Skin Temperature Response of Normal Human Subjects to Various Conditions

By Walter Redisch, M.D., Edward Sheckman, M.D., and J. Murray Steele, M.D.

Ten healthy volunteers (five males and five females), 25 to 41 years of age, were exposed to several different environmental conditions in a constant temperature room. It was found that at 20°C and about 55 per cent humidity, about five hours after the last meal, the behavior of the temperature of the toe in contrast to that of the finger was consistent, reliable and reproducible. These conditions, somewhat cooler than those frequently used, were deemed suitable for testing vasodilator drugs or procedures.

INVESTIGATION of skin temperature has generally been conducted at environmental temperatures between 23°C and 31°C. This range represents the approximate limits of the zone of vasomotor regulation or the condition of comfort.1-3 The environmental conditions most often selected have been temperatures from 24 to 27°C, relative humidity of 40 to 50 per cent, and wind velocity of less than 1 meter per second. The subject was generally in the basal state, awake, lightly clothed, and in a semireclining or supine position. Most of the work in this field has been carried out within these limits.1-4

These conditions, however, were found to be unsuitable for testing the effect of vasodilator drugs on skin temperatures, for two reasons: first, the period of time necessary for adaptation was impractically long and spontaneous variations in temperatures recorded interfered with the interpretation of the curves; second, it was necessary to have the room cool enough to maintain the extremities in gentle vasoconstriction so that dilation of the vessels could be readily recognized.

It has been shown that even under carefully controlled conditions within the zone of vasomotor regulation, a period of from one to two hours is required for adaptation to change in environmental temperature, change in posture, and partial disrobing.4-9 Instability of finger temperatures has been specifically pointed out under various conditions6, 10, 11, 12 and is apparent, although not specifically mentioned, in curves published by Sheard and his group.7, 11, 14

It was the object of this study to learn the most comfortable environmental conditions under which surface temperature of the extremities of normal individuals is sufficiently predictable, reproducible, and cool enough to test vasodilation.

METHODS AND MATERIAL

Experiments were conducted in a constant temperature room. After preliminary trial at various temperatures, two sets of environmental conditions were chosen for further study: 20°C ± 1°C and 22°C ± 1°C, with relative humidity between 51 and 57 per cent and wind velocity at a little less than 1 meter per second. These environmental conditions were each varied further by allowing the patients to have lunch 30 to 90 minutes before beginning the experiment in one series and omitting lunch in another so that the experiment was begun about five hours after breakfast. Ten subjects were tested under all of these four conditions. Five of the subjects were also tested at the lower temperature (20°C), having fasted since the evening of the previous day except for water. The subjects were healthy adults, five men and five women, varying from 25 to 41 years of age.

The experimental period was 180 minutes or longer, beginning between 12:00 noon and 1:30 p.m. in the first four conditions, and between 9:00 and 10:00 a.m. in the fifth condition. The subjects were supine, head elevated on one pillow, wore cotton pajamas, and were covered with one sheet. They were kept awake throughout the period by means
of conversation, reading or music. None of the subjects had taken any drug or alcoholic beverage on the day of the experiment or smoked for at least 30 minutes prior to the beginning of the experimental period.

Temperatures were recorded automatically by means of a six point Leeds and Northrup Speedomax. This machine affords an accuracy of ±0.15 C. The rate of recording was such that the temperature at each of the six points was recorded every 22.5 seconds through a three hour experimental period. Thus a quasicontinuous curve was obtained. Welded iron-constantan thermocouples were made from 30 gauge thermocouple wire insulated with extruded nylon. The thermocouples were placed on the skin under a 1 cm. square of foam rubber held in place by scotch tape. The rectal thermocouple was fixed by 00 silk and collodium within a 16 F soft urethral catheter. Temperatures were recorded in all subjects from the midforehead, palmar surface of the terminal phalanx of the right middle finger, and the plantar surface of the distal phalanx of both great toes. Rectal temperatures were recorded in about half the experiments. The sixth thermocouple was used as an exploratory one, temperatures being taken from different sites such as the skin over the zygoma, the xiphoid and the lateral aspect of the leg or thigh.

RESULTS

The five sets of circumstances under which skin temperatures were studied were, then:

1. L-22 C., 30 to 90 minutes after lunch at 22 C.
2. NL-22 C., five hours after breakfast; no lunch; at 22 C.
3. L-20 C., 30 to 90 minutes after lunch at 20 C.
4. NL-20 C., five hours after breakfast; no lunch; at 20 C.
5. NB-20 C., following fast from the previous evening (no breakfast), except for water, beginning at 9 a.m. the next morning.

