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Regional Variation of Human Skin Surface Temperature

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Dear Editor:

In addition to ultraviolet irradiation, heat causes skin aging, called thermal aging[1]. The reliable acquisition of regional skin surface temperature (SST), especially for the exposed area, is important to characterize thermal aging as well as to obtain physiological reference values.

A century ago, Benedict et al.[2] reported the regional variation of SST of 28.1 (calf) −34.7°C (waist) in a normally-clothed woman at about 17°C. Other following studies described that the head had the highest skin temperature[3] and recently, that the neck has a higher skin temperature than the forearm in the younger individuals[4].

Although regional SST was previously reported[2-4], these studies had limitations including a small number of participants (only one or two), no control of the environmental conditions (temperature and/or humidity)[3,4], limited body regions, or technical limitations of the thermometer used such as improper skin contact or lack of dynamic measurement[2]. While more recent studies were performed in more tightly regulated environmental conditions[5,6], these studies did not address regional SST. Therefore, we examined mean SST by measuring the temperature of 15 representative exposed body sites. To measure the temperature accurately and reliably, the participants were sufficiently acclimated in a temperature and humidity controlled room, and the digital thermometer with continuous monitoring system was employed. This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB no. 1607-060-775), and conducted according to the Declaration of Helsinki.

Thirty (23 males, 7 females) healthy participants aged 25.2±1.8 (mean±standard deviation) years were recruited. They had no other diseases related to blood circulation and metabolism, such as rosacea and thyroid diseases on history taking. This study was conducted within one month in the same season (in August, summer). The room in which participants were measured was tightly regulated by the temperature and humidity. The temperature and humidity were recorded at 3-minute intervals during the SST measurements. Study participants exposed their legs and arms after entering the room. After 15 minutes of acclimation, SST was measured by trained investigators using a digital thermometer (Fluke 51 II thermometer; Fluke, Everett, WA, USA) with a surface probe (model 80PK-3A), which could continuously monitor the temperature without giving a pressure to the skin. Participants maintained a supine position and the temperature was recorded once if it remained stable for more than 5 seconds. The SST of 8 facial regions (forehead, cheek, chin, ear, nose tip, eyelid, nasolabial area, and perioral area) and 7 body regions (anterior neck, palm, forearm, upper arm, sole, shin, and thigh) were measured (Fig. 1A). Each region was evaluated bilaterally except for the forehead, nose tip, and chin, where a single site was measured. The R program (ver. 3.0.1, https://www.R-project.org) was used for all statistical analyses, and the paired t-test was used to compare SST between both sides of the 12 regions. Only 3 regions (sole, shin, and thigh) were significantly different between the right and left side (Supplementary Table 1). The mean SST of both sides was used in 9 regions, in which no significant difference was seen between two sides. Among 15 regions, ten groups were categorized based on SST

