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생활과학석사 학위논문

Body Regional Heat Pain Thresholds in Korean Young Males

-20대 남성의 인체 부위별 열통증 분포-

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이 논문을 생활과학 석사 학위논문으로 제출함

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박성진

Abstract

Body Regional Pain Thresholds in Korean Young Males

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Sense of pain and temperature are extremely important for our survival. Cutaneous thermal thresholds have been measured by the method of either level or limit. The purpose of this study was to examine body regional heat pain thresholds using the method of both limit and level. A total of 16 young males (23.2 ± 3.2 yr, 174.9 ± 4.9 cm, 70.1 ± 8.6 kg, and 1.85 ± 0.12 m^2) participated in this study. Subjects were laid in a supine position at an air temperature of 28°C and 35%RH. A thermal stimulator was used and the temperature increase of the probe was set at 0.1°C·s^{-1} for the method of limit and 0.5°C·$step^{-1}$. All measurements were repeated three times on the following 14 body regions: the forehead, neck (back), chest, abdomen, upper back, upper arm, forearm, waist, hand, palm, thigh, calf, foot, and sole. For the method of limit, we measured warmth and heat thresholds along with heat pain thresholds on the 14 regions. The results showed that 1) pain thresholds were 3.2±2.1°C greater for the method of level than for the method of limit and this result corresponded to all 14 body regions (all $P<0.05$); 2) the correlation coefficient (r) between values by the two methods was 0.819 (N=14, $P<0.01$); 3) lower body regions (the thigh, calf and sole) had higher heat pain thresholds than upper body regions (the neck, chest, forearm and waist) by both methods; and 4) body regional subcutaneous fat thickness showed no relationships with heat pain thresholds except the upper arm. These results confirmed that the heat pain thresholds of the human body vary based on body sites, type of heat stimuli and the size of the area heated. This study also that the role of subcutaneous fat thickness on heat pain sensitivity could be a site specific phenomenon. Therefore, it could be inferred that the method of limit would be a better choice when dealing with thermal pain related to therapeutic or thermal use of heat such as hot packs whereas the method of level should be used in cases such as testing protective garments for firefighters.

Keywords: heat pain thresholds, method of limit, method of level, subcutaneous fat thickness, regional difference and low temperature burn

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Chapter 1. Introduction

Many burns reported are from direct contact with surfaces of temperatures above 70℃ but some burns are caused by prolonged exposure to lower temperatures such as from the therapeutic or thermal use of heat like hot packs or electric pads (Barillo et al. 2000). Lee et al. (2015), Hwang et al. (2012), and Son et al. (2013) reported that firefighters are identified at increased risk of burns at lower temperatures due to their characteristics of work and garments. A low temperature burn can occur at approximately 44℃ when the skin is in sustained exposure for approximately 6 hours (ASTM C1055, 2003). From 44℃ to about 51℃ the time required for skin damage decreases by approximately 50% for each 1℃ (ASTM C1055, 2003). In the human body, the ability to perceive various ranges of temperature depends on various kinds of receptors located in the skin. Pure thermal sensation is evoked due to the change of skin temperature in the range of 13~45℃ and heat pain sensation occurs at the temperatures above 45℃ or below 15~18℃ (Lynette, 2002). Accumulated studies suggest that transient receptor potential (TRP) channels are the main attributor for the distinct thermal sensitivities. TRP channels are activated by heating through the deformation of protein shape. Its activation temperature is known to range from a warmth at (>25°C for TRPV4; >31°C for TRPV3), to heat at (>43°C for TRPV1), to noxious heat at (>52 °C for TRPV2) and to cooling, (<28°C for TRPM8; <18°C for TRPA1) (Voets et al. 2004).

There are many literatures that have examined the measurement of thermal sensation. Early studies directly investigated the number of cold and warm spots per surface area (Strughold and Porz, 1931). Stevens (1979) investigated the differences of perceptual thermal sensitivity to cold across the body with a 20 cm^2 temperature regulated probe. Lee et al (2010) found ethnic differences in thermal thresholds at 12 sites with method of limit which gives a increasing or decreasing temperature stimulus at a constant rate of change starting from an adaptation temperature until the subject reports sensation by pressing a button (Reulen et al. 2003). Ouzzahra et al. (2012) provided a body map of thermal sensation to cold (20°C, 10 seconds steady state sensation) at 16 body sites before and after exercise. Similarly, heat pain sensation has been investigated to specify its mechanism by measuring cutaneous thermal thresholds. The heat pain thresholds is measured in calorific energy, temperature or stimulus duration. However several studies have reported great variability concerning many aspects of these pain thresholds. Physiological and psychophysical factors that affect variability include site variations in the respective thickness of different skin layers (epidermis, dermis, fat and muscle), microcirculation and susceptibility (Bjerke, 2010). Physiological variations such as age (Woodrow et al. 1972), gender (Riley et at. 1998) and blood pressure (Fillingim & Maixner, 1996) had been considered as well. Chery-Croze (1983) and Jones & Berris (2002) pointed out that the great variability of the pain thresholds may be due to the diversity of experimental conditions- area of application, adapting temperature, intensity and amount of previous stimulation, duration, rates of stimulation, hour and date of measurement. Chong et al. (2004) also reviewed the influence of different stimulus characteristics with the method of limits providing continuous heat stimulation and the method of levels providing intermittent heat stimulation shown in other literature for heat pain detection respectively. Although several studies have compared regional distribution of heat pain sensitivity, little is known on regional variations across the body. Moreover, method of limit or method of level are commonly used in heat pain thresholds measurement (Chong et al. 2004) but the comparison between two methodologies has not yet been examined.

The purpose of this study was therefore investing the heat pain thresholds via different measurement types in sites across the entire body of healthy young males as well as the role of subcutaneous fat thickness in heat pain sensation. This study will be able to provide guidance for the determination of acceptable surface conditions for heated systems and is applicable in development protective clothing to prevent serious burn injuries by suggesting heat pain thresholds in sites across the entire body.

The working hypothesis of this study was that

H1. The heat pain thresholds would be higher with the method of level than with the method of limit

H2. The heat pain thresholds would be higher in lower extremities than in the torso and upper extremities.

H3. There would be a correlation between heat pain thresholds and the thickness of subcutaneous fat

Chapter 2. Method

2.1 Subjects and testing conditions

Sixteen healthy Korean young males (23.2 ± 3.2 yr, 174.9 ± 4.9 cm, 70.1 ± 8.6 kg, and 1.85 ± 0.12 m^2) participated in this study. Their regional distribution of subcutaneous fat thickness was different at 10 body sites shown in Table 1 (Mean±SD: 9.8±3.2mm, P<0.05). The abdomens had the greatest thickness (16.9±6.9 mm) and the foreheads (5.4±1.3mm) had the lowest thickness.