At the end of the period of study the skin temperatures all were between 18 and 38 C. For purposes of easy description of behavior of skin temperatures, this 20 degree range was divided in four 5 degree zones and the number of individuals falling into each zone counted (table 1).

<table>
<thead>
<tr>
<th>Zones of Temperature</th>
<th>Environmental Conditions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L-22 C.</td>
</tr>
<tr>
<td>33.1-38 C.</td>
<td></td>
</tr>
<tr>
<td>28.1-33 C.</td>
<td>.</td>
</tr>
<tr>
<td>23.1-28 C.</td>
<td>.</td>
</tr>
<tr>
<td>18 -23 C.</td>
<td>.</td>
</tr>
</tbody>
</table>

* L—with lunch; NL—without lunch.

Table 1.—Tabulation of 10 Individuals According to Surface Temperatures of Their Extremities at the End of Experimental Period under Four Different Environmental Conditions

Table 2.—Data on Adaptation of Toes under Five Environmental Conditions

<table>
<thead>
<tr>
<th>Environmental Condition*</th>
<th>Number Tested</th>
<th>Number Adapted</th>
<th>Average Adaptation Time</th>
<th>Range of Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>L—22 C.</td>
<td>10</td>
<td>4</td>
<td>99</td>
<td>25.7—26.5</td>
</tr>
<tr>
<td>NL—22 C.</td>
<td>10</td>
<td>9</td>
<td>91</td>
<td>23.2—24.2</td>
</tr>
<tr>
<td>L—20 C.</td>
<td>10</td>
<td>7</td>
<td>92</td>
<td>21.7—22.7</td>
</tr>
<tr>
<td>NL—20 C.</td>
<td>10</td>
<td>10</td>
<td>60</td>
<td>20.5—21.5</td>
</tr>
<tr>
<td>NB—20 C.</td>
<td>5</td>
<td>5</td>
<td>118</td>
<td>20.5—21.5</td>
</tr>
</tbody>
</table>

* L—with lunch; NL—without lunch; NB—without breakfast.

Toes: As the conditions are changed successively from condition 1 to condition 5, the frequency with which toe temperatures reach the
SKIN TEMPERATURE RESPONSE OF NORMAL SUBJECTS

lower zones increases progressively (table 1). In L-22 C. the distribution is more widely spread and there is little tendency for the toe temperatures to fall. Under conditions NL-20 C. and NB-20 C., only once did a toe fail to reach the lowest temperature zone. Under conditions NL-22 C. and L-20 C. the pattern of distribution is intermediate between these two tendencies to fall, and ends at a much lower level than that of the fingers. These differences are least apparent in condition L-22 C. and most apparent in NL-20 C. and NB-20 C. (table 2).

Forehead. The temperatures taken from the forehead began and remained in the highest zone throughout all but two of the 45 experiments.

Figs. 1 (left) and 2 (right). Simplification of quasicontinuous curves of temperatures taken from the great toes, finger, and forehead, under conditions 1 to 4 for each individual. The columns represent the range of the temperatures taken at the designated point in each of the 20 successive nine-minute periods.

LGT—left great toe; RGT—right great toe; RMF—right middle finger; F—forehead; Ordinate—temperatures in degrees centigrade; Abscisse—time in minutes.

extremes with the majority of toes ending in zone 18 C. to 23 C.

Fingers. The number of individuals whose finger temperatures remained in zone 23 C. to 28 C. also become progressively fewer as conditions are changed in succession from L-22 C. to NB-20 C. Very few finger temperatures fall into zone 18 C. to 23 C., however, either at the beginning or at the end of the experimental periods (table 1).

In general, the temperature of the toes begins at a lower level than that of the fingers, shows a much more consistent and marked tendency to fall, and ends at a much lower level than that of the fingers. These differences are least apparent in condition L-22 C. and most apparent in NL-20 C. and NB-20 C. (table 2).

The time taken for the temperature of the toes to arrive at a sufficiently steady state to test for a vasodilator effect was usually about 90 minutes, although usually a steady downward trend would permit testing within 45 minutes to an hour (figs. 1, 2, and 3). On the other hand, the fingers usually failed to behave in a predictable fashion. Even under the coolest environmental and strictest basal conditions imposed, they continued, as has often
been reported, to fluctuate widely and irregularly. The fingers are, therefore, obviously not suitable for testing vasomotor drugs.

With the exception of three instances occurring in different individuals, the temperature of the forehead was stable and adapted from the onset of the experiments.

The height of the column in the abstracts of the temperature records (figs. 1, 2, and 3) affords an index of the spontaneous variations during any given period of time. The variability of the surface temperature of the finger, regardless of the environmental conditions or metabolic state, in contradistinction to that of the toes, is readily apparent.

