Regional differences in temperature sensation and thermal comfort in humans

Mayumi Nakamura,1 Tamae Yoda,2 Larry I. Crawshaw,5,6 Saki Yasuhara,2 Yasuyo Saito,2 Momoko Kasuga,1 Kei Nagashima,2,3 and Kazuyuki Kanosue1,2,3

1Faculty of Sport Sciences, 2Faculty of Human Sciences, and 3Consolidated Research Institute for Advanced Science and Medical Care, Waseda University, Tokorozawa, Saitama, Japan; 4Faculty of International Liberal Arts, Dokkyo University, Soka, Saitama, Japan; 5Department of Biology, Portland State University, Portland, Oregon, and 6Department of Behavioral Neuroscience, Oregon Health and Science University, Portland, Oregon

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Regional differences in temperature sensation and thermal comfort in humans. J Appl Physiol 105: 1897–1906, 2008. First published October 9, 2008; doi:10.1152/japplphysiol.90466.2008.— Sensations evoked by thermal stimulation (temperature-related sensations) can be divided into two categories: “temperature sensation” and “thermal comfort.” Although several studies have investigated regional differences in temperature sensation, less is known about the sensitivity differences in thermal comfort for the various body regions. In the present study, we examined regional differences in temperature-related sensations with special attention to thermal comfort. Healthy male subjects sitting in an environment of mild heat or cold were locally cooled or warmed with water-perfused stimulators. Areas stimulated were the face, chest, abdomen, and thigh. Temperature sensation and thermal comfort of the stimulated areas were reported by the subjects, as was whole body thermal comfort. During mild heat exposure, facial cooling was most comfortable and facial warming was most uncomfortable. On the other hand, during mild cold exposure, neither warming nor cooling of the face had a major effect. The chest and abdomen had characteristics opposite to those of the face. Local warming of the chest and abdomen did produce a strong comfort sensation during whole body cold exposure. The thermal comfort seen in this study suggests that if given the chance, humans would preferentially cool the head in the heat, and they would maintain the warmth of the trunk areas in the cold. The qualitative differences seen in thermal comfort for the various areas cannot be explained solely by the density or properties of the peripheral thermal receptors and thus must reflect processing mechanisms in the central nervous system. Skin temperature; cold exposure; heat exposure

Sensations evoked by thermal stimulation (temperature-related sensations) can be divided into two categories: “temperature sensation” and “thermal comfort” (17). Temperature sensation is utilized by the body to obtain information concerning the thermal condition of external objects or the environment, and it is evoked by signals from warm and cold receptors in the skin. Thermal comfort (which in this paper also embraces thermal discomfort) is important for temperature regulation in that it drives an individual to search for the appropriate thermal environment or to make local alterations or postural changes to maintain normal body temperature. Thermal comfort depends on the temperature of the skin when the internal body temperature is constant (24, 25). And thermal comfort is affected by the thermal state of not only the skin but also the body core (4, 5, 11, 21, 27). Furthermore, thermal hedonic responses are also influenced by circadian rhythms (6). Humans have little problem discerning local from whole body sensations for thermal comfort. For example, during cold exposure if one dips the hands into warm water he or she would feel local comfort of the hand, but simultaneously whole body discomfort would remain.

Interestingly, the sensitivity of temperature sensation is not uniform, but rather it depends on the body region. The face has usually been reported to be the most sensitive, whereas the extremities, by comparison, are poor, and other regions are intermediate (14, 37, 38). However, for cold, the trunk has been observed to be the most sensitive, followed by the limbs, and then the head (36). Less is known about the sensitivity differences in thermal comfort for the various body regions (1, 3, 12, 42).

Cotter and Taylor (12) assessed whole body thermal comfort when local thermal stimulation of various skin sites was applied in mildly heat-stressed humans. Although they reported that the face displayed stronger sensitivity than other body regions for producing changes in whole body thermal comfort, they did not analyze how the stimulated site itself was locally felt. Zhang et al. (42) and Arens et al. (1) measured both local and whole body thermal comfort by applying local warming and cooling in a warm, neutral, or cool environment. Sensitivity differences between the local areas could not be directly compared, however, because the size of local temperature stimulation was different among the areas stimulated. Attia and Engel (3) reported that the thermal alliesthesial response in men is independent of the skin location stimulated using a small thermal stimulator of 55-mm length and 27-mm width (0.001485 m²). However, thermal pleasure does depend on the dimension of area stimulated (24). Regional differences in thermal comfort are more likely when using a larger thermal stimulator.