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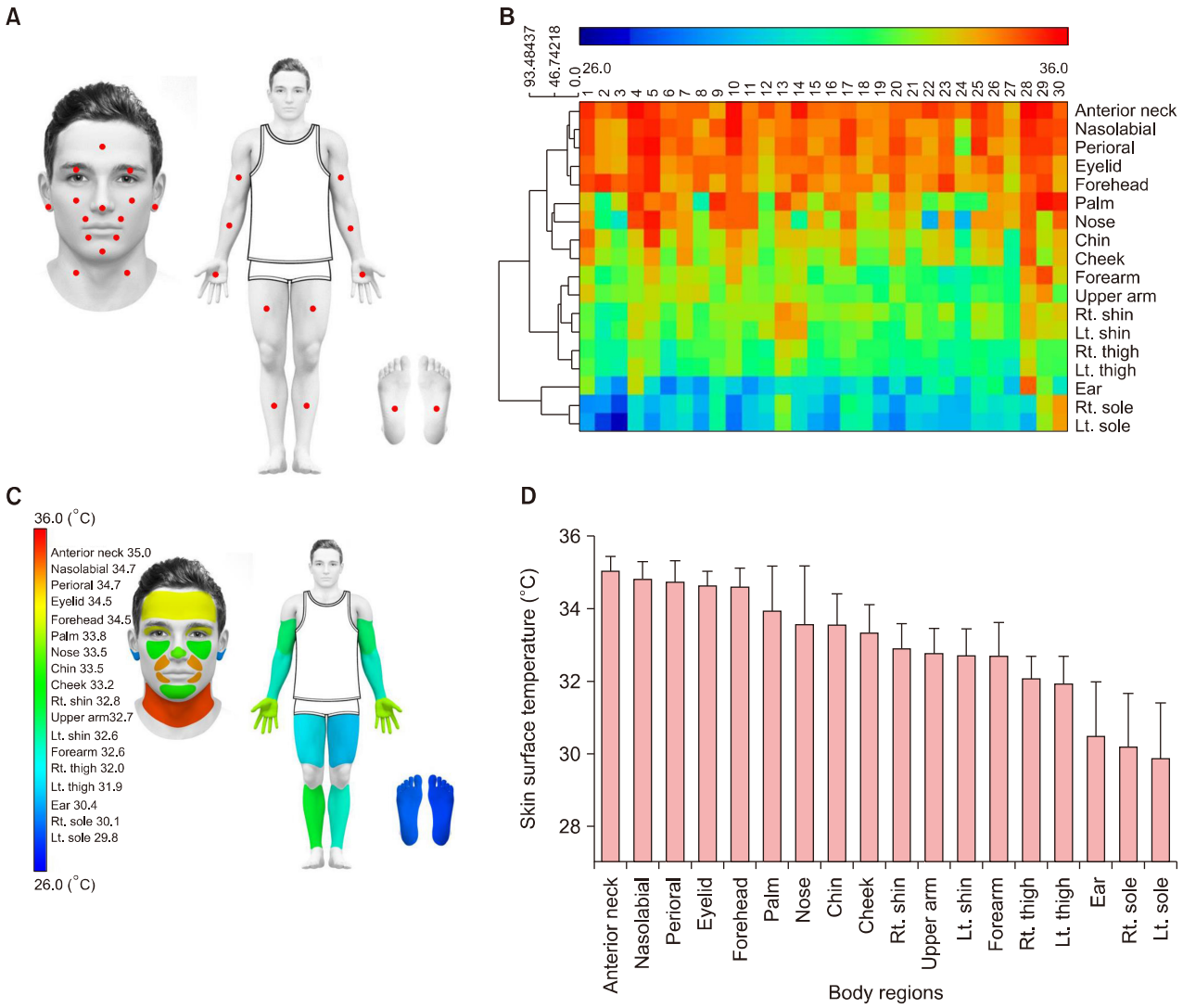

Fig. 1. (A) Schematic diagram of the regions that measured skin surface temperature (SST). As a whole, a total of 15 regions were measured. In the face, 8 regions were measured. And another 7 regions were the anterior neck, palm, forearm, upper arm, sole, shin, and thigh. Except for forehead, nose tip, and chin, both sides of each region were measured. (B) Heat map and hierarchical clustering of SST. Participants maintained a supine position and the temperature was recorded if it remained stable for more than 5 seconds. The color refers to SST. The lowest temperature was depicted as blue, and the highest as red (26°C~36°C). Hierarchical clustering was performed using the "Manhattan distance" metric. All participants were represented on the x-axis (1~30), and body regions on the right (Rt.) y-axis. The left (Lt.) y-axis depicts hierarchical clustering. The top left figures show the mean distance between the regions in hierarchical clustering. (C) SST of the regions were depicted as different colors for quick reference. (D) The SST according to regions. The graphs show the average temperature and standard deviation.

similarity using the repeated measures ANOVA, followed by the Newman–Keuls multiple comparison test (Table 1). The heat map and pictorial diagram in Fig. 1B, C shows the overall summary of regional SST measurements from all participants. Moreover, the body regions of similar SST were clustered by hierarchical clustering through the Manhattan distance metric (Fig. 1B). The clustering results were similar to the categorization in Table 1. The regional variation of SST was exemplified by its descending order of temperature (Fig. 1D, Supplementary Table 2) and the pictorial diagram (Fig. 1C) revealed a region-dependent SST distribution from the anterior neck to left sole. During the period of measurement, the temperature and humidity were constantly regulated, with 24.4°C±1.1°C and 46.3%±6.5%, respectively.