Table 1 Subcutaneous fat thickness measured with ultrasound at 10 different body sites presented as mean±SD.

Body site	Subcutanous fat thickness (mm)	Body site	Subcutaneous fat thickness (mm)
Forehead	5.4±1.3	Upper Arm	9.4±2.3
Neck	11.6±1.5	Forearm	6.3±1.4
Chest	8.8±2.6	Waist	10.9±1.3
Abdomen	16.9±6.9	Thigh	8.0±1.7
Back	11.3±1.6	Calf	9.6±3.6

All subjects were free of skin disorders, neurological illnesses and other medical conditions. They were disallowed alcohol and heavy exercise from the day before the tests. All the tests were performed in a quiet room seated in a comfortable recliner at an air temperature of 28°C and 35%RH. Subjects were visited twice. In the first visit, heat pain thresholds detection was performed and in the second visit warm thresholds detection with cutaneous fat thickness were measured. All tests were performed at the same time from AM 9:00 to PM 1:00, wearing underwear and short pants. Testing sites were shaved if necessary. Standardized instructions, purpose and potential risks of this study were given and a training session of every test was performed. All the subjects were volunteers and signed the informed consent form. This study was approved by the Institutional Review Board of Seoul National University (IRB No. 1704/003-009).

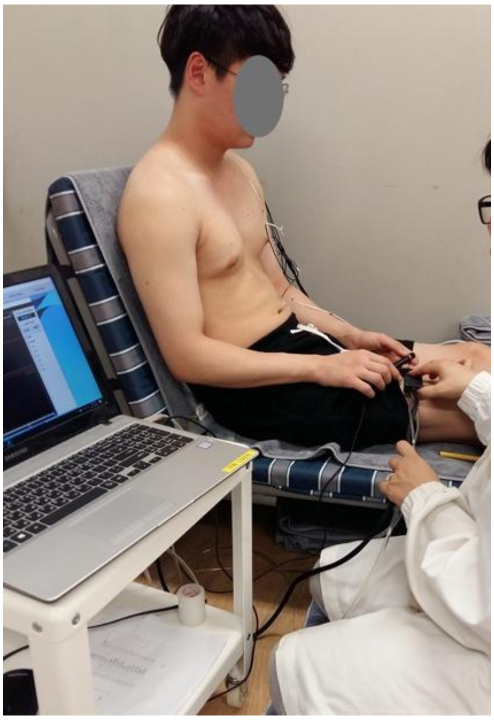

Figure 1 Subject sitting in a comfortable recliner to be assessed for heat pain thresholds.

2.2 Measurements

1) Warm thresholds

Cutaneous thermal thresholds were measured by the method of limit using a Peltier thermode (intercross 200, Intercross Co., Japan) at the fourteen sites (Fig.2). The thermode size was 6.25cm^2. The starting temperature was the skin temperature of each site and the linear increasing rate of temperature change was 1^{o}C/s in all of the tests. All measurements were repeated three times on the following 14 body regions: the forehead, neck, back, chest, abdomen, upper back, upper arm, forearm, waist, hand, palm, thigh, calf, foot, and sole.

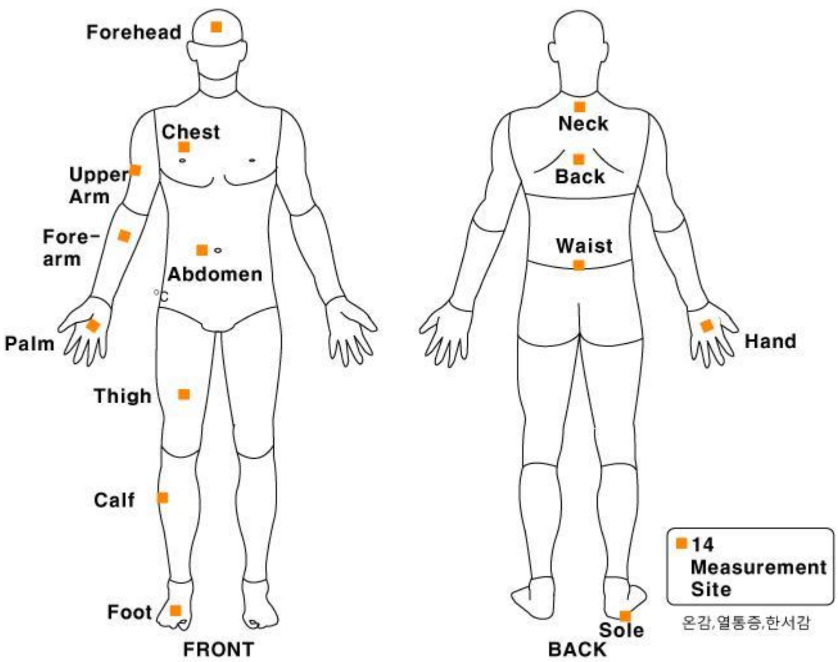

Figure 2 14 measurement body sites: the forehead, neck, chest, abdomen, back, upper arm, forearm, waist, hand, palm, thigh, calf, foot and sole.

2) Heat pain thresholds

Heat pain thresholds were measured by the method of limit and the method of level. A thermal stimulator (Intercross-210, Intercross Co., Japan, stimulator size: 1 cm^2) was applied to the skin and the temperature of the stimulator increased until the subject reported feeling a sensation of heat pain by pressing a button. All measurements were repeated three times at each of fourteen randomly chosen sites (Fig 2). Thresholds were considered as the average the three measurements taken in at least 20 minutes interstimulus intervals. For safety the temperature limit was set at 50°C. The machine would stop automatically if the temperature limit was reached. When the subject did not report any sensation and the limit was reached, a 'no response' was recorded. Cutaneous thermal thresholds were measured on the right side of the body except for the forehead, neck, back and waist which were measured on the center of the body.