Recently, our laboratory developed a system to monitor temperature-related sensations of many body locations as well as to comprehensively depict the distribution of overall skin temperature (Tsk) and the local sensations (31). The system consists of a console with levers to report up to 52 temperature-related sensations and software that facilitates the visualization and comparison of the distribution of Tsk and temperature-related sensations by displaying them on identical configurations of the human body. In an initial experiment, subjects were exposed to step changes of ambient temperature from 23°C to 33°C and asked to assess the sensations at many surface areas.

Address for reprint requests and other correspondence: M. Nakamura, Faculty of Sport Sciences, Waseda Univ., 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan (e-mail: m.nakamura@suou.waseda.jp).

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The face tended to show stronger discomfort during heat exposure than other areas of the body, and the abdomen tended to show stronger discomfort during cold exposure. These tendencies are interesting but not conclusive, because the experiment was done only with whole body heat or cold exposure. Thus $T_{sk}$ differed depending on body area, which made an accurate comparison of sensation in different areas difficult.

Understanding how the elicitation of thermal comfort, local as well as whole body, differs among certain body regions is the goal of this study. The information will be valuable not only for physiological understanding but also for the design of a comfortable environment and efficient clothing. The results will also aid in the optimization of medical and nursing practices. To these ends, we examined regional differences in temperature sensation and thermal comfort by applying local temperature stimulation during whole body exposure to mild heat or cold. We paid special attention to the face and abdomen, because as noted above, these areas showed unusual tendencies in thermal comfort in previous studies.

**METHODS**

*Experiment 1 (Mild Heat Exposure)*

**Subjects.** Eleven healthy male subjects (mean ± SE: age 23.0 ± 0.7 yr, weight 66.2 ± 1.7 kg, height 1.73 ± 0.02 m) participated in this study. Each subject gave informed consent for the experimental protocol, which was approved by the Human Research Ethics Committee in the Faculty of Sport Sciences, Waseda University. The experiments were conducted in accordance with the Declaration of Helsinki. Subjects were instructed to avoid alcohol from the evening of the day before the experiment; caffeinated drinks, hot food, and physical training on the experiment day; and eating for at least 1 h before participation in the experiment.

**Experimental procedure.** The experiments were done in the period from November to December 2006. Subjects arrived at the laboratory at 9:30 AM or 2:30 PM, changed to short pants (only), and entered a room from November to December 2006. Subjects arrived at the laboratory at 9:30 AM or 2:30 PM, changed to short pants (only), and entered a room. The time of the day before the experiment; caffeinated drinks, hot food, and physical training on the experiment day; and eating for at least 1 h before participation in the experiment.

**Experimental procedure.** The experiments were done in the period from February to March 2007. Ten healthy male subjects (age 21.5 ± 0.5 yr, weight 64.9 ± 1.8 kg, height 1.73 ± 0.02 m) participated in this study. Subjects sitting in the climatic chamber at 21.3 ± 0.1°C with a relative humidity of 50% were locally cooled and warmed with the same water perfused stimulators as in experiment 1. In this condition, overall $T_{sk}$ was lower than that during the mild heat exposure of experiment 1. Therefore, water temperature for the basal condition was set at 33°C, 2°C lower than for experiment 1.

In a preliminary experiment, local stimulation temperatures as in experiment 1 (25°C for cooling, and 42°C for warming) were tested, but the subjects reported only weak sensations following local cooling of the four areas. For this reason, the water source for local cooling was set at 22°C, 3°C lower than in experiment 1. The water source temperature for local warming was the same as in experiment 1, 42°C.

