TEMPERATURE SENSATION AND THERMOREGULATORY VASCULAR REACTIONS IN MAN

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Continuous monitoring of the temperature of the human skin with a highly sensitive thermometer combined with simultaneous recording of verbal descriptions of temperature sensation showed that the most important thermoregulatory reactions of the skin vessels of the limbs are linked in a definite manner with the appearance of a given temperature sensation.

KEY WORDS: temperature regulation in man; physical thermoregulation; vascular reactions; temperature sensation.

In man under optimal temperature conditions, constant wave-like fluctuations of the skin temperature take place on the fingers and toes, which play the role of principal heat exchangers. Negative correlation is found between these waves and fluctuations of brain temperature (measured in the external auditory meatus). During exposure to a warming microclimate, when the air temperature is slowly (0.1-0.15 deg/min) raised, after a certain time interval (about 30 min) the cutaneous vessels of the fingers suddenly dilate sharply, and 20 min later so also do the vessels of the toes, so that the skin temperature in these areas increases by 5-8° in 5-10 min. Meanwhile the temperature in the external auditory meatus falls. In other parts of the body temperature changes of this type are either extremely slight or they do not occur whatsoever [2, 3].

The investigation described below was carried out to study the connection between these important thermoregulatory reactions and the subjective temperature sensation in man.

EXPERIMENTAL METHOD

The level and dynamics of the skin temperatures (on the fingers and toes, on the chest and cheek) and the central temperature (in the external auditory meatus) were recorded by continuous precision thermometry [1]. The sensitivity was 0.1° for measurement of the skin and air temperatures and 0.01° for measurement of the temperature in the external auditory meatus. The temperature sensations were recorded at the same time. Without preliminary questioning by the experimenter, the subject reported the appearance of a particular temperature sensation. The appropriate score on a five-point system (1 – cold, 2 – chilly, 3 – comfortable, 4 – warm, 5 – hot) was recorded on the temperature chart opposite the values of the skin and air temperature recorded at that moment by the digital printing device of a potentiometer.

Young, clinically healthy subjects, wearing clothing with a heat insulation of 0.7-1 clo, were investigated. During the experiment the subjects sat in an armchair in a comfortable and relaxed position. Altogether 29 experiments, each lasting 3 h, were carried out on nine subjects. The method of parametric statistics was used to analyze the results.

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TABLE 1. Threshold Temperatures for Appearance of Different Temperature Sensations in the Zone of the Heat Optimum

Temperature sensation	No. of estimates	Skin temperature				Temperature in external auditory meatus
		on cheek	on chest	on fingers	on toes	
Chilly	10	32,5±0,4	34,5±0,2	30,6±0,6	29,6±0,8	36,86±0,06
Comfortable	22	32,9±0,2	34,4±0,1	30,9±0,4	29,6±0,2	36,72±0,05
				$P<0,05$		
Warm	9	33,1±0,3	34,6±0,1	32,4±0,6	30,3±0,7	36,75±0,08
				$P<0,05$		
Hot	2	34,3±0,5	35,0±0,3	34,4±0,8	32,0±0,5	36,62±0,1

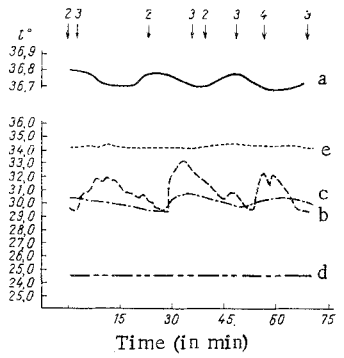

Fig. 1. Temperature sensations and thermoregulatory vascular reactions in man in a thermoneutral zone: a) temperature in external auditory meatus; b) of skin of fingers; c) of skin of toes; d) of air in chamber; e) of skin of chest. Arrows mark times of appearance of temperature sensation: 1) "cold," 2) "chilly," 3) "confortable," 4) "warm."

EXPERIMENTAL RESULTS

The results of 11 experiments on seven subjects showed that under optimal heat conditions, with the ambient temperature unchanged, the subjects reports a whole range of sensations from "chilly" to "hot" (Table 1).

The subjects reported that they felt "comfortable" or "warm" or even "hot" as the skin temperature on the fingers and toes began to rise or at the peak of this rise, and they felt "comfortable" or "chilly" when the temperature started to fall or actually decreased (Fig. 1). In other words, the appearance or change of a subjective temperature sensation apparently coincided with changes in vascular tone in the distal parts of the limbs. Positive correlation was in fact found between the temperature sensations and the dynamics of the skin temperature of the fingers and toes ($\eta_{43} = 0.53$ when $P < 0.001$ for the fingers and $\eta_{43} = 0.31$ when $P < 0.05$ for the toes). As regards the dynamics of the temperature on other parts of the body, no such correlation was found.

