adaptation. For those recently exposed to cold, as represented by the Negros and non-resident Caucasians, the response seems to be insulative, i. e. the periphery cools to conserve heat in the body core. This response is manifested in the lower mean finger temperatures and higher HRT. For those with a longer cold experience, as represented by resident Caucasians, the response seems to become intermediate between a high metabolic response and an insulative response. This is manifested by an intermediate response in both finger temperature and HRT, between the non-resident Caucasian and the Alaska Native or Old Crow Indian. Those with a cold exposure experience that spans many generations, such as that of the arctic Indians and Eskimos, seem to show a predominantly metabolic, or chemical heat production response, which is manifested in their higher finger temperatures and faster HRT. In short, it seems as if in the long term adaptation to cold, there is a trend from insulative to metabolic acclimatization.

It is interesting to note within this context, that the same pattern of events seems to exist in the development of the response to cold from childhood to adulthood. The increase in mean finger temperature with age may be associated with higher thyroid activity representing a trend from an insulative to a metabolic response to cold.

As noted in Table 10, there was a reduction in HRT among the resident Caucasians, from the 5 through 9 year age group to the 10 through 14 year age group, and an increase in HRT from the 10 through 14 year age group to the 15 through 19 year age group. This may be indicative of an increase in thyroid activity from the beginning of school age to puberty and a decrease in thyroid activity from puberty to adulthood. If this were the case these results would be in agreement with those of Beckers, Malvaux and DeVisscher (1965 p 202) who found an increase in thyroid activity from adolescence to adulthood; however, because of the changes in muscle response, tissue growth, heat loss and metabolic rates that occur with age, the HRT measurement does not provide a valid basis for comparison of thyroid activity.

The shortening of HRT seen among resident Caucasians during the puberal period is not evident among the Old Crow Indians. The absence of this phenomenon cannot be explained unless it could be related to diet. It has been noted that the primary source of iodine is dietary (Nocenti, 1961 p 782) (Nelson, 1964 p 1275-1276) and that hypothyroidism is associated with malnutrition (Nelson, 1964 p 168). The people of Old Crow had been existing in a state of protein starvation, if not all around malnutrition, at the time of testing. This situation came about through a series of misfortunes. A forest fire, during the previous summer, had destroyed the lichens in the area that the caribou depend upon for food. The caribou, which the people traditionally depend upon for winter meat, consequently took an alternate migration route which bypassed the Village area. The low rainfall of the previous summer caused low water levels in the Porcupine River, which is the only traffic to Old Crow aside from air transport. Because of the low water, the supply barge could not bring provisions to the Village store, and air freight is so expensive that the people could not afford to have their winter supplies flown to Old Crow. In addition, the low water resulted in a much reduced salmon run, so that this essential food was also in short supply. In consideration of these events, it is possible that the effects of inadequate nutrition could be manifested in a reduction in thyroid activity, especially during the puberal years when adequate nutrition is so important.

Since protein is important in muscular development (Nelson, 1964 p 166-167) and protein deficiency has been shown to detract from muscular performance (Yoshimura, 1965 p 85-110), the absence of a shortened half relaxation time during the puberal years in the Old Crow group, may reflect the effects of protein deficiency on the triceps surea muscle.

Little is known concerning the mechanisms involved in the changes seen in thyroid function between childhood and adulthood (Beckers, et al. 1965 p 205). It would, however, seem possible from observations made in related studies to attribute the indications of increased thyroid function between the 5 through 9 and 10 through 14 year age groups to the increased utilization of thyroid hormone in growth (Nelson, 1964 p 168) and in heat production. As mentioned earlier, this additional heat source during this period may help compensate for small body size.

Beyond the puberal years the requirement for thyroid hormone in growth as well as in heat production could be expected to be reduced, for complete growth has almost been achieved and body size is no longer a limiting factor as related to normal adult heat production.

In comparing results of HRT measurements between males and females, it was found that in general the males evidenced a shorter HRT than did the females, among the resident Caucasians and Old Crow Indians. Although the difference between the sexes was not significant in any age group, or in a consolidation of age groups, it was most conspicuous during the puberal years. The indication of higher thyroid activity in the males (shorter HRT) is in agreement with the observations that basal metabolic rate (BMR) is slightly higher in males than in females (Nelson, 1964 p 31). Agreement is also found in the work of Oddie, et al. (1968 p 776) who found radioiodine clearance rates lower in males than in females, and a dietary iodine intake in males that was about 33% higher than it was for females. This intake was found to rise sharply with growth. An increased thyroid activity in adolescent males over that of females is also shown in the work of Beckers, et al. (1965 p 203).