**RESULTS**

*Experiment 1 (Mild Heat Exposure)*

**Local cooling.** $T_{co}$ during the 30 min of local cooling trials was 37.3 ± 0.1°C, and it remained unaltered during the period of local stimulations. Mean $T_{sk}$ was also the same (34.4 ± 0.1) when local cooling was initiated at each of the local areas.
Although the local basal $T_{sk}$ of the stimulated areas differed by $1°C$, $T_{sk}$ for the face was significantly higher than for the chest ($P < 0.05$), abdomen and thigh ($P < 0.01$), and significantly lower for the thigh than for the abdomen ($P < 0.05$), face and chest ($P < 0.01$, Fig. 4A). The magnitude of local $\Delta T_{sk}$ during 90 s of cooling was greater for the thigh than for the abdomen ($P < 0.05$), face and chest ($P < 0.01$; Fig. 4B).

Before local cooling, subjects reported “slightly hot” for local temperature sensation and “slightly uncomfortable” for local comfort (open bars in Figs. 4C left and D left). Neither sensation differed significantly among the four areas to be stimulated. At the end of 90 s of cooling, subjects reported a definite “cold” sensation (score $-4.8 \pm 0.3$) with no significant difference among the four areas (solid bars in Fig. 4C left). Nor was a significant difference observed among the magnitude of change in local temperature sensation ($\Delta$local temperature sensation) during 90 s of cooling of the four stimulated areas (Fig. 4C right). The concurrent estimations of local thermal comfort, however, did depend on the area stimulated. While facial cooling produced a strong “comfortable” feeling, abdominal cooling produced no local comfort, and the difference between face and abdomen was significant ($P < 0.01$; solid bars in Fig. 4D left). And chest or thigh cooling produced a sufficient change in comfort score to convert uncomfortable to comfortable. The magnitude of change in local thermal comfort ($\Delta$local thermal comfort) during 90 s of cooling of the four stimulated areas was greater for the face than for the chest ($P < 0.05$), and abdomen ($P < 0.01$; Fig. 4D right).

As for whole body thermal comfort, the subjects reported very similar “uncomfortable” responses just before local cooling of each area (open bars in Fig. 4E left). After local cooling, the changes in whole body thermal comfort ($\Delta$whole body thermal comfort) differed depending on the area cooled. During facial cooling, “uncomfortable” changed to “comfortable.” This effect was observed also for thigh cooling but not for chest or abdominal cooling (Fig. 4E left). The score of whole body thermal comfort at the end of cooling was significantly higher for the face than for the abdomen ($P < 0.05$; solid bars in Fig. 4E left). The magnitude of $\Delta$whole body thermal comfort during 90 s of cooling was greater for the face than for the abdomen ($P < 0.01$; Fig. 4E, right).

Local warming. $T_{co}$ during the 30 min of local warming trials was $37.3 \pm 0.1°C$, and mean $T_{sk}$ during the same 30 min of local warming trials was $34.3 \pm 0.1°C$. Neither value differed for any time period during stimulation of the four areas. At the start of warming, local $T_{sk}$ of the stimulated areas was significantly higher for the face than for the chest ($P < 0.05$), abdomen, and thigh ($P < 0.01$), and it was significantly lower for the thigh than for the abdomen ($P < 0.05$), face, and chest ($P < 0.01$; Fig. 5A). The magnitude of local $\Delta T_{sk}$ during 90 s of warming was greater for the thigh than for the abdomen ($P < 0.05$), face, and chest ($P < 0.01$; Fig. 5B).

Before local warming, subjects reported “slightly hot” for local temperature sensation and “slightly uncomfortable” for local comfort (open bars in Fig. 5C left and D left). The two types of sensation did not significantly differ among the four areas. At the end of 90 s of warming, subjects reported a distinct “hot” sensation that was significantly stronger for the face than for the thigh ($P < 0.05$; solid bars in Fig. 5C left). The magnitude of $\Delta$local temperature sensation during 90 s of warming of the four stimulated areas was greater for the face than for the thigh ($P < 0.05$; Fig. 5C right). And local thermal discomfort increased. This effect was stronger for the face than for the chest ($P < 0.05$, solid bars in Fig. 5D). Although the magnitude of $\Delta$local thermal comfort was greater for the face, a significant difference was not observed among the four areas stimulated (Fig. 5D right).

For whole body thermal comfort, subjects reported “uncomfortable” just before local warming of each area without any significant difference among the four areas (open bars in Fig. 5E left). Local warming increased the “uncomfortable” feeling except for chest warming. Although this effect was stronger for facial warming, a significant difference was not observed among the four areas stimulated (solid bars in Fig. 5E left and 5E right).