A. B. C.

Figure 3 A. Heat pain thresholds detection system, B. Thermode size 6.25cm^2, C. Thermode size 1cm^2

Method of limit. Method of limit for heat pain thresholds were utilized by Verdugo and Ochoa (1992) and Yarnistky and colleagues (1995) and for warm and cold sensation thresholds by Reulen and colleagues (2003). The stimuli of thermode in method of limit started from the baseline near skin temperature and increased at a constant setting rate until the subjects perceives cold, warm, or heat pain sensation. We set the temperature increase of the probe at 0.1°C·s^{-1} (Fig.4) and measured warm and hot. thresholds along with the heat pain thresholds on the 14 sites at the starting temperature of 33°C. The subject was instructed to press a button as soon as warm, hot and pain was perceived.

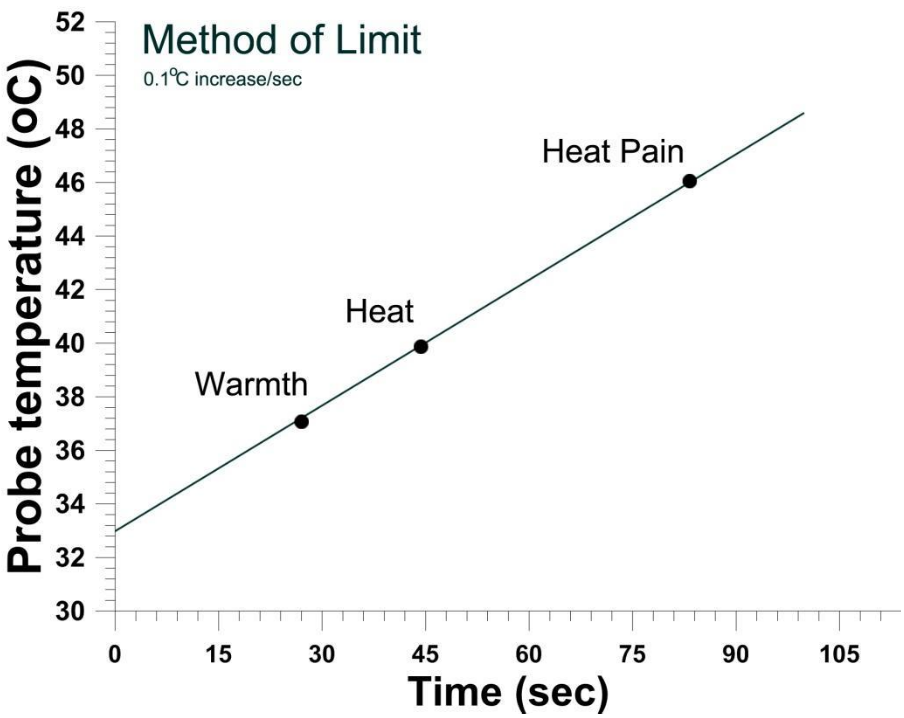

Figure 4 Method of limit.

Method of level. Method of level utilizes stimuli of predetermined levels of intensity and duration. We always initially set the thermode at the starting baseline temperature of 33°C. The thermode temperature increased to the first stimuli of 44°C from the baseline temperature at the rate of 10°C/sec, maintains for 3 seconds and went back to the baseline temperature of 33°C. Interstimulus intervals were 5 seconds and duration of stimulus in each level was 3 seconds. Subsequent stimuli were of progressively 0.5°C higher intensity (Fig.5). The subject was instructed to press a button as soon as pain was perceived. At the first stimuli, the subject was asked thermal sensation scaled as none, slightly warm, warm, hot. Temperature limit was 50°C. The machine stopped automatically if the temperature limit was reached. If the subject had not report any sensation and the limit was reached, the heat pain threshold was considered as 50°C. If the subject pressed the button at the first stimuli of 44°C, the heat pain thresholds was considered as 44°C. All cutaneous thermal thresholds were detected on the right side of the body with the exception of the forehead, neck, back and waist which were measured on the center of the body in order to limit the duration of the test.

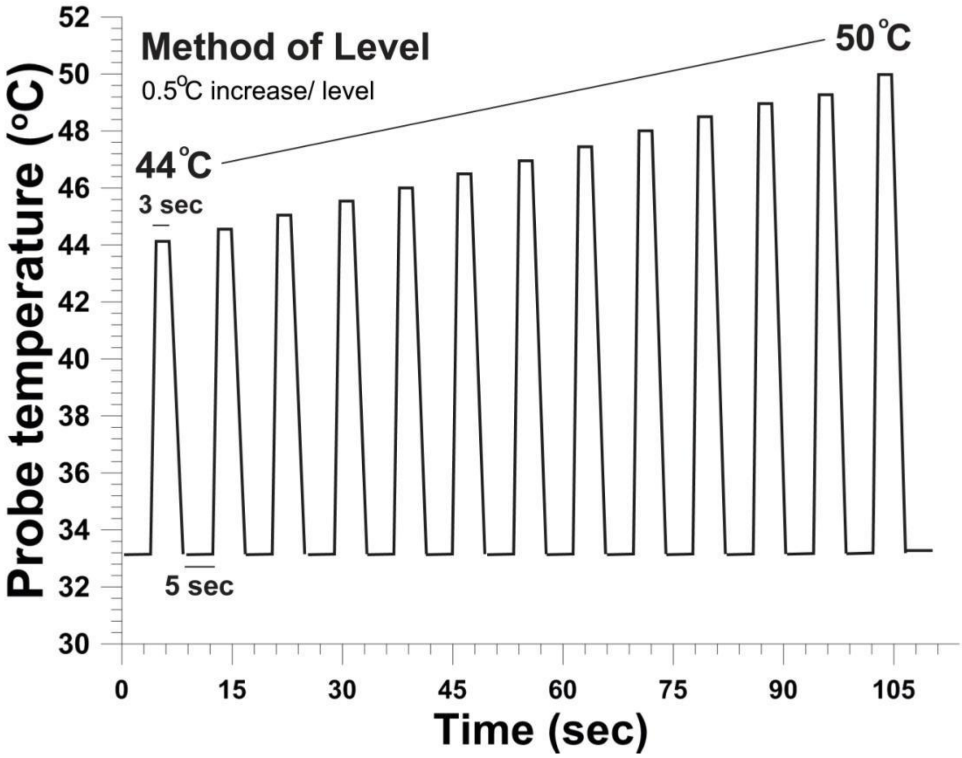

Figure 5 Method of level.

3) Initial skin temperature

Skin temperature probes were attached to the 14 sites using a data logger (LT-8A; Gram Corporation, Japan). All measurements for skin temperature were performed on the left side of the body except for the forehead, neck, back and waist which were measured on the center of the body. Initial skin temperature was recorded at the beginning of the measurement of heat pain thresholds with the method of level.

