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SHIFTS IN PHYSICAL THERMOREGULATION IN MAN DURING ACCLIMATIZATION IN THE EXTREME NORTH

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The division of thermoregulation mechanisms into chemical and physical, accepted from the times of Rubner, has been considerably developed in the following.

The reactions of physical thermoregulation to the cooling of the skin surfaces studied particularly in detail, and the leading role of the reflex changes of the vascular tonus was established directly in the cooled area as well as at a distance from it. The considerable experience in the clinical application of hypothermia has clearly shown that the cooling of the internal organs even by five to 10 degrees does not by itself cause a common cold and can be tolerated without consequences only as a result of one necessary condition -- all thermoregulatory mechanisms have to be eliminated by means of deep anesthesia. Serious consequences are inescapable if the anesthesia is discontinued or lightened before the body temperature approaches its normal state during passive rewarming. The importance of the thermoregulatory reactions in the pathogenetic mechanism of the common cold has thus received an evident confirmation.

In studying the physiological shifts developing in the human body during its acclimatization to the Extreme North, it was necessary to pay attention to the changes in its thermoregulatory reaction that may take place as a result of more or less intense influences of low temperature, so frequent in the North. We were interested to determine exactly how these changes are manifested, when they take place, what is the connection between them and the level of morbidity, and what hygienic conclusions can be drawn in order to greatly facilitate the process of acclimatization of the organism under the severe climatical conditions of the Extreme North.

We expounded the question of changes in the domain of chemical thermoregulation in preceeding works. In this work we will consider shifts in the domain of physical thermoregulation, more exactly the changes characterizing vascular reactions to cooling.

Methods. The vascular reactions to the cooling of the region of the forehead and of the extremities were studied. Cold stimuli to the area of the forehead were produced by means of aluminum cylinders 45 millimeters in diameter, filled with melting snow. The cylinder was placed on the skin above the nose for a period of 30 seconds. Prior to and after the stimulation, the temperature of the skin in this area was measured with a sensitive thermoelectrode connected to a multichannel galvanometer. The temperature was registered every 30 seconds until a stable level was obtained.

The cooling of the extremities, the wrists, and the feet was achieved by immersing them in a container with water at a temperature of 0 degrees. To prevent the skin from getting wet each extremity was covered with an adherent, but not tight, polyethylene glove or sock under which thermoelectrodes leading to the distal phalanges of the fingers and toes were fastened. The subjects under observation were given instructions to keep their hand or foot in the water until the moment the sensations of pain became unbearable. They were questioned periodically about their general feeling and about the sensations in the cooled areas. Prior to and after the termination of the experiment, the tactile sensitivity was determined by means of hair and bristles of Frey, and the ability to perform fine movements with the fingers, by repeating a certain pattern of a tortuous contour with a pencil on paper. In part of these observations recordings were taken of the reflected reactions in symmetrical points of the ipsilateral and contralateral half of the body.

The observations were conducted during the winter in one of the points on the Arctic seashore under low, medium and elevated temperatures of the dwelling. The subjects (totaling approximately 300 men) were mainly people who came to the North from the central areas of the country. Among them were workers and clerks of various occupations and of varying periods of work in the North. Some of them were constantly working in heated dwellings and were relatively rarely subjected to cold. Others worked constantly in the open air, which under the conditions of the Arctic means under frequent and prolonged influences of low temperatures and strong winds. The microclimatical living conditions were more or less equal for all subjects and were close to comfortable. Besides people who arrived into the polar region, observations were also conducted on 40 natives of the Extreme North (Yakuts, Chukchi and Eskimos) who worked as "kayurs" [?] and were engaged in fishing under ice and deer raising.