Another fact must be noted in the analysis of the data in Table 1. The skin temperature of the hand and foot on the appearance of a "chilly" feeling was in fact very close to the skin temperature when the subject felt "comfortable." A subjective assessment of "warm" was made at higher temperatures, i.e., the difference between the threshold temperatures at the time of appearance of these sensations and temperature described as "comfortable" increased significantly. The impression was obtained that man is more sensitive to vasoconstriction, i.e., to a fall of skin temperature, than to its elevation.

During exposure to a warming microclimate (18 experiments on nine subjects) in most cases the subjects did not observe the increase in air temperature (the temperature in the chamber rose from 23 to 28°C at a rate of 0.1 deg/min) until vasodilatation occurred in the skin of the fingers or toes. Despite the fact that the air temperature was increased by almost 4%, as a rule (in 78% of cases) the subject reported a change in the temperature sensation either at the time of onset of reflex vasodilatation or when it reached maximal development (Table 2; Figs. 2 and 3).

During exposure to external heat the subjects in most cases reacted sufficiently clearly to sudden vasodilatation in the skin of the fingers and toes by a change in their subjective sensation of temperature.

In the modern view [4], general temperature sensations are determined by impulses from thermoreceptors of the subcutaneous vessels, which are essentially stretch receptors (mechanoreceptors) and respond to displacement of the smooth muscles of the vessels. It can accordingly be postulated that

TABLE 2. Threshold Temperatures for Onset of Temperature Sensations during Exposure to a Warming Microclimate (n = 18)

Period of reaction	Temperature at time of onset of temperature sensation						No. of reports of a change in temp. sensation	Mean rating of temp. sensation, in points
	air	skin of chest	skin of cheek	skin of foot	skin of hand	in external auditory meatus		
Before elevation of air temperature in chamber (initial background)	23.3±0.2	34.2±0.1	32.2±0.3	26.4±0.9	27.6±0.2	36.75±0.05	–	2.7
During latent period of reflex vasodilatation	27.4±1.4	34.4±0.2	32.7±0.4	26.3±0.8	27.3±0.4	36.76±0.1	4	3.5
At moment of onset of reaction	28.2±0.8	34.3±0.2	33.6±0.3	24.5±1.1	27.9±0.5	36.68±0.1	5	4.0
At moment of maximal vasodilatation	28.2±0.5	34.8±0.4	34.3±0.3	28.9±1.6	30.9±0.9	36.89±0.03	9	4.2

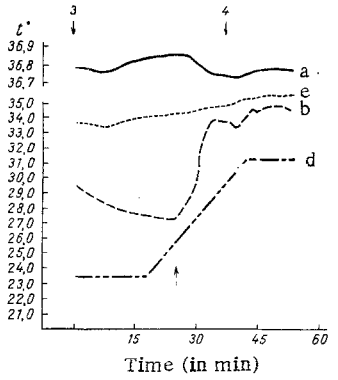

Fig. 2

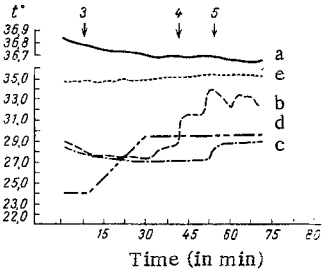

Fig. 3

Fig. 2. Temperature sensations and thermoregulatory vascular reaction in man during exposure to a warming microclimate. Legend as in Fig. 1. Subject assessed his temperature state as "comfortable" (rating 3) before beginning of heating. For almost 20 min he did not notice the heating although the air in the chamber was heated to almost 29.5°C; only after the appearance of vasodilatation in the skin of the fingers (the beginning of the reaction is marked by an arrow) did he state that he felt "warm" (rating 4).

Fig. 3. Temperature sensations and thermoregulatory vascular reaction in upper and lower limbs during exposure to a warming microclimate. Legend as in Fig. 1. Subject reported that he felt "warm" (rating 4) at the time of onset of vasodilatation in the skin of the fingers, and when the reaction developed in the skin of the toes he felt "hot" (rating 5).

changes in the lumen of the vessels of a thermoregulatory character are also responsible for the change in subjective temperature sense in man.

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