Experiment 2 (Mild Cold Exposure)

Local cooling. $T_{co}$ during the 30 min of local cooling trials was $37.1 \pm 0.1°C$, and mean $T_{sk}$ during the same 30 min of local

![Fig. 3. Typical example of skin temperature ($T_{sk}$) change ($\Delta$) during local warming and cooling of 4 stimulated areas in 1 subject.](image-url)
cooling trials was 29.4 ± 0.2°C. Neither value differed for any time period during stimulation of the four areas. The difference in local Tsk values at the start of local cooling among the stimulated areas was more prominent than in experiment 1, and significant differences were observed for all combinations of the four areas (P < 0.01; Fig. 6A). The Tsk was highest for the face (34.9 ± 0.1°C) and lowest for the thigh (33.1 ± 0.1°C). The magnitude of local ΔTsk during 90 s of cooling was greater for the thigh than for the other three areas (P < 0.01; Fig. 6B).

Before local cooling, subjects reported sensations close to “neutral” both for local temperature sensation and for thermal comfort (open bars in Fig. 6C left and D left). Neither sensation

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Fig. 4. Local skin temperature and temperature-related sensations during local cooling of 4 areas in mild heat exposure experiment. A: local Tsk at the start of cooling. B: magnitude of local ΔTsk during 90 s of cooling. C left: local temperature sensation of areas stimulated (stim). C right: magnitude of local temperature sensation changes during 90 s of cooling of areas stimulated. D left: local thermal comfort of areas stimulated. D right: magnitude of local thermal comfort changes during 90 s of cooling of areas stimulated. E left: whole body thermal comfort during the stimulation of each area. E right: magnitude of whole body thermal comfort changes during 90 s of cooling of areas stimulated. In left graph of C–E, open bars show the sensations before stimulation and solid bars show the sensations at the end of stimulation. Values are means ± SE for 11 subjects. *P < 0.05; **P < 0.01, significant differences among the 4 stimulated sites.
differed significantly among the four areas. At the end of 90 s of cooling, subjects reported a definite “cold” sensation (score $-4.1 \pm 0.3$), and no significant difference was observed among the four areas (solid bars in Fig. 6C left). The magnitude of $\Delta$local temperature sensation during 90 s of cooling of the four stimulated areas was greater for the abdomen than for the face ($P < 0.05$; Fig. 6C right). For local thermal comfort, whereas facial cooling produced no local “uncomfortable” feeling, cooling of the other body surfaces produced clear “uncomfortable” feeling (solid bars in Fig. 6D left). Local
discomfort at the end of cooling was significantly stronger for the abdomen and thigh than for the face (*P < 0.01; solid bars in Fig. 6D left). The magnitude of Δlocal thermal comfort during 90 s of cooling of the four stimulated areas was greater for the abdomen, thigh (*P < 0.01), and chest (*P < 0.05) than for the face (Fig. 6D right).

For whole body thermal comfort subjects reported “uncomfortable” just before local cooling of each area without any
significant difference among the four areas (solid bars in Fig. 6E left). The whole body “uncomfortable” sensation was increased by local cooling, but significant differences between the stimulated areas were not observed (solid bars in Fig. 6E left and 6E right).

Local warming. $T_{co}$ during the 30 min of local warming trials was $37.1 \pm 0.1{\degree}C$ and mean $T_{sk}$ during the same 30 min of local warming trials was $29.3 \pm 0.2{\degree}C$. Neither value differed for any time period during stimulation of the four areas. At the start of warming, significant differences in local $T_{sk}$ values among the stimulated areas were observed in all combinations of the four stimulated areas ($P < 0.01$; Fig. 7A). The magnitude of local $\Delta T_{sk}$ during 90 s of local warming was greater for the thigh than for the other three areas ($P < 0.01$; Fig. 7B).