The rectal temperatures were within normal range in all individuals under all conditions and showed no tendency to change throughout the experimental periods. The temperatures over the zygoma, over the xiphoid process of the sternum and the lateral aspect of the leg and thigh behaved similarly to the forehead temperatures but at lower levels. Temperatures

The diagram shows the simplification of quasicontinuous curves of temperatures taken from the great toe, finger and forehead for the five individuals tested under condition 5. The columns represent the range of the temperatures taken at the designated point in each of the 20 successive nine-minute periods.

**Fig. 3.** Simplification of quasicontinuous curves of temperatures taken from the great toe, finger and forehead for the five individuals tested under condition 5. The columns represent the range of the temperatures taken at the designated point in each of the 20 successive nine-minute periods.

LGT—left great toe; RGT—right great toe; RMF—right middle finger; F—forehead; Ordinate—temperatures in degrees centigrade; Abscisse—time in minutes.

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tion. To compare various substances accurately, the stimulus to constriction should be uniform. In this study, a standard period of inactivity in a comfortable, cool environment, and, in more than half of the experiments, the withholding of food, have been the stimuli used to produce, in a relatively short time, a standard state of increased vasomotor tone in normal individuals.

The variability of finger temperature is consistent with the concept that the fingers participate to a greater extent than any other area in the fine adjustments of the heat dissipation mechanism. The temperature of the finger becomes more stable at high environmental temperatures, when it approaches "maximal vasodilation." At such temperature levels response to vasodilating agents or procedures cannot be expected. The fingers might more readily be employed to test vasoconstrictor drugs. If environmental temperatures are low enough to cool the fingers, temperatures considerably below the lower temperature used in this study would be necessary and would involve considerable discomfort for the subject.

The forehead temperatures as well as those of the face, trunk, and the upper portions of the extremities show great stability. Consequently, relatively small changes in the temperature of these areas after the use of an agent or procedure can be regarded as significant. Insofar as the forehead is concerned, a relatively abrupt rise of temperature of as little as 1 degree cannot be expected to occur spontaneously.

The patterns of response in the toes differed greatly under the five conditions. Under condition L-22 C. adaptation occurred in less than half of the individuals and when it did occur, was late and at relatively high temperature. In at least half of the subjects, curves were generally unstable. Consequently, this condition must be regarded as unsuitable for experiments with vasodilating agents or procedures.

Under condition NL-20 C. temperature of the toes reached a steady enough state at suitable levels quickly enough to be practical for study of vasodilator drugs. A variation away from the trend of two degrees or more, after an adaptation period of an hour would be unlikely to occur by chance.

Under condition NB-20 C. (fig. 3) adaptation or the establishment of a reliable trend occurred in all cases, but later than under any of the other conditions. This condition was not considered practical because the subjects were restless and complained of cold, hunger and drowsiness.

Some individuals adapt well without lunch at 22 C. and others adapt well at 20 C. with lunch (figs. 1 and 2). All subjects, however, adapted well when the lower temperature and fasting were both imposed. It is concluded that condition NL-20 C. is the most suitable for experiments designed to test and compare vasodilating agents or procedures by means of skin surface temperature of the lower extremities, specifically the plantar surface of the toes.

Striking qualitative differences in the patterns of response of the terminal phalanges of the extremities and other areas of skin to various stimuli are apparent. The forehead, trunk, thigh and leg remain close to body temperature. The terminal phalanges vary so widely that it is evident that they are the principal participants in the mechanisms responsible for regulation of heat loss. The coarse adjustment appears to be chiefly accomplished by the toes. The fact that the fine minute to minute adjustment is accomplished by the fingers may easily account for their unreliability as a test object for vasodilator effects.

Summary

1. A study of several environmental conditions has shown that at 20 C. with a humidity of 50 to 55 per cent after a fast of at least four hours, the temperature of the skin of the plantar surface of the toes of most normal individuals is a suitable test object for vasodilator effects. Under these circumstances a steady downward trend or stabilization of surface temperature will usually take place within an hour. A rise of 2 degrees or more can, therefore, be attributed to the effect of a vasodilator agent since it would not be expected to occur spontaneously.

2. The temperature of the skin of the fingers
is too variable to be suitable for testing vasodilator agents under any of the conditions tested.

3. The forehead, trunk, thigh and leg are characterized by stable temperature curves at levels near rectal temperature. These sites are considered suitable for the testing of vasodilating agents and procedures insofar as they affect the "blush" areas. A rise of 1 C. or more in these areas cannot be expected to occur spontaneously.

REFERENCES
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