In this study, the anterior neck showed the highest SST of 35.0°C±0.5°C, while the left sole showed the lowest SST of 29.8°C±1.6°C. Interestingly, the SST of the right lower extremity was higher than that of the left lower extremity. SST is known to correlate with blood flow[7], and exercise

Table 1. Groups which show statistically similar temperature and the cases that show statistically significant difference between groups

Group	Anatomical location	Mean±SD (°C)	Groups of which temperature is statistically different versus each group
1	Anterior neck, nasolabial, perioral, eyelid, forehead	34.7±0.6	1 vs. 2, 3, 4, 5, 6, 7, 8, 9, 10
2	Palm	33.8±1.3	2 vs. 4, 5, 6, 7, 8, 9, 10
3	Nose, chin	33.5±1.3	3 vs. 5, 6, 7, 8, 9, 10
4	Cheek	33.2±0.9	4 vs. 6, 7, 8, 9, 10
5	Right shin	32.8±0.7	5 vs. 7, 8, 9, 10
6	Upper arm, left shin, forearm	32.6±0.9	6 vs. 7, 8, 9, 10
7	Right thigh, left thigh	31.9±0.7	7 vs. 8, 9, 10
8	Ear	30.4±1.5	8 vs. 10
9	Right sole	30.1±1.5	
10	Left sole	29.8±1.6	

SD: standard deviation.

training increases blood flow of the skin[8]. The relative high SST of the right side might be due to more blood flow on the right side, because most people are right-side dominant, which is associated with more blood flow. However, its physiological implication is doubtful and requires further research, considering the small difference of SST between right and left (see 95% confidential interval in Supplementary Table 1).

Humidity is an important factor affecting SST[9]. Previous studies have a limitation that they did not mention the controlled humidity[2-4]. On the other hand, the ambient temperature and humidity in the present study were tightly regulated.

There are some limitations to this study. The recruited participants were of a limited age range and showed skewed gender distribution. In addition, we did not simultaneously measure other factors such as skin blood flow, which might correlate with skin temperature.

We can conclude that the SST is different according to body region. The accepted skin temperature of 32°C to −35°C[2] is a vague description and the temperature of skin surface can exhibit about 5°C variation according to body region in the standard environment. These results are the most comprehensive measurements throughout exposed area. The SST values obtained in our study could be used as important reference values in the future studies. For instance, it would be interesting to investigate the changing SST according to the chronological aging. Skin blood flow may be affected by aging[10], so the changing of temperatures by aging at the various body sites may vary. This study can elucidate the relation between skin blood flow and the surface temperature. Further studies are warranted to elucidate the factors contributing to regional differences in surface temperature.

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SUPPLEMENTARY MATERIALS

Supplementary data can be found via http://anndermatol.org/src/sm/ad-31-349-s001.pdf.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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Adiponectin Promotes Caspase-14 Expression in Normal Human Epidermal Keratinocytes

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Dear Editor:

Filaggrin (FLG) and its high molecular-weight precursor profilaggrin (proFLG) are filament-associated proteins that aggregate keratin fibers in keratinocytes. The cellular processing of proFLG and FLG provides an important material source of natural moisturizing factors (NMF), and multiple proteolytic enzymes including peptidylarginine deiminase (PAD) 1, PAD 3, caspase-14, calpain 1 and bleomycin hydrolase have been implicated in their proteolytic processing[1]. Among these proteases, caspase-14 is considered the key enzyme, as it is thought to directly cleave the FLG repeat in preparation for complete breakdown by other enzymes[2]. Adiponectin, an adipokine secreted from adipocytes, has primary effects on energy metabolism and anti-diabetic in nature. It has been well known that adiponectin also has anti-inflammatory effects[3].

Recently, there are a few reports investigating the effects of adiponectin on skin. It has been shown that adiponectin

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Supplementary Table 1. Whether the surface temperature shows difference between right and left according to the body regions

Skin surface temperature between the right and left	Anatomical location	95% confidence interval (°C)
Not significantly different	Cheek, ear, eyelid, nasolabial, perioral, anterior neck, palm, forearm, upper arm	
Significantly different ($p<0.05$, right>left)	Sole	0.21, 0.50
	Shin	0.08, 0.35
	Thigh	0.0074, 0.29

Supplementary Table 2. Skin surface temperature of each region from 30 volunteers

Anatomical location	Mean±SD (°C)
Anterior neck	35.0±0.5
Nasolabial	34.7±0.5
Perioral	34.7±0.7
Eyelid	34.5±0.4
Forehead	34.5±0.6
Palm	33.8±1.3
Nose	33.5±1.6
Chin	33.5±0.9
Cheek	33.2±0.8
Right shin	32.8±0.7
Upper arm	32.7±0.7
Left shin	32.6±0.8
Forearm	32.6±1.0
Right thigh	32.0±0.7
Left thigh	31.9±0.8
Ear	30.4±1.6
Right sole	30.1±1.5
Left sole	29.8±1.6

SD: standard deviation.