Before local warming, subjects reported sensations close to “neutral” both for local temperature sensation and local comfort (open bars in Fig. 7C left and D left). Neither type of sensation differed significantly among the four areas. At the end of 90 s of warming, subjects reported a distinct “hot” sensation (score 3.5 $\pm$ 0.2), and no significant difference was observed among the four areas (solid bars in Fig. 7C left). Nor was a significant difference observed among the magnitude of $\Delta$local temperature sensation during 90 s of warming of the four stimulated areas (Fig. 7C right). The concurrent estimations of local thermal comfort, however, did depend on the area stimulated. Although warming of the abdomen and chest produced a definite “comfortable” feeling, facial warming had only a little effect that was weaker than chest ($P < 0.05$) and abdomen ($P < 0.01$; solid bars in Fig. 7D left). The magnitude of $\Delta$local thermal comfort during 90 s of warming of the four stimulated areas was greater for the abdomen than for the face ($P < 0.01$; Fig. 7D right).

For whole body thermal comfort, subjects reported “uncomfortable” just before local warming of each area without any significant difference among the four areas (open bars in Fig. 7E left). Whole body discomfort was decreased by local warming. Although this effect was stronger for the chest and abdominal warming, a significant difference was not observed among the four areas stimulated (solid bars in Fig. 7E left and Fig. 7E right).

**DISCUSSION**

In the present study, four body surfaces of equivalent area (0.027 m$^2$) were heated or cooled, and the ensuing temperature-related sensations were analyzed with special attention to thermal comfort in healthy male subjects. Definite regional differences in local thermal comfort were observed. During mild heat exposure, when the subjects’ whole body sensation was “uncomfortable,” local cooling was most comfortable and local warming was most uncomfortable when applied to the face (Figs. 4D and 5D). On the other hand, during mild cold exposure, in which whole body thermal comfort was “uncomfortable,” neither warming nor cooling of the face had a major effect (Figs. 6D and 7D). The chest and abdomen had characteristics opposite to those of the face. Local cooling of these areas did not produce explicit comfort even during whole body heat exposure (Fig. 4D). But local warming of the chest and abdomen did produce strong comfort during whole body cold exposure (Fig. 7D). This effect was more prominent for the abdomen than for the chest.

**Effect of Adapting Temperature and Stimulus Magnitude**

Although the areas locally stimulated were adapted to 35 or 33$^\circ{\degree}C$ before stimulation, local $T_{sk}$ values at the start of stimulation were not necessarily the same. In the mild heat exposure experiment, the $T_{sk}$ values were in the range of 35–36$^\circ{\degree}C$, but they were highest in the face and decreased, in order, from chest, to abdomen, to thigh (Figs. 4A and 5A). Although the magnitudes of thermal stimulation ($\Delta T_{sk}$) were larger in the reverse order both for heating and cooling, there was no significant difference among the face, chest, and abdomen (Figs. 4B and 5B). The difference in the $\Delta T_{sk}$ values among the various areas is likely caused by differences in skin blood flow due to vasomotor status and tissue vascularity. For the ambient temperature utilized in the heat exposure (experiment 1), the skin vessels of all areas would be expected to be vasodilated. In the mild cold exposure experiment, differences in local $T_{sk}$ values and $\Delta T_{sk}$ values were more prominent (Figs. 6, A and B, and 7, A and B), probably due to cold-induced skin vasoconstriction that was stronger for the chest and thigh than for the face and abdomen.

When skin is warmed at a constant rate of temperature change, starting from various levels of temperature adaptation, the response magnitude of skin warm fibers is larger at higher adapting temperatures (15, 19). Furthermore, warm sensations are more sensitive at higher adapting temperatures, and cold sensations are more sensitive at lower adapting temperatures (17). In the present study, despite differences in $T_{sk}$ values and $\Delta T_{sk}$ values, we could find little difference in temperature sensation among the four areas (Figs. 4C, 5C, 6C, and 7C). Additionally, the regional differences in thermal comfort never correlated with differences in $T_{sk}$ values or $\Delta T_{sk}$ values; e.g., thermal comfort was never stronger for the thigh, although the $\Delta T_{sk}$ of the thigh was always larger than that of other areas. Regional differences in thermal comfort observed in the present study, therefore, cannot be explained simply by invoking the slight differences in local temperature produced by the thermal stimulation.

