ERRORS IN SKIN TEMPERATURE MEASUREMENTS DUE TO CHANGES IN EVAPORATION UNDER THE SENSOR

(UDC 612.51:612.59]-087.7.088)

V. V. Yakovlev and B. A. Utekhin

Moscow

(Presented by Active Member of the Academy of Medical Sciences of the USSR P.G. Gorizontov)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 60, No. 10,
pp. 121-123, October, 1965
Original article submitted April 14, 1964

The method of measuring skin temperature is widely used to estimate heat exchange in the human organism. The various designs of thermoelectric sensors described by a number of authors [1-4, 6-9] can be divided into two groups—contact and distant. The former, which are tightly applied to the skin surface, prevent evaporation of sweat and, consequently, in the area under the sensor the temperature is higher than at any other point of the skin, i.e., greater than the true temperature. Evidently the greater the sweating and evaporation, the greater the error in the measurement. The present investigation was devoted to a study of the magnitude of error associated with the disturbance of sweat evaporation from the portion of skin under a sensor in skin thermometry.

To solve this problem one of the authors (V. V. Yakovlev) designed a reticular sensor which is a mesh wound in a zig-zag fashion in one plane by nickel wire (diameter 70 μ). Between the wire loops of the sensor is a space (0.5 mm) through which sweat freely passes and evaporates. The height of the sensor is equal to the diameter of the nickel wire. Thus, by using in the experiments two types of contact sensors which did not impede evaporation (reticular) and types that did prevent evaporation of sweat, we proposed to elicit the error in measuring skin temperature.

The majority of sensors preventing evaporation of sweat can be assigned to two basic groups: point (diameter less than 1 mm) and flat (area from 2-4 to 300-400 mm^2).

To compare the data obtained by the indicated 3 types of contact sensors, we carried out 22 experiments on healthy males aged 20-24 years. In an experimental heat chamber the temperature was maintained at the level of 45 ± 1° C. The temperature in the room where the control measurements were made was 20 ± 0.5°. On the skin surface of the forehead of the testee we placed a row of reticular (15 × 40 mm), point (diameter 0.3-1 mm), and flat (15 × 25 mm) sensors. After adaptation in a room with a temperature of 20° where the skin temperature was measured 4 times, the testee was placed in the hot chamber and performed an assigned task of average exertion (10 min) with subsequent rest (10 min).

TABLE 1. Maximal Divergence of Thermometric Data in Various Experiments (in degrees)

	Number of experiment									
	1	2	3	4	5	6	7	8	9	10
Between flat and reticular sensor. .	2,3	3,1	3,3	2,4	1,6	2,0	1,2	3,2	3,0	2,4
Between point and reticular sensor...	1,4	2,7	3,0	1,6	1,8	2,0	0,8	3,8	3,3	1,4

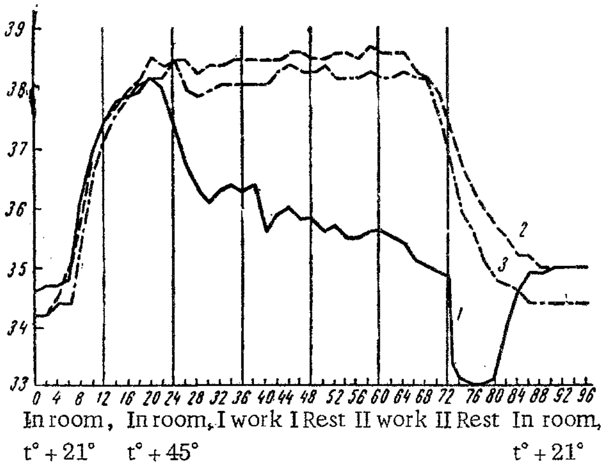

Fig. 1. Measurement of the temperature of the forehead skin by reticular sensor (1), flat (2), and point (3).

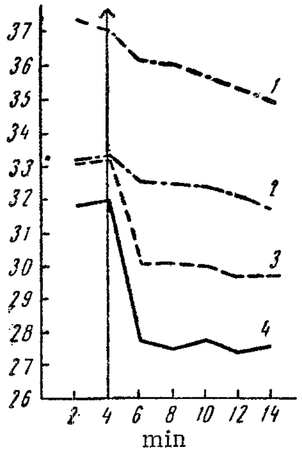

Fig. 2. Measurement of temperature of the surface of a chamois on a test stand measured by point sensor (2) and reticular sensor (4). Curves 1 and 3, respectively, denote changes of water temperature in a basin and on the inside surface of a chamois; the vertical arrow indicates the moment of wetting the chamois.