4) Subcutaneous fat thickness

BFI measure (SEIKOSHA Co.,LTD, Japan) was used to obtain the ultrasound measurements of fat thickness. The 10 sites; forehead, neck, back, chest, abdomen, upper back, upper arm, forearm, waist, thigh, calf were each marked with a dot and three measurements were made at each site. Evaluation of fat thickness on the images (Fig.6) was calculated automatically via the "Quick" mode of the software.

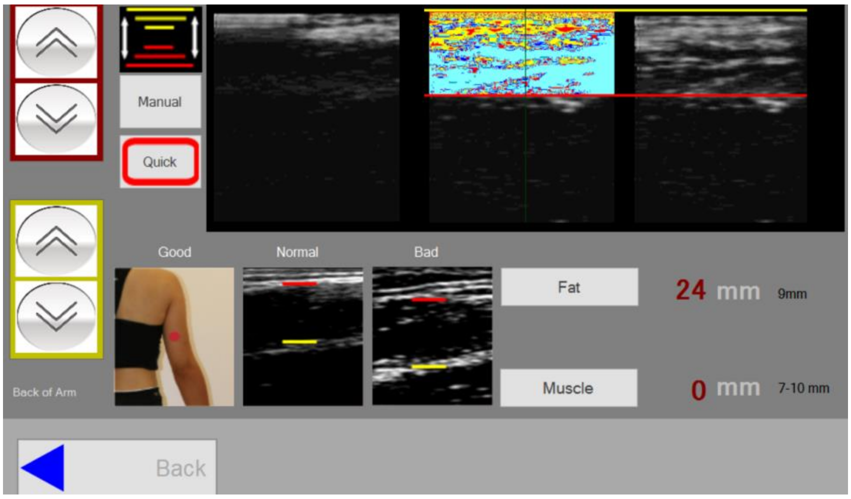

Figure 6 Print screen of automatic ultrasound subcutaneous fat thickness measurement.

5) Thermal sensation

When measuring heat pain thresholds with the method of level, the subjects were asked for their initial thermal sensation. The purpose of asking for their initial thermal sensation was to ascertain how the same stimuli (44°C for 3 seconds) were felt in different body sites. The initial thermal sensation was scaled as none (1), slightly warm (2), warm (3) and hot (4).

2.3 Statistical analysis

Statistical analysis was performed using IBM SPSS v.21.0. Each measures was assessed to see the differences in body regions using Tukey post hoc test with One way ANOVA. Method difference of heat pain detection thresholds was analyzed using independent sample t-test. Pearson's correlation coefficients analysis between measured items was performed. Measurements were expressed in mean±SD and significance levels for all analysis were set to smaller than 0.05.

Chapter 3. Results

3.1 Heat pain thresholds - method of level

Heat pain thresholds measured with the method of level showed significant regional variance ($P<0.05$). Chest (45.3±1.5ºC, N=16) was distinguished from the thigh (48.0±1.9 ºC, N=16, P=0.006), calf (47.7±2.0 ºC, N=16, P=0.031), and sole (48.0±2.0, N=16, P=0.008) for heat pain thresholds (Fig. 7).

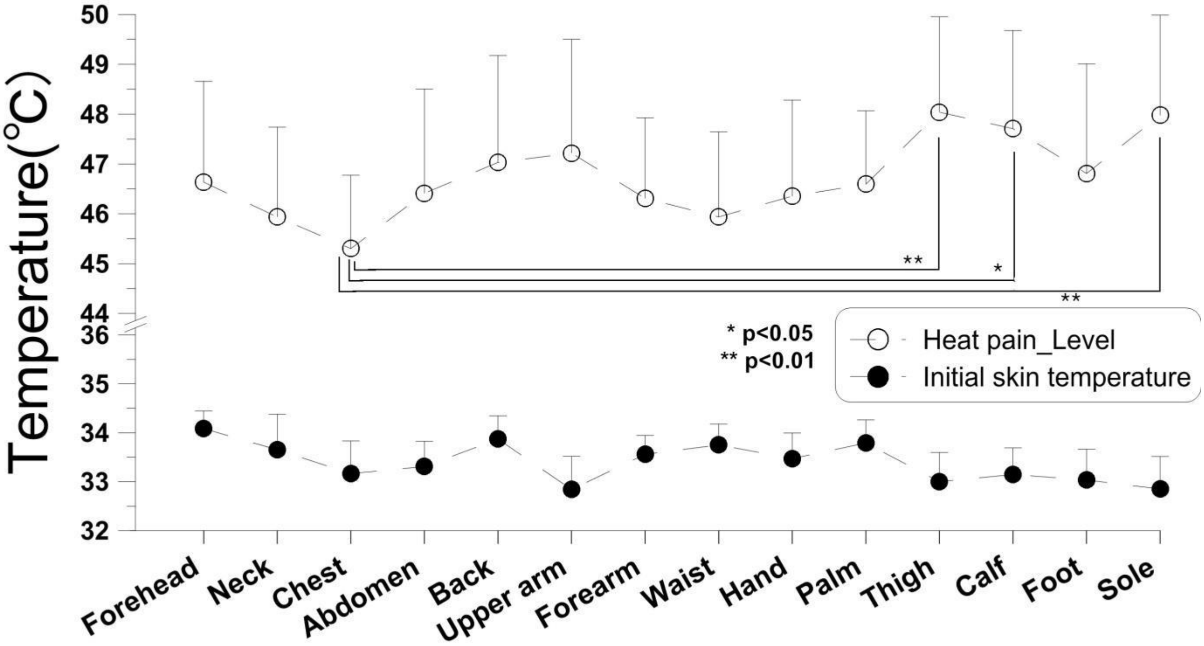

Figure 7 Heat pain thresholds measured with the method of level at 14 sites along with initial skin temperature. Values were expressed as mean±SD of 16 subjects. * indicates significant variance between chest with other 13 body sites. (*P<0.05, **P<0.01, ***P<0.001)

Table 2 Initial skin temperature and heat pain thresholds measured with method of level at 14 different body sites presented as mean±SD (* indicates significant body regional difference between chest with other 13 body sites (*P<0.05, **P<0.01, ***P<0.001)).