**Mechanism for the Regional Difference in Thermal Comfort**

It is generally assumed that inputs from the same warm or cold skin thermoreceptors are utilized for both temperature sensation and thermal comfort, although there is no direct experimental evidence for this supposition. Although it is difficult to quantitatively evaluate differences in the density of skin thermoreceptors in humans, the density of hot and cold spots would be expected to correlate positively with the density of warm and cold receptors (17). The distribution of peripheral warm and cold spots over the body surface is not uniform (22, 33, 39, 40), and the face is one of the areas where both warm and cold spots are particularly dense. Although this high density might be invoked to explain the strong thermal comfort produced by facial stimulation in the heat exposure experiment, the same facial stimulation produced only a slight change in thermal comfort during cold exposure. Similarly, the chest and abdomen have particularly dense cold spots (39). Although thermal stimulation, especially warming, of these areas produced a distinct change in thermal comfort during
cold exposure, the same stimulation during heat exposure had a minor effect. Thus, the location-dependent effect of thermal stimulation on thermal comfort cannot be explained simply by the density of cold or warm spots. Additionally, it should be noted that regional differences in temperature sensation were not seen with stimulation that did produce regional differences in thermal comfort. The above observations make it unlikely that regional differences in thermal comfort can be entirely explained by the properties and distribution of peripheral thermoreceptors. A more plausible explanation is that central nervous processing is responsible for the production of the regional differences in thermal comfort. Feelings of warmth and cold correlate with neural activity in insular cortex (13, 32), and the amygdala, mid-orbitofrontal and pregenual cingu-

Fig. 7. Local $T_{sk}$ and temperature-related sensations during local warming of 4 areas in mild cold exposure experiment. A: local $T_{sk}$ at the start of warming. B: magnitude of local $\Delta T_{sk}$ during 90 s of warming. C left: local temperature sensation of areas stimulated. C right: magnitude of local temperature sensation changes during 90 s of warming of areas stimulated. D left: local thermal comfort of areas stimulated. D right: magnitude of local thermal comfort changes during 90 s of warming of areas stimulated. E left: whole body thermal comfort during the stimulation of each area. E right: magnitude of whole-body thermal comfort changes during 90 s of warming of areas stimulated. In left graph of C–E open bars show the sensations before stimulation and solid bars show the sensations at the end of stimulation. Values are means ± SE ($n = 10$). *$P < 0.05$, **$P < 0.01$, significant differences among the four stimulated sites.
late cortex, and ventral striatum have been implicated in the
genesis of thermal comfort (18, 34). We speculate that a central
nervous system map weighing the input from each body area
would be involved in the production of regional differences in
thermal comfort.

It is well known that thermal comfort is affected by the
thermal state of the body (4, 5, 11, 21, 24, 25, 27). The same
hand warming produces a comfortable or uncomfortable feel-
ing depending on whether the individual is hypothermic or
hyperthermic. Thus a thermal stimulation is felt comfortable
when it serves to regain normal body temperature, and felt
uncomfortable when it worsens internal thermal conditions.

Somehow, the central nervous system processes sensory input
so that it is perceived as comfortable or uncomfortable depend-
ing on the thermal status of the body. Interestingly, the direc-
tion of this alteration in hedonic valence is not uniform for all
body areas. As we showed, feelings of comfort in the face are
very sensitive to local temperature stimuli in the heat, but they
are less sensitive in the cold. The abdomen demonstrates the
opposite tendency. It will be of interest to determine how this
alliesthesia (8) occurs and how regional differences between
sensation and comfort are created.

Meaning of the Regional Difference in Thermal Comfort

Thermal comfort and discomfort are specific aspects of the
pleasure-pain system of animals. In an overall sense, comfort
and discomfort (including pain) function to interrupt other
ongoing behaviors to focus the organism on a particular,
significant threat to its well-being. What is the function of the
regional difference in thermal comfort? It is well known that
even in homeothermic animals, the magnitude of temperature
fluctuation inside the body in different thermal environments is
dependent on the particular body part (2). The temperature of
the body core fluctuates only slightly, whereas that of the
periphery, such as arms and legs, shows large changes. The
basic function of temperature regulation must be to maintain
the temperature of the body core because the vital organs are
located there. Regional differences in thermal comfort can be
considered in this light.