It was noted that while a difference in HRT was present between the sexes in the winter, among the resident Caucasians, this difference was conspicuous only during the summer among the Old Crow Indians. One can only speculate as to the reasons for this, but there might be a relationship between this phenomenon and the inadequacy of diet referred to earlier. It has been shown that during the puberal years the females accumulate fat while the males accumulate muscle (Nelson, 1964 p 32). Thus the male might tend to rely more on hormonal heat production and the female on heat conservation which would be provided by her insulative layer of subcutaneous adipose tissue. During the summer testing period the circumstances which resulted in the restriction of diet at Old Crow had not yet come to pass, and the people were normally nourished. Under these conditions a normal difference in HRT between the sexes could be expected (assuming that a difference is the normal response). During the winter season there was a marked reduction in food supply, as described above. Under these circumstances the females may not have been able to sustain their insulating fat layer and consequently may have had to place a greater dependence upon muscular and hormonal thermogenesis, thus raising their thyroid activity to, or near the levels of that indicated for males.

The differences in HRT noted between the ethnic and residence groups are similar to those noted for finger temperatures. These differences are interpreted as a reflection of adaptation to a cold climate which is based upon the duration of cold exposure that characterized each group tested. Since an increase in thyroid function has been shown to be related to cold exposure, one would expect the Old Crow Indians to show evidence of a higher thyroid activity, and the resident Caucasians evidence of a thyroid activity intermediate between that of the Old Crow Indians and the non-resident Caucasians. This would be expected simply on the basis of the relative amount of cold exposure experienced by these groups. The observation that differences between the Old Crow

Indians and the resident Caucasians could not be detected in the puberal age groups is again attributed to dietary insufficiency in the Old Crow population.

It was noted that although exercise has been shown to shorten HRT in subjects in good physical condition, the HRT observed in the Old Crow Indians who were not exercised prior to testing, was shorter than that found in the resident Caucasians who were exercised prior to testing. This may indicate that long exposure to a cold climate has increased the thyroid activity of the Old Crow Indians to the extent noted. On the other hand, it may be that the activity involved in walking from the school house to the trailer, where HRT measurements were being taken, (a distance of about 70 yards) constituted an exercise state, thus shortening the HRT. Since Verdy, et al. (1968 p 169-171) found that a 3 to 5 minute walk in hospital corridors shortened HRT, the effects of a brisk 70 yard tag game or snowball fight cannot be overlooked. It must be mentioned, however, that although this type of activity was almost impossible to avoid, a period of roughly 5 minutes was provided for equilibration. A final consideration is that the state of physical conditioning in the Old Crow Indians may have been sufficiently better than that in the resident Caucasians to influence the results in the manner observed, or it may be that the results were generated by a combination of these factors.

The increase in peripheral nerve conduction velocity with age seen in this study, has been reported by Gamstorp (1964 p 198-199) who found increases in median nerve conduction velocity from 1 year of age to 16 years of age. Wagman and Lesse, however, (1952 p 236-244) report that from 5 to 9 years of age until adult size is reached, conduction velocity would remain static, but the time involved for a motor impulse to travel from the spinal cord to the end of a limb would increase, because the distance increases with growth. It is possible that the difference between these two reports lies in the fact that Wagman and Lesse used the ulnar nerve in their studies. Gamstorp used both the ulnar and the median nerve, and found that in the ulnar nerve the maximum conduction velocity is reached as early as from 1 to 3 years of age.

Support for the observation that median nerve conduction velocity increased with age comes from several sources. It has been shown that there is a decrease in nerve conduction velocity with cooling of the nerve (Petajan, 1968 p 597; deJong, Hershey and Wagman, 1966 p 805; Miller and Irving, 1967 p 1296). This being the case a lowered conduction velocity would be expected to parallel the lower finger temperatures seen in the younger (and smaller) children, and to increase with age (and size) as mean finger temperature was seen to increase with age. There may also be a relationship between increasing median nerve conduction velocity with age and thyroid activity, since the nervous system is greatly affected by thyroid deficiency (Nocenti, 1961 p 788). The increase in thyroid activity up through the puberal years would thus lend support to the increase in nerve conduction velocity up to this time in life. From the prepubescent years through the puberal years the growth demands for thyroid hormone are great, but subsequent to this time more thyroid hormone might be available for adaptation or development of nervous tissue since requirements for body growth would no longer be as great. If this were the case, the drop in thyroid activity seen from the puberal age group to the 15 thru 19 year age group would not conflict with the increase in median nerve conduction velocity seen between these 2 age groups.