It follows from Fig. 1 that until the start of the task, i.e., up to the moment when appreciable sweating was absent, all 3 types of sensors indicated the same temperature. The curve characterizing the skin temperature recorded from the surface of the forehead by the reticular sensor 2-4 min after the start of the task markedly dropped and with slight fluctuations held at a rather low level (35.5°). The skin temperature measured by the flat and point sensors did not change up to the end of the experiment and held at a high level (38°). Only after the testee left the chamber did the readings of all 3 sensors return to the initial figures after a certain time. The maximal divergence between the temperature measured by the reticular sensor on one hand and by the flat and point sensors on the other was more than 3° (see Table 1).

As is apparent from Table 1, the skin temperature recorded by the point and flat sensors is higher than the temperature recorded by the reticular one. Apparently we must acknowledge that the higher temperature recorded by the point and flat sensors is due to absence of evaporation of sweat from the area covered by the active element of the sensor.

If our assumption concerning the influence of free evaporation from the skin surface under the sensor is true, then, having covered the reticular sensor by a waterproof material, which, so to speak, converts it to a flat sensor, we should obtain a rise of temperature. Actually, in the experiment where the reticular sensor was covered with plaster during the period of the appreciable drop of skin temperature, the temperature rose for 1-2 min and reached the level of the readings of the point and flat sensors. Thus, these physiological investigations show that the temperature recorded by our reticular sensors is several degrees lower than that obtained when using flat and point sensors.

On the basis of our investigations we could conclude that the measurement of skin temperature by means of any type of contact sensor (with the exception of reticular) leads to a certain error associated with disruption of evaporation of sweat from the area of skin under the sensor. However, before we can make such a definite conclusion it was necessary to additionally test the sensors on a test stand. The latter was a metal basin filled with warm water. A layer (0.5 mm) of polyvinyl chloride and a layer of chamois were glued on the outside surface of the basin. Between the plastic and the chamois as well as on the surface of the chamois we attached reticular sensors by means of which we measured the temperature of the inside and outside surfaces of the chamois. We see from Fig. 2, where there are 4 curves reflecting the temperature changes of the chamois surface measured by different sensors, that when the surface of the chamois is moistened the temperature measured by the reticular sensor markedly drops, whereas the measurement made by the point sensor indicates no such drop.

Thus, the experiments carried out on the test stand yielded the same results as the experiments on people: the use of contact sensors when measuring the temperature of the body surface when the body becomes moist leads to errors. The error is evidently inversely proportional to the humidity of the ambient air (the lower the humidity, the higher the error) and directly proportional to the amount of sweating. Only with 100% air humidity and when sweating is absent will the error equal zero.

LITERATURE CITED

1. A. N. Boiko, Transactions of the All-Union Research Institute of Metrology [in Russian], Leningrad, No. 4 (59) (1947), p. 31.
2. R. A. Kaladze, Fiziol. zh. SSSR, 6 (1957), p. 588.
3. G. S. Litvin, In the book: Innovators' and Inventors' Suggestions in Traumatology and Orthopedics [in Russian], Kazan', 2 (1960), p.58.
4. S. I. Lyutinskii, Byull. éksper. biol. i med., 9 (1961), p. 120.
5. N. N. Mishchuk, Electrometric Method of Investigating Sweating and Its Use Experimentally and in the Clinic [in Russian], Leningrad, (1948).
6. G. É. Olinskii, Kurortol. i fizioter., 5 (1936), p. 94.
7. O. V. Saks, Abstracts of Reports of the 2nd All-Union Conference on the Use of Radio Electronics in Biology and Medicine [in Russian], Moscow, (1962), p. 116.
8. V. V. Tret'yakov and P. A. Ondzul, Byull. éksper. biol., 2 (1961), p. 115.
9. V. Ya. Éskin, Transactions of the Institute of Regional Medicine [in Russian], AN KirgizSSR, Frunze, 2 (1959), p. 227.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.