Body site	Initial skin temp.(ºC)	Heat Pain Thresholds-Level (ºC)
Forehead	35.1±0.9	46.6±2.0
Neck	34.2±1.1	45.9±1.8
Chest	32.5±1.1	45.3±1.5
Abdomen	32.4±1.4	46.4±2.1
Back	34.7±0.9	47.0±2.1
Upper Arm	31.8±0.8	47.2±2.3
Forearm	33.7±1.5	46.3±1.6
Waist	34.0±1.1	45.9±1.7
Hand	33.9±1.0	46.4±1.9
Palm	34.9±0.6	46.6±1.5
Thigh	32.3±1.0	48.0±1.9**
Calf	32.6±1.1	47.7±2.0
Foot	31.6±1.9	46.8±2.2*
Sole	31.7±2.1	48.0±2.0**
Mean±SD	33.2±1.2	46.7±0.8

3.2 Heat pain thresholds - method of limit

The temperature of warm, hot and heat pain thresholds measured with the method of limit is shown in Table 3. The results of the measurements are the average values of 16 subjects with the standard deviation obtained from the 14 body sites. No significant difference was found for the thresholds of warm, hot and heat pain at all 14 sites with the method of limit.

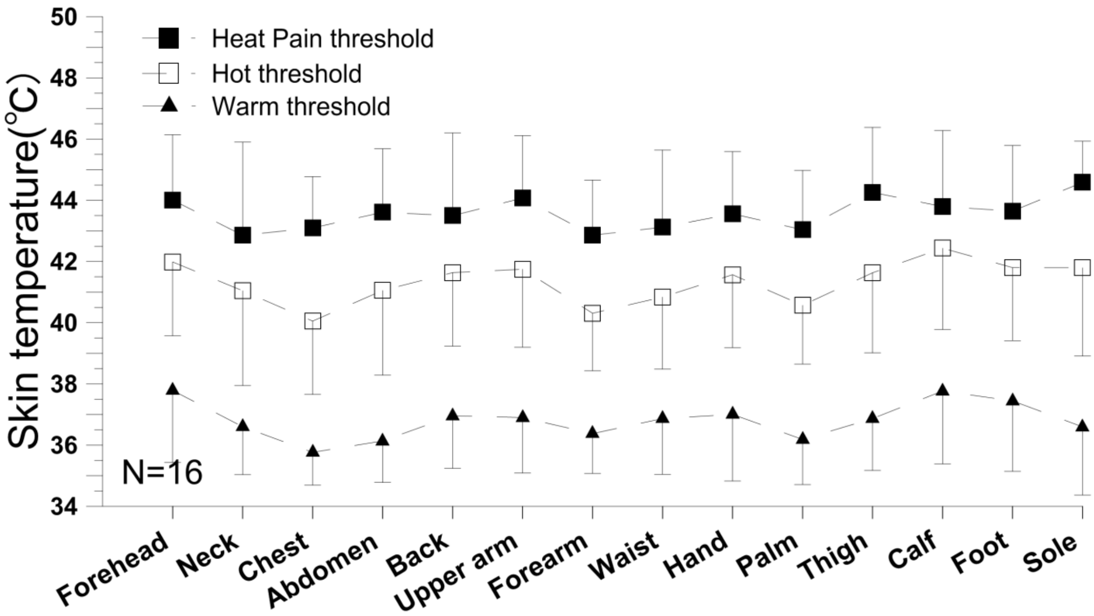

Figure 8 Thermal detection thresholds (warm, hot and heat pain thresholds) with the method of limit at 14 different body sites presented as mean±SD.

Table 3 Temperature of warm, hot and pain thresholds measured with method of limit at 14 different body sites presented as mean±SD.

Body site	Warmth Thresholds -Limit (°C)	Hot Thresholds -Limit (°C)	Pain Thresholds -Limit (°C)
Forehead	37.8±2.4	42.0±2.4	44.0±2.1
Neck	36.6±1.6	41.0±3.1	42.9±3.0
Chest	35.8±1.1	40.1±2.4	43.1±1.7
Abdomen	36.1±1.4	41.1±2.8	43.6±2.1
Back	37.0±1.7	41.6±2.4	43.5±2.7
Upper Arm	36.9±1.8	41.7±2.5	44.1±2.0
Forearm	36.4±1.3	40.3±1.9	42.9±1.8
Waist	36.9±1.8	40.8±2.4	43.1±2.5
Hand	37.0±2.2	41.6±2.4	43.6±2.0
Palm	36.2±1.5	40.6±1.9	43.0±1.9
Thigh	36.9±1.7	41.6±2.6	44.3±2.1
Calf	37.8±2.4	42.4±2.7	43.8±2.5
Foot	37.4±2.3	41.8±2.4	43.6±2.1
Sole	36.6±2.2	41.8±2.9	44.6±1.3
Mean±SD	36.8±0.6	41.3±0.7	43.6±0.5

3.3 Heat pain thresholds: method of level vs. method of limit

Fig.10 shows the results of correlation of pain detection thresholds measured with method of level and method of limit. The correlation coefficient (r) between two methods was 0.521 (N=224(14 body sites x 16 subjects), P<0.01) and 0.819 (N=14, P<0.01) with the mean thresholds of 16 subjects at 14 body sites. It shows a strong linear relation between method of limit and method of level at the 14 body sites. Heat pain thresholds with the method of level were 3.2±0.5^{o}C greater on the average compared with the method of limit. This result corresponded to all 14 body regions (all P<0.05). Regional difference of heat pain thresholds with the method of level were found but not with the method of limit.

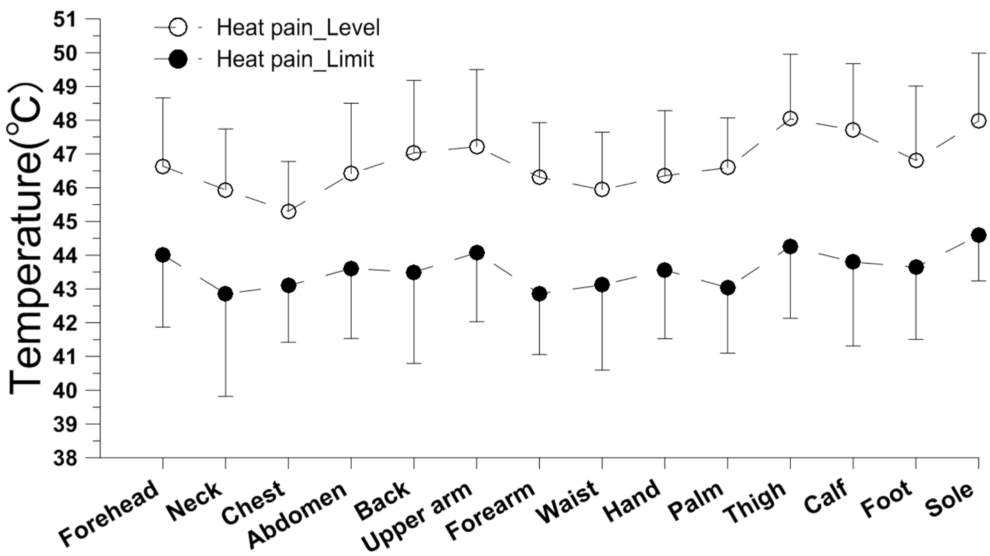

Figure 9 Heat pain thresholds measured with method of level and limit at 14 body sites. Values were express as mean±SD of 16 subjects.