A positive relationship has been established between increasing nerve conduction velocity and increasing nerve fiber diameter (Hursh, 1939 in Wagman and Lesse, 1952 p 235) (Gasser and Grundfest, 1939 p 393-414). It has also been observed that the degree of myelinization affects nerve conduction velocity (Johnson and Olsen, 1960 p 2). Wagman and Lesse (1952 p 235) have described an increase in nerve fiber diameter in the kitten from birth to 3 months of age, and have noted that during this period the relationship between nerve conduction velocity and growth is linear. Zimney (1969 personal communication) on the other hand advises that myelinization of peripheral nerves in humans is not complete until puberty. These observations all tend to support findings of an increased conduction velocity with age, at least until the time of puberty. Beyond this time it is possible that the conduction velocity of the median nerve would continue to show an increase with age when measured in the forefinger. In the references cited above the conduction velocity was measured in the arm and wrist rather than in the fingers where the effects of cold would more readily be manifested.

It has been noted that while the Old Crow Indians and non-resident Caucasians show a positive relationship between median nerve conduction velocity and increasing finger temperature, the resident Caucasians show very little change in conduction velocity with increasing finger temperature, although, in the latter case the effect may be obscured in the wide scatter of points. It may also be noted, however, that at lower finger temperatures the conduction velocities of the resident Caucasians and the Old Crow Indians are about the same, while those of the non-resident Caucasians are considerably lower (Figures 20, 21 and 22). The major difference seen between these groups is reflected at higher finger temperatures, _i. e._ the non-resident Caucasians and the Old Crow Indians show a greater response to a rise in finger temperature than do the resident Caucasians. Petajan (1968 p 597) reported that climbers on Mt. McKinley who had suffered cold injury, showed a loss of temperature sensitivity in which a greater loss of warm sensation than of cold sensation was manifested. On the basis of this observation, the foregoing responses relating nerve conduction velocity to finger temperature, may be interpreted in terms of adaptation. If cold exposure can be said to reduce the ability to sense warmth, then the resident Caucasians might be reflecting an intermediate adaptation to cold, while the non-resident Caucasians are reflecting virtually no cold exposure experience. The Old Crow Indians, having had many generations of cold exposure experience, might be expected to have recovered a greater measure of heat sensitivity. Although the resident Caucasians did not experience the same severity of cold exposure as did the climbers, they probably experienced a more sustained cold exposure throughout the winter months. If this is the case, we might be witnessing an adaptive response to cold in this group, and a pathological response as well.

During the room temperature conduction velocity measurements, it was observed that during the spring the resident and non-resident Caucasians showed a higher median nerve conduction velocity than the Old Crow Indians although the Old Crow group had the highest mean finger temperatures. It is also observed that although the mean finger temperature of the resident and non-resident Caucasians are almost identical, the non-residents show a disproportionally higher conduction velocity. This may reflect a pathological effect of cold upon the nerve, for when the same test was performed at the same time of year under conditions of cold exposure, i. e. the environmental room at Fairbanks and the ice house at Old Crow, the Old Crow Indians showed the highest nerve conduction velocity, the resident Caucasians the next highest and the non-resident Caucasians the lowest. An interpretation of this observation is not possible with the available data but experiments on thermal sensitivity appear to be indicated.

In every test where cold exposure was involved, regardless of season, the Old Crow Indians had the highest nerve conduction velocity, the resident Caucasians the next highest and the non-resident Caucasians the lowest. This response parallels that seen in finger temperature measurements and HRT measurements and is taken to represent differential adaptation between these 3 groups based upon cold exposure experience.

The higher median nerve conduction velocity seen in males as opposed to females, is attributed to the higher finger temperature found in males. This, in turn, can be related to the lower HRT seen in males, the larger body size, the greater muscle mass and the greater heat producing capacity of the androgenic hormones found in males.