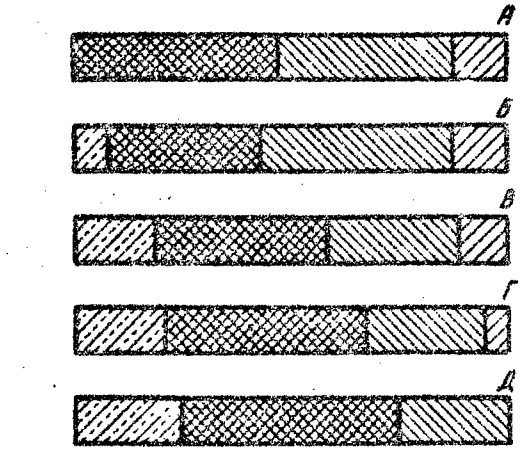
It is apparent that considerable individual and typo-

logical peculiarities in the character of vascular reactions could occasionally be observed in some individuals. However, it was possible to detect certain differences connected with the type of work as well as with the length of habitation in the North. This could primarily be related to the rapidity with which the temperature of the exposed part of the body returned to normal after cooling (see Table).

Time elapsed until complete restoration of the temperature of the forehead after the standard cooling (in minutes)

Time spent in the polar region by the subject	Type of work	No. of subjects	Average for the group
1 year	in a dwelling	22	9.7
2 years	" " "	28	9.9
1 year	in open air	33	8.8
2 years	" " "	48	8.4
Native population	" " "	40	7.0

Attention is called to the fact that, generally speaking, the restoration of the initial thermal status was the faster, the longer and the more frequently the given group was exposed to cold. The change in the rapidity of the vascular reactions depending on the training for existence under conditions of extreme cold can be seen from Figure 1: in the groups that were subjected to more frequent influences of cold the number of people with a slow vascular reaction (over 13 minutes) decreases and the number of people with a rapid one (4-6 minutes) increases. Comparing these data with the reactions observed by a similar method among inhabitants of a moderate climate where complete restoration took place most often after 15 minutes or more it becomes clear that, generally speaking, the inhabitants of the Arctic show a shift toward more flexible vascular reactions. A further analysis of the material called attention to the fact that the rapidity of the vascular reaction definitely depends on the temperature in the dwelling, (Figure 2). In following the course of the restoration of the temperature curve in the same subjects under varying temperatures of the dwelling we noticed that during the first stage the vascular re-



- rapid reactions (4-6 minutes)
- accelerated reactions (7-9 minutes)
- slowed reactions (10-12 minutes)
- slow reactions (13-15 minutes)

Figure 1. The lability of the vascular reactions to the cooling of the forehead in different groups.

Inhabitants of the Arctic working in heated dwellings: a- having spent one year. b- having spent more than two years.

Inhabitants of the Arctic working in the open air: c- having spent one year. d- having spent more than two years. e- native inhabitants of the North (Chukchi, Yakuts and Eskimos).

action takes place independently of the temperature of the dwelling once the cooling is stopped; at a later stage the restoration takes place more rapidly, the higher the temperature in the dwelling. Thus it becomes apparent that during the process of acclimatization the vascular reactions to cooling of the exposed parts (forehead, face) become more lively and more labile by the end of the first year of residence in the North, and that this lability increases at a higher temperature in the dwelling. A large number of observations on many tens of population permitted us to

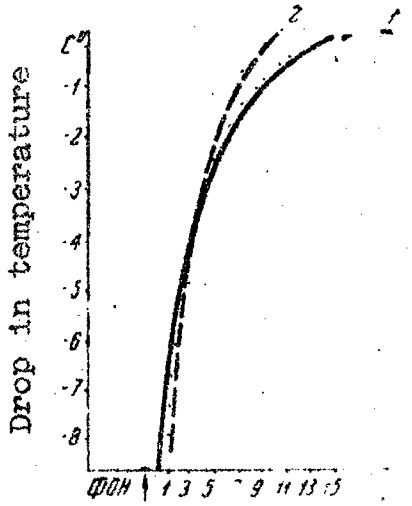
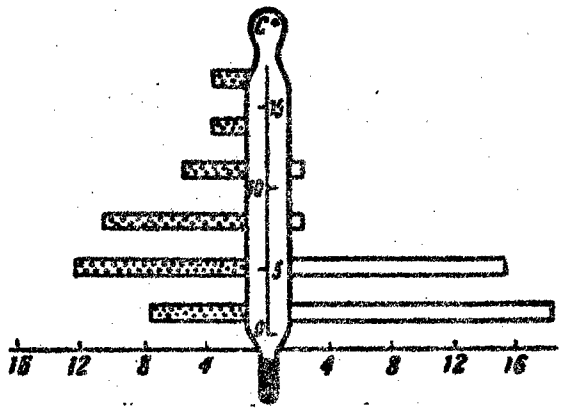


Figure 2. Restoration of the temperature of the skin of the forehead after cooling under different temperatures of the dwelling.