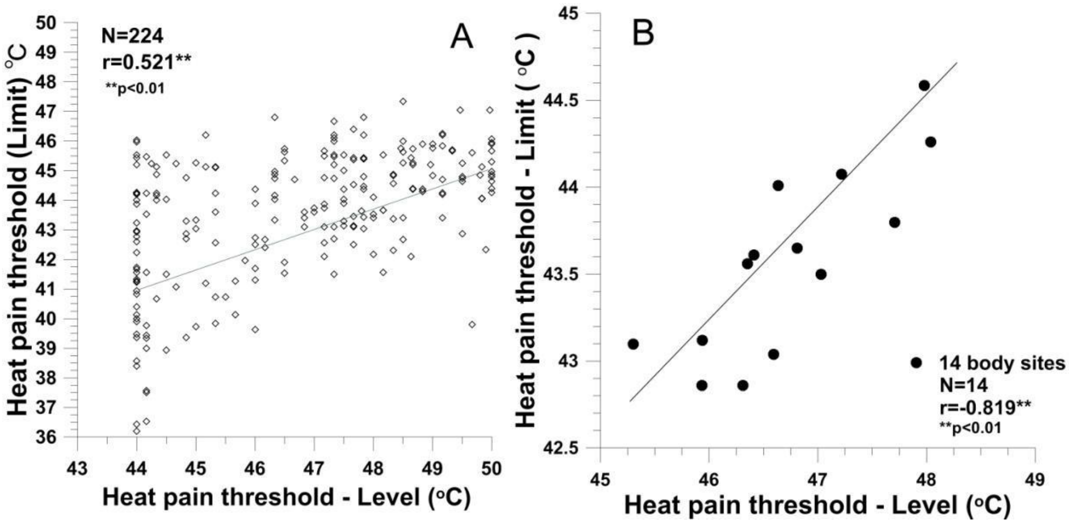

Figure 10 A. Scatter plot of heat pain detection thresholds measured with method of level and heat pain thresholds measured with method of limit (N=224). **B.** Scatter plot of mean of 16 subjects heat pain thresholds of 14 body sites measured with limit and level method (N=14).

Table 4 Heat pain thresholds presented in °C of method of limit and method of level and its difference.

Body site	Heat pain thresholds -Level (°C)	Heat Pain thresholds -Limit (°C)	Thresholds Difference (°C)	P-value
Forehead	46.6±2.0	44.0±2.1	2.6	0.001
Neck	45.9±1.8	42.9±3.0	3.1	0.002
Chest	45.3±1.5	43.1±1.7	2.2	0.001
Abdomen	46.4±2.1	43.6±2.1	2.8	0.001
Back	47.0±2.1	43.5±2.7	3.5	0.001
Upper Arm	47.2±2.3	44.1±2.0	3.1	0.001
Forearm	46.3±1.6	42.9±1.8	3.5	0.001
Waist	45.9±1.7	43.1±2.5	2.8	0.001
Hand	46.4±1.9	43.6±2.0	2.8	0.001
Palm	46.6±1.5	43.0±1.9	3.6	0.001
Thigh	48.0±1.9	44.3±2.1	3.8	0.001
Calf	47.7±2.0	43.8±2.5	3.9	0.001
Foot	46.8±2.2	43.6±2.1	3.2	0.001
Sole	48.0±2.0	44.6±1.3	3.4	0.001
Mean±SD	46.7±0.8	43.6±0.5	3.2±0.5	

3.4 Subcutaneous fat thickness: correlation with the heat pain thresholds (level)

Subcutaneous fat thickness in young healthy group did not show correlation with heat pain thresholds measured with method of level (r=-0.004, P=0.960, N=160). However, significant correlation with the upper arm only (r=0.596, P=0.015, N=16) was found.

Table 5 Correlation coefficient with heat pain thresholds and subcutaneous fat thickness.

Body site	Heat pain thresholds -Level (ºC)	Subcutaneous fat thickness(mm)	Correlation coefficient
Forehead	46.6±2.0	5.4±1.3	-0.339 (P=0.198)
Neck	45.9±1.8	11.6±1.5	0.075 (P=0.783)
Chest	45.3±1.5	8.8±2.6	-0.248 (P=0.355)
Abdomen	46.4±2.1	16.9±6.9	0.174 (P=0.519)
Back	47.0±2.1	11.3±1.6	0.353 (P=0.181)
Upper Arm	47.2±2.3	9.4±2.3	0.596 (P=0.015)*
Forearm	46.3±1.6	6.3±1.4	0.050 (P=0.855)
Waist	45.9±1.7	10.9±1.3	-0.331 (P=0.211)
Thigh	48.0±1.9	8.0±1.7	-0.032 (P=0.906)
Calf	47.7±2.0	9.6±3.6	-0.156 (P=0.565)
Mean±SD	46.7±0.9	9.8±3.2	

3.5 Warm thresholds: thermode size 6.25cm^2 vs. 1cm^2

Warm thresholds were detected with two different thermode sizes, 6.25cm^2 and 1cm$^{2.}$. Warm thresholds is 35.6±0.7ºC measured with 6.26 cm^2 thermode and 36.8±0.6 ºC with 1 cm^2 thermode. 1.2±0.5ºC was greater on average with the larger thermode ($P<0.05$).