The monthly decline in nerve conduction velocity in resident Caucasians, from October to June, is paralleled by the decline in finger temperature in this group, when all age groups are combined (Table II and Figure 12). Although there is an inadequate sample of HRT measurements among the resident Caucasians in the spring and summer, the increase in HRT seen in the Old Crow Indians during the summer (Table 10) indicates a possibility of parallel response in thyroid function. Wilson (1966 p 10) found a similar pattern in basal metabolic rate measurements made in the antarctic. He reports a high basal metabolic rate in the fall, a decrease in the winter and a rise again in the spring, and indicates that these responses may be influenced by activity patterns. The winter was a time of cold, darkness and consequent inactivity, while the spring and fall were times of high activity, thus requiring a higher metabolic rate. This type of reasoning could also apply to the results shown in this study. On the other hand, the decrease in nerve conduction velocity may be related directly to the decrease in finger temperature. The decrease in finger temperature may then represent an adaptation to cold in that it would signify a reduction in heat loss. The results may also represent a combination of these interpretations.

It will be noted that throughout this study, the experiemental results obtained from measurements made on the old Crow Indians showed a tendency toward a more distinct delineation between age groups, males and females and the seasonal influences upon these groups than were detected in measurements made on Caucasians. This seems to illustrate the advantages of working with the genetically and culturally more homogeneous population.

It will also have been noted that the focus in this study has been centered upon physiological adaptation to a cold environment, with little reference to cultural implications. Certainly the responses to environmental stimuli observed in humans, cannot be considered to be independent of culture, for eating habits, habits of dress, home temperature and diurnal and seasonal activity patterns must all exert an influence on these responses. Still the parallel relationships of the results obtained in this study, indicate that in spite of technological advances culture has not made man independent of his environment. In fact, it seems as if relatively little environmental influence is required to either enhance or create physiological adjustment.

As a final note, it is desired to emphasize that in speculating upon the possible mechanisms involved in the observed results in this study, a direct extrapolation between responses seen in the finger and those taking place in the body as a whole is not intended. It is only desired to point out that since the results of the 3 tests all show a similar pattern, that there may be a relationship between such parameters as thyroid function and finger temperature and nerve conduction in the finger.

SUMMARY

The physiological development of the human adaptation to cold was

studied by evaluating the peripheral skin temperature, HRT and peripheral nerve conduction velocity in children ranging in age from 5 to 19 years. These children represented Alaska Native, Old Crow Indian, resident Caucasian, non-resident Caucasian and Negro populations. The enhanced responses to each of these tests with age that was observed in all groups, gave evidence that there is a progressive development of physiological response to cold, and that this response paralleled growth to maturity. Dependency of these responses upon growth was also reflected in differences between males and females, in which the larger body size and muscle mass in the male was associated with a greater heat producing ability. This greater heat production was assumed to be related to the higher finger temperatures, indications of greater thyroid activity and higher nerve conduction velocity seen in the male. These observations, however, are not considered as an indication that the male is better adapted to cold than the female. The female responses may be indicative of a more efficient heat conservation which is supported by her thicker insulating layer of adipose tissue.

More distinct increases in peripheral skin temperature, HRT,and peripheral nerve conduction velocity were observed during the puberal years than during any other age periods. In the case of peripheral skin temperature and peripheral nerve conduction velocity the increase is attributed to the higher metabolic rate associated with the growth spurt that characterizes this period in development. In the case of HRT, however, the number of variables involved which might affect this measurement in developing children preclude any definite associations.

Differences in finger temperature, HRT and peripheral nerve conduction velocity between ethnic and residence groups, was taken to reflect differences in levels of adaptation to cold. This, in turn, is related to the cold exposure experience of each group. In this analysis the Alaska Natives and Old Crow Indians showed the highest mean finger temperatures, shortest HRT and fastest nerve conduction velocity of the groups studied, with the resident Caucasians showing the next highest response and the non-resident Caucasians and Negroes showing the lowest response. It is readily observed that this order follows the degree of cold exposure experienced by the respective groups.

Seasonal changes in peripheral skin temperature, HRT and peripheral nerve conduction velocity are attributed to either variations in seasonal activity, or a seasonal circulatory adaptation, or to a combination of these factors.

Although the effects of culture upon response to the environment are recognized, the results indicate that relatively little exposure to environmental extremes is required to enhance or create a physiological response.

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