1 - Temperature of the dwelling, 19 degrees.
2 - Temperature of the dwelling, 25 degrees.

detect the following changes depending on the degree of acclimatization as far as the vascular reactions to cooling of the extremities is concerned. As is shown in Figure 3, the temperature of the distal parts of an extremity in a group not accustomed to work in the cold rapidly dropped to a very low level, five or even three degrees, during cooling in a bath; among people accustomed to work in the cold there were many that maintained the temperature of the extremity at a much higher level, 10-15 or even 18 degrees during the same extent of cooling. As a rule these people could tolerate the ice bath for a period of several tenths of minutes and even several hours, whereas, among the untrained, the majority of the observed subjects could tolerate this degree of cold for only five - 15 minutes. Thus trained people were losing much more heat during cooling of the extremity than the untrained ones. This type of reaction



Number of People

Figure 3. The drop in skin temperature of the wrist or foot during cooling in a bath with melting snow (temperature of the water, 0 degrees)

a- working in the cold.
b- not working in the cold.

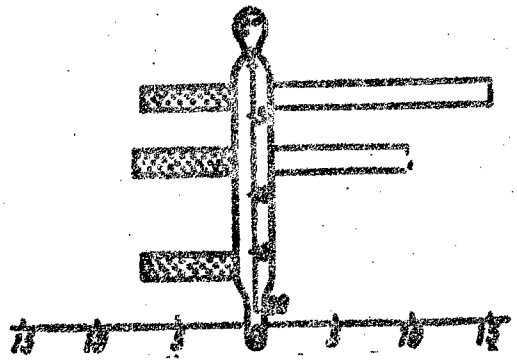
may, at first sight, appear as contradictory to the principle of a more perfect heat equilibrium with advancing training with respect to cold, and apparently leading to disturbances in the thermal balance of the body. Actually it is well-known that the lowering of the temperature in the cooled sectors takes place not as much as a result of increased heat loss but due to active vasoconstriction, mainly of the arterioles leading to a decreased blood flow through the cooled sector.

A similar reaction is also observed during severance of nerves which, in the opinion of some investigators, means that it takes place within the limits of axon reflexes, i. e., false reflexes. The adaptive character of this local regulation is self-evident. It is directed to the maximal decrease in heat loss at this particular sector where heat loss due to physical causes could become particularly great.

The regulation of the tonus of peripheral vessels of various parts of the body taking place via the higher nervous centers in the cortex and subcortex as opposed to the cerebral spinal and local reactions

is based on larger exteroceptive and interoceptive signalization on the thermal conditions of all organs and tissues and therefore has a more uniform character, regulating the local reactions in the interest of the organism as a whole and of its most important organs. Therefore, the local vascular reactions to cold are inhibited during acclimatizing as a result of higher cortical regulation which achieves the most complete adaptation of the body to the environmental conditions, i. e., with advancing training with respect to cold the reactions diminish, rather than become more active. The cortical vasodilatory impulses counteract and dominate the local vasoconstrictor influences. Under conditions of intense cooling the extremities remain warmer, which insures better conditions for performing their functions. Some increase in general heat loss that unavoidably takes place under these circumstances can be compensated by other thermoregulatory reactions. During the study of the dynamics of the modifications in the gaseous exchange in individuals during various periods after their arrival in the North, and who were frequently subjected to the influences of cold, we actually were able to observe that after approximately six-12 months a change appears in the thermoregulatory metabolism, which brings it to a higher level. Thus heat formation in the body during some periods increases either due to higher heat losses as was shown above or due to the change in the oxidative processes in the tissues to another way of thermogenesis; it therefore becomes possible to maintain the temperatures of the working organs at a higher level without impairing the general heat balance. The uniform character of such reactions definitely indicates their cortical regulation.