The head contains the brain, which possesses a high, con-
tinuous rate of heat production. The human brain is particularly
susceptible to heat damage and can only tolerate temperatures
up to about 40.5°C, while organs of the torso core temperatures
can tolerate temperatures that exceed 42°C (41). It is critical
for organism viability that heat be rapidly removed from the
head area, and special systems to cool the brain are suggested
to exist in humans (9, 29) and are well documented in many
animals (41). In humans, venous blood from the scalp and the
face is posited to flow, via the emissary veins, into the brain
during hyperthermia at a rate sufficient to produce selective
brain cooling (9, 29). A hot face would further heat an already
overheated brain. Preference for a low facial temperature in
the heat would help avoid heat-induced damage to the brain.

Preference for a warm abdomen similarly must reflect im-
portant aspects of the organism’s need to conserve and produce
heat. For most mammals, the abdomen and inner thighs are
thinly furred areas that can be utilized to dissipate heat during
exercise or in a hot environment. In the cold, mammals curl up,
which greatly decreases the surface area and shields the thinly
furred areas (26). Although humans are not furred, they do
benefit from a fetallike position in the cold, which minimizes
the surface area for heat loss. The adoption of this posture
warms the abdomen, and the pleasant feelings that ensue must
contribute to the initiation and maintenance of this postural
adjustment. Furthermore, a warm abdomen facilitates diges-
tion, which in the act of altering chemical energy into forms
that the body can utilize to produce heat (and all its other
functions), also releases substantial amounts of heat in the
process (41).

Thermal Comfort and Autonomic Thermoregulation

Previous works have repeatedly found that, per unit area of
skin, facial temperature exerts the largest peripheral influence
on autonomic thermoregulation (7, 12, 14, 28). The effect is
not dependent on the ambient temperature. Heating the face in
a warm environment produces a considerably greater increase
in sweat rate than heating other skin areas (12, 28), whereas
cooling the face in a warm environment produces a consider-
ably greater decrease (12, 14). Belding et al. (7) also found that
at low ambient temperatures, warming the face induced per-
ipheral vasodilatation, whereas warming the same area of the
chest or a much larger area of the leg had no effect. Such a
strong, consistent facial sensitivity might be explained by a
high density of thermoreceptors (cold and warm spots) in the
face.

However, for thermal comfort, the predominance of facial
thermosensitivity is dependent on the ambient temperature. The
whole ody comfort sensation is likely the primary input for
behavioral thermoregulation and if an individual is in a situa-
tion where feelings of comfort can be acted on, it is possible to
maintain without utilizing the energy and fluid resources nec-
essary for autonomic regulation. The different regional sensi-
tivities of thermal comfort and autonomic thermoregulation
could indicate that autonomic and behavioral temperature reg-
ulation are controlled separately in the central nervous system.
The ability to regulate body temperature by behavioral (but not
autonomic) means remains in animals whose medial preoptic
area/anterior hypothalamus has been lesioned (10, 23, 35).
Indeed, it has recently been reported that the afferent neuronal
pathways for discriminative sensation or localization of a
thermal stimulus and for homeostatic control of body temper-
ature are separate (30).

The comfort sensations seen in this study indicate that if
given the chance, humans would preferentially cool the head
in the heat, and they would maintain the warmth of the abdomen
in the cold. These regional differences in the thermal comfort
are consistent with the biological roles of each body part. The
qualitative differences seen in thermal comfort for the various
areas cannot be explained solely by the density or properties of
the peripheral thermal receptors. It seems certain that these
differences are due to dissimilar neuronal pathways and pro-
cessing in the central nervous system. We investigated only
dynamic responses in this study during the 90 s of thermal
stimulation. Comfortableness occurs when discomfort disap-
ppears, and it does not continue for a long time (20). It would
be interesting to see how the regional differences in thermal
comfort were altered by longer periods of thermal stimulation.
Because we tested only in mild heat and cold ambient tem-
peratures, and only in male subjects, it would be interesting to
know how these regional differences in thermal comfort might
be changed under different thermal condition and/or in female subjects. Furthermore, in the present study, we only tested four areas. It would be valuable to examine the thermal and comfort sensitivities of other body areas, such as hands and feet, and consider how the properties of each area’s thermal and comfort sensations related to the physiological functions subserved by that particular area.

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