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SKIN TEMPERATURES OF THE EXTREMITIES UNDER VARIOUS PHYSICAL AND PHYSIO- LOGICAL CONDITIONS *

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ABRIDGMENT

It is to be emphasized that, in a consideration of the surface temperatures in the thermal regulation of the body, the total area of the skin is important. Hence attention should not be focused alone on the lower portions of the extremities or on the fingers and toes, which are a relatively small part of the whole surface. Thus a study of average skin temperature is of more vital interest to the physiologist, metabolist and physicist than to the clinician. During the past decade there has been an awakening of interest in the subject of peripheral vascular disease. Clinicians have become increasingly interested in skin temperature, particularly of the extremities. It is probable, however, that the clinician seldom has occasion to utilize the average skin temperature, as developed by Hardy and DuBois, Burton and Bazett, and Winslow, Herrington and Gagge, and others. In conditions of peripheral vascular disease the clinician is concerned chiefly with the supply of blood to the extremities and digits. He uses surface temperature (and often inaccurately and incorrectly unless he has controlled conditions of both patient and environment) as an index of supply of blood to the skin. When an occlusive arterial disease is present, preservation of the extremity depends on an adequate supply of blood to the diseased part. Gangrene, when it develops, begins in the skin and not in the deeper tissues, and it invariably begins in the area of the skin which has the poorest blood supply. The significance of skin temperatures of the digits thus becomes obvious.

My colleagues and I have studied the surface temperatures of the extremities of numerous subjects with normal blood circulation as well as of patients with peripheral vascular disease under controlled environmental conditions with the subjects in the basal metabolic state. Such investigations have clarified many previous vague conceptions concerning the significance of changes in skin temperature and resulting blood flow in the extremities. This work

* For a review of the literature and important investigations on "Skin temperatures and thermal regulation of the body with special reference to the extremities," the reader is referred to an article by the author in *Medical Physics*, Chicago, Year Book Publishers, 1944, pp. 1523-1555.

has been important from both diagnostic and prognostic standpoints. Studies of the surface temperatures of the fingers and toes serve in the differentiation of occlusive arterial disease and vaso-spastic conditions. Furthermore, data on temperatures of the extremities are highly desirable, if not essential, in selection of subjects for sympathectomy.

A few statements of fact should be appreciated fully and should be borne clearly in mind.

1. There is no such thing as a "normal" of skin temperature of any area of the body as there is a rectal, oral or even axillary temperature.

2. Various internal and external factors control skin temperature; hence one must always define the conditions under which the skin temperatures are taken.

3. The skin temperatures of the extremities and digits are of much greater significance in peripheral vascular disease than average skin temperature.

4. The skin temperatures of the fingers and toes serve as the most sensitive indicators of the changes in vasomotor tone of the superficial vessels—a process which, presumably, occurs over the whole integument of the body.

5. Various portions of the body surface play relatively different roles in elimination of heat from the body. Increasing atmospheric temperature or increasing heat production through ingestion of food causes a much greater shift of blood to the extremities than to other parts of the body surface, as shown by Burton and Murlin, Maddock and Coller, and Sheard, Roth, Williams and Horton.

6. The skin temperatures of the extremities, particularly of the toes and fingers, under controlled standard environmental conditions, are influenced markedly by the metabolic rate.

7. The close or "needle-valvelike" regulation of loss of heat is maintained chiefly by vasomotor control of the peripheral blood vessels and consequent adjustments of the shift of blood and changes in blood flow to the integument of the extremities.

8. Under controlled environmental temperatures (77° F. and 40 per cent relative humidity have been chosen), the vascular dilatation and regulation, and hence skin temperatures, are the maximal possible in the upper extremities and fingers under the imposed conditions before similar regulation and dilatation occur in the lower extremities and toes.

Hence skin temperatures may be used to investigate the distribution of blood, which may be shifted from the deeper to the superficial tissues of the body to produce greater cooling or, in turn, may be shifted from the superficial to the deeper tissues, through augmented vasoconstriction of the peripheral blood vessels, to effect greater conservation of heat through a decrease of blood supply to the periphery. The human body adjusts itself to low tempera-

tures chiefly by vasoconstriction of the peripheral blood vessels and to high atmospheric temperatures largely by an increase of sweat (and consequent loss of heat by evaporation) subsequent to maximal vasodilatation of the peripheral vascular system. The relatively constant internal temperature of the body is the result of the balance between production of heat in the body and loss of heat from the body. If environmental temperature and relative humidity are maintained at some comfortable level, such as 25° C. (77° F.) and 40 per cent relative humidity, and if individuals, in the basal state, lightly clothed and supine, are allowed to remain for an hour or more under those environmental conditions, the toes will exhibit the lowest temperatures. In the zone of comfortable temperatures (approximately 23° to 29° C., or 73° to 84° F.), the regulation of dissipation of heat apparently is controlled largely by the lower extremities; in fact, it seems as though the flow through the lower portions of the legs and feet were thermostatically controlled.

The greater portion of the researches conducted thus far have been concerned with individuals with normal circulation of the blood as well as those who have peripheral vascular disease when placed under environmental temperatures ranging from 18° to 34° C. (65° to 93° F.). These investigations deal with (1) control of environmental conditions and subjects of test; (2) effects of posture on skin temperatures of the extremities; (3) relationship between basal metabolic rates and temperatures of the toes under an environmental temperature of 25° to 25.5° C. (77° to 78° F.) and 40 per cent relative humidity (assumed as standard conditions in all these investigations); (4) thermal changes produced in the extremities by the ingestion of food; (5) changes in temperatures of the fingers and toes and relative roles of the upper and lower extremities in the regulation of dissipation of heat from the body when the subjects were placed under closely controlled environmental conditions which were changed by increments of 1° to 2° C. within the range of 18° to 34° C., and (6) effects of changes of relative humidity on the skin temperatures of the extremities.

In many instances of peripheral vascular disease, the extremities are moist and cool to the touch, and the subjects complain of cold hands or feet, as the case may be. When *vasospasm* is marked, thereby interfering with normal control of loss of heat through vasomotor regulation of the peripheral blood supply, it is probable that dissipation of heat is assisted by evaporation of sweat which is present in abnormal amounts. As a result of vasospasm and the abnormally high degree of evaporative regulation, which are present under environmental conditions that normally call for dissipation of heat chiefly by the processes of radiation and convection, the temperatures of the toes may be several degrees centigrade below room temperature (25° C.). Temperatures of the fingers may range from normal values (32° to 34° C.) to temperatures indicative

of pronounced vasoconstriction of the peripheral vessels of the upper extremities. As the atmospheric temperatures are progressively increased, environmental conditions may be found in which considerable dilatation of the peripheral vessels occurs in functional vasospasm. In general, there will be corresponding changes in the temperatures of the toes which are commensurate with the values found in normal subjects, although conditions are encountered in which there is evidence of tissue heating only, with little vasodilatation of blood vessels. In *organic occlusion* of the lower extremities, with some superimposed spasm, environmental temperatures may be established in which the lower extremities will be normally dry and in which the temperatures of the toes will be above atmospheric temperature, thereby indicating increased blood supply. This range of atmospheric condition varies with the degree of vasospasm and occlusion, but may be set at 28° to 32° C. (82° to 90° F.).

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RECOVERY OF RADIUM TUBES FROM SEWERS *

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A SENSITIVE ELECTRON RAY VOLTMETER **

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