Another important change taking place during the process of acclimatization pertains to the thresholds of sensitivity to pain during cooling. Mechan, Stall and Hardy, who have called attention to the very high tolerance of the Eskimos to cooling of their hands have touched upon the problem of the cause of this increased tolerance: are the Eskimos under these circumstances less sensitive or only more patient? In the light of the data by Aschoff, Greenfield and Shepherd, demonstrating that the moment when the sensation of cold turns into the sensation of pain is connected with an increased wave of vasoconstrictor impulses, the above-mentioned facts about maintaining the temperature of cooled extremities at a higher level indicates that trained people should experience less intense sensations of pain. However, the problem doesn't at all end here, as is indicated by the analysis of a large series of observations. As can be seen from Figure 4, the transition of local thermal



Number of people

Figure 4. The drop in skin temperature of the wrist or foot at the moment of the appearance of pain.

a- working in the cold.
b- not working in the cold.

sensations into a diffuse feeling of pain takes place among trained people at a much lower drop in the temperature of the organ. If in people untrained to cold the pain often appears in the presence of a small drop of the temperature -- even by five - 10 degrees -- a part of the trained people has painful sensations only when the temperature decreases by 15 degrees, and in some of them even more.

A third peculiarity is, as was already stated, with regard to the vascular reactions on the forehead, a quicker restoration of the temperature after cooling takes place in trained people, whereas in untrained, the restoration is more prolonged even after a considerably lesser duration of the stimulus. Finally a fourth peculiarity consists in the more limited and localized character of the vasomotor reaction in the immediate area of cooling, and the absence of its spread to other symmetrical sectors.

All the above properties can easily be noticed by comparing the vascular reactions to cooling among people in the various stages of training for work in the cold. Therefore, in untrained people, cooling of the wrist produces a rapid drop in the temperature to very low levels, -3 to -7 degrees. A sensation of cold changes into pain after six - 10 minutes and

rapidly reaches an intolerable level, which results in a demand that the experiment be discontinued. The restoration of the temperature is protracted, the return to the initial level being observed after 12-15 minutes. The symmetrical sectors that were not cooled show a marked reflected reaction.

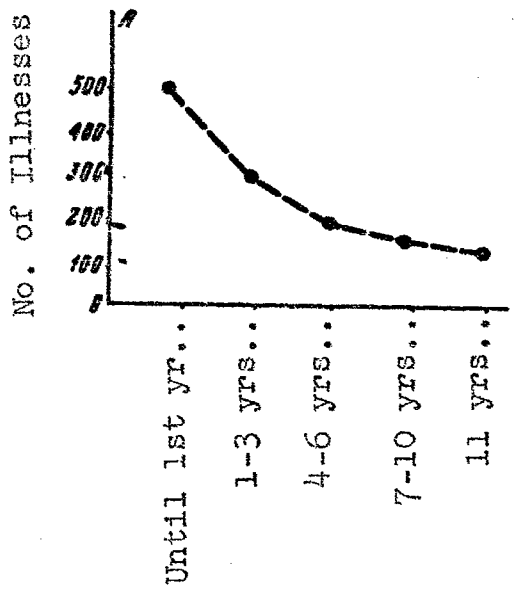
Thus during the process of acclimatization there is an increase in the threshold to sensation of pain, increase in the lability of the vascular reactions in the cooled area, inhibition of the vascular tonus in the distal parts of the extremity as well as inhibition of the reflected reactions in depth and on the parts of the body that were not cooled. Whereas the last two reactions result in a higher resistance of the body to common colds, the first reaction increases the functional capabilities of the working organs. And actually during the prolonged cooling, trained people did not lose the ability to perform fine motor movements as, for instance, following with a sharp pencil a complicated contour made on paper, whereas in untrained people after less prolonged cooling, the hands "stiffened" to such a degree that they were barely able to hold the pencil in their hand, frequently used to break it, and followed the given contour inaccurately.

The above cited data can be supplemented with the results of observations of several American investigators who established that the blood flow through the extremities in the Eskimos is about twice that in untrained Americans under the same temperatures of the surrounding air, and that the Eskimos show an increase in the total volume of blood plasma. All these facts correlate well with one another as well as with the facts confirmed by us and other authors, decrease of the level of systolic and diastolic pressures in the natives and settlers of the North.

What then is the hygienic importance of the above phenomenon?

The first general conclusion pertains to the connection between these data and the morbidity level of the Arctic population. It was said above that the observed change in several functions takes place immediately during the first year of life and work in the North.