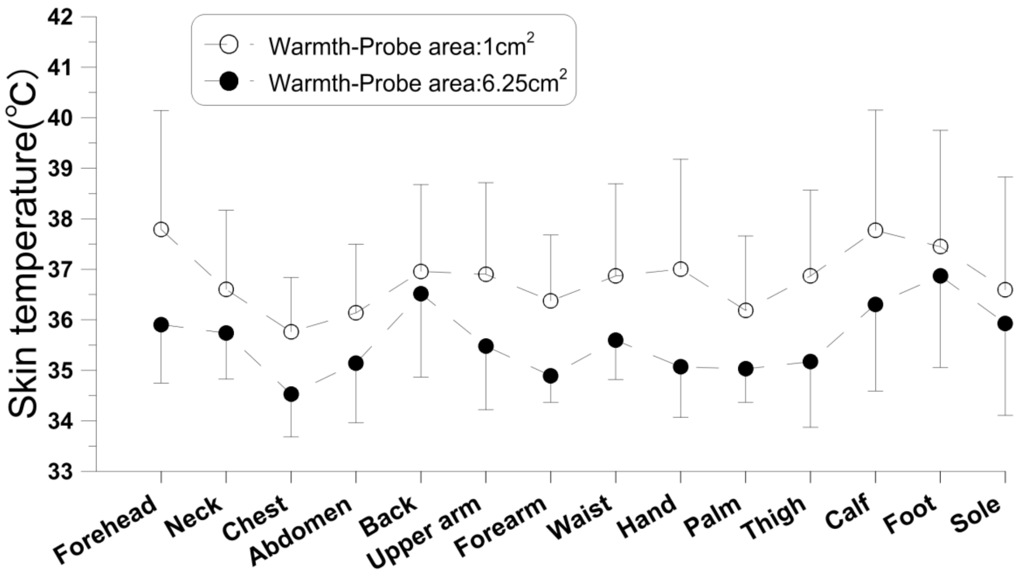

Figure 11 Warm detection thresholds measured with 2 different probes, 6.25cm^2 and 1cm^2 at 14 different body body sites presented as mean±SD.

Table 6 Warm detection thresholds measured with 2 different probe sizes, 6.25cm^2 and 1cm^2

Body site	Warm-thresholds (6.25cm^2) (^{o}C)	Warm-thresholds (1cm^2) (^{o}C)	Thresholds Difference (^{o}C)	P-value
Forehead	35.9±1.2	37.8±2.4	1.9	0.029
Neck	35.7±0.9	36.6±1.6	0.9	0.068
Chest	34.5±0.8	35.8±1.1	1.2	0.001
Abdomen	35.1±1.2	36.1±1.4	1.0	0.035
Back	36.5±1.6	37.0±1.7	0.4	0.046
Upper Arm	35.5±1.3	36.9±1.8	1.5	0.016
Forearm	34.9±0.5	36.4±1.3	1.5	0.001
Waist	35.6±0.8	36.9±1.8	1.3	0.016
Hand	35.1±1.0	37.0±2.2	1.9	0.003
Palm	35.0±0.7	36.2±1.5	1.2	0.008
Thigh	35.2±1.3	36.9±1.7	1.7	0.003
Calf	36.3±1.7	37.8±2.4	1.5	0.055
Foot	36.9±1.8	37.4±2.3	0.5	0.441
Sole	35.9±1.8	36.6±2.2	0.7	0.360
Mean±SD	35.6±0.7	36.8±0.6	1.2±0.5	

3.6 Initial thermal sensation

Initial thermal sensation had significant difference in 14 body sites (P<0.05) (Fig. 12). Subjects felt higher sensation in chest and lower sensation at back, calf, foot and sole significantly from the same stimuli of 44 °C for 3 seconds.

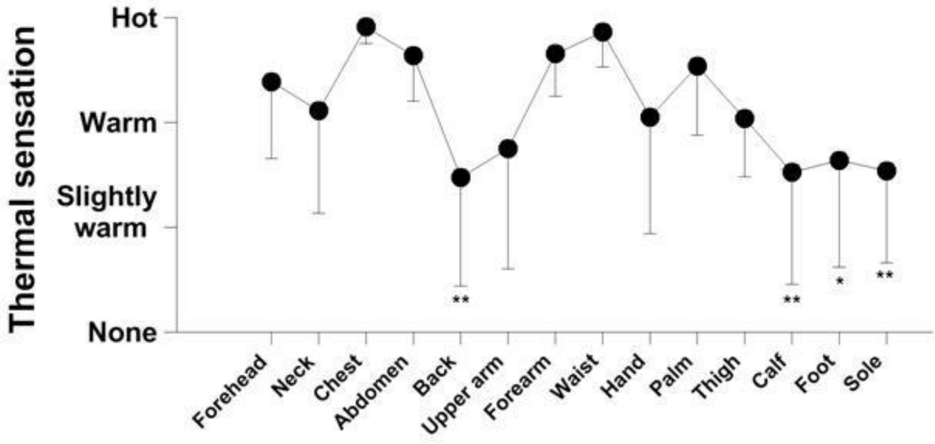

Figure 12 Initial thermal sensation scaled as none (1), slightly warm (2), warm (3) and hot (4). The sensations were measured at the first stimuli of the method of level. * indicates a significant difference with the chest which is the most sensitive in initial and distinctive sensation among the 14 sites. (*P<0.05, **P<0.01, ***P<0.001)

Table 7 Initial thermal sensation at 14 different body sites presented as mean±SD..

Body site	Initial thermal sensation
Forehead	3.4±0.7
Neck	3.1±1.0
Chest	3.9±0.2
Abdomen	3.6±0.4
Back	2.5±1.0
Upper Arm	2.8±1.1
Forearm	3.7±0.4
Waist	3.9±0.3
Hand	3.1±1.1
Palm	3.5±0.7
Thigh	3.0±0.6
Calf	2.5±1.1
Foot	2.6±1.0
Sole	2.5±0.9
Mean±SD	3.2±0.5

3.7 Thermal sensation: correlation with the heat pain thresholds (Level)

In relation to the pain thresholds, results show that the higher the pain thresholds the lower the thermal sensation (Fig.13, r=-0.744, p=0.002, N=14). Initial thermal sensation is negatively related to heat pain thresholds. Especially the back (r=-0.659, p=0.014), calf (r=-0.650, p=0.012) and sole (r=-0.624, p=0.023) were significantly related. Subjects reported 'hot' in the chest area but 'none' or 'warm' in the back, calf and sole at the first stimuli of the method of level.