And it is exactly during this period that the greatest frequency of illnesses, as well as the highest number of sick people, is observed -- as was indicated by a special analysis of the composition and level of general morbidity of the Arctic population conducted by Ye. I. Soltyskiy (Figure 5). The same pertains to the number of illnesses connected with the factor of exposure to cold as well as for the number of occupational trauma, the main causes of which



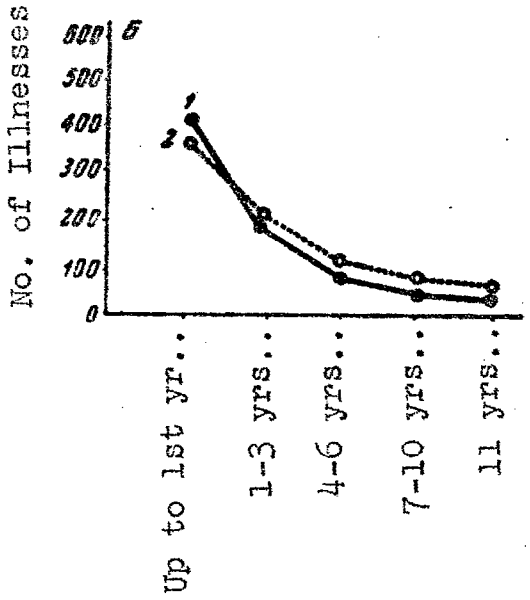


Figure 5. Level of general morbidity of inhabitants of the polar area depending on the time lived in the Arctic (per thousand population).

а- total number of illnesses. б- total number of people taken sick.

1- Tiksie. 2- The Inlet of Foresight.

are the marked cooling of the extremities and the insufficiency of the artificial illumination of the working areas during the dark period of the year.

It is barely necessary to prove that in this case there is a deep inner connection of a cause-result relationship between both types of phenomena -- the physiological changes and the morbidity. The important hygienic conclusion can be drawn that special attention should be directed toward the development and application of several hygienic measures, particularly during the period of acclimatization when human health is most vulnerable.

More specific conclusions pertain to such problems as the necessity of better utilization of modern technical means toward the improvement of the working conditions in the mines with constant freezing, on the open projects, and so forth. Sources of radiant heating may prove to be particularly effective under these circumstances as well as the creation of stations for periodical rewarming, etc. An important role belongs to the regulation of permissible periods of work in the open under various combinations of meteorological conditions.

It is necessary to speed up the establishment of definite norms for the microclimate of residences, communal and industrial dwellings as well as medical and children's institutions adapted to the climatical particularities of the Extreme North. With this in mind the data should be taken into account dealing with the dependence of the speed of restoration of the vascular reactions after cooling. New data on the role of the muscular tonus during moderate degrees of cooling make clear, and to a certain degree explain, the rationale of the fact incontrovertibly established by several investigators that the population of the Extreme North definitely prefers to maintain in their dwellings a temperature somewhat higher than in moderate climates.

Finally, important conclusions should be drawn with regard to developing rational forms of training and hardening for work under conditions of intense cold, developing of measures of personal hygiene and prophylaxis, new and more perfected types of work clothing, and so forth. The tremendous work in cultivation of the Extreme North which lies before us during the years of completion of the Seven-Year Plan, the marked increase of the duration of navigation via the Northern Sea routes due to the introduction of powerful ice breakers, the great construction works in Siberia -- all this will necessitate attracting tens of thousands of Soviet people for the work in the extreme north. In connection with this there is a marked increase in the importance of hygienic problems determining the successful course of the process of ac-

climatizing the population.

Conclusions

1. The shifts in the domain of physical thermoregulation in man during his acclimatization in the Extreme North were studied by recording the vascular reactions to cooling of an area of the forehead, the wrists, and the feet.

2. The discovered shifts in the domain of physical thermoregulation can partly explain a decrease in the level of general morbidity and especially of the number of illnesses connected with exposure to cold that take place during the process of acclimatization of the population to the conditions of the Extreme North. These shifts should be taken into consideration in the development of rational ways of "hardening" and training in the conditions of marked exposure to cold and measures of personal hygiene and prophylaxis, as well as new types of work clothing.

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