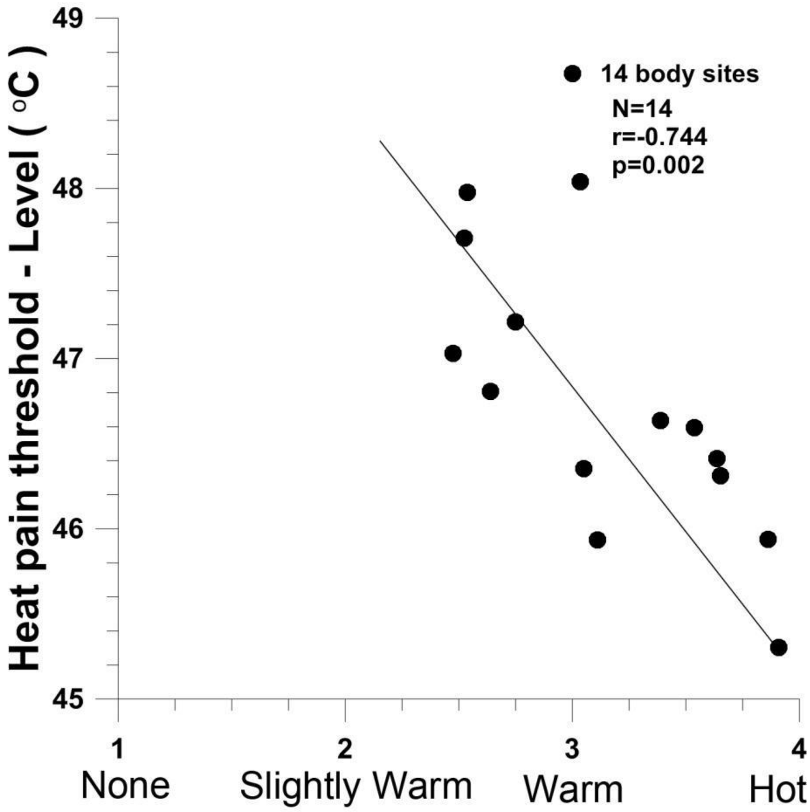

Figure 13 Correlation between the heat pain thresholds and the initial thermal sensation of 14 body sites.

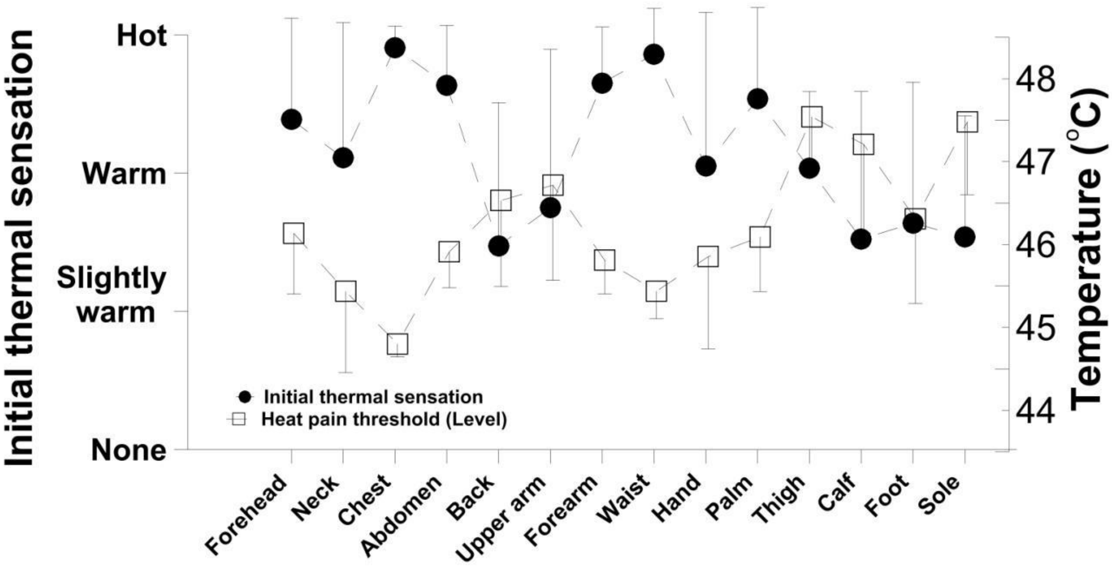

Figure 14 Sensitivity of the heat pain measured with the method of level and the initial thermal sensation at the 14 body sites.

Chapter 4. Discussion

4.1 Heat pain thresholds measurement method

Thermal thresholds are commonly measured using either the method of limit or the method of level. Levy et al. (1989) and Reulen et al. (2002) had compared both methods for warm and cool thermal thresholds. Method of limits for heat pain thresholds has been studied by Verdugo and Ohoa (1992) and Yarnisky et al.(1994). A heat pain thresholds study using the method of level was only done by Dyck and collegues (1993). However, their conclusions are not sufficient to make a decision on whether one testing protocol and algorithm are better than another. Instead, influences of different stimulus characteristics are suggested in respect to inclusion of reaction time, the effect of rate of temperature change of the thermode, thermode size and number of examiners involved. In this study, the method of limit and the method of level in heat pain thresholds detection were examined. Heat pain thresholds with the method of level (46.7±0.8 ^{o}C) was higher than those with the method of limit (43.6±0.5 ^{o}C). This result suggests that using the method of limit would be better when dealing with thermal pain related to therapeutic or thermal use of heat such as hot packs and the method of level would be better for cases such as protective garments for firefighters.

4.2 Body regional differences of heat pain thresholds

In several studies, heat pain thresholds in different body sites are examined to identify if there is a preferred site of testing for clinical pain testing. Also it is studied for the predicting pain and burn degrees. Variation of heat pain sensitivity to noxious stimulation in different body areas was initially suggested by Hardy et al. (1953). They obtained the highest pain thresholds on the heel of the foot and the lowest thresholds on the lower back, buttocks and thighs. Taylor et al. (1993) reported thresholds in glabrous skin of the hand and foot were significantly greater than for the hairy skin of the forearm and calf and there was no significant difference in heat pain sensitivity between comparable sites on the upper versus lower extremities, or between left and right sides. Dyck and colleagues (1993) found heat pain thresholds are lowest in the face and volar arms and highest in the legs and feet. Yarnitsky et al. (1994) and Hagander (1999) showed that the heat pain thresholds were similar in hands and feet. This study seems to contradict Taylor and affirm Dick, Yarnisky and Hagander. Although it is not available for full comparison of each numerical value in thresholds across all body sites due to the different measurement methods with the least body sites, heat pain thresholds across the body are shown to be different somehow. Regional difference of heat pain thresholds are considered to be affected by the various levels of tissue thermal transference and by the various distribution of heat pain receptors known as TRPV1 by many authors shown in Tab 8. In this study, the greater the heat flux to the skin, the correspondingly lower the difference of sensitivity of heat pain in various body sites was observed. This suggests that different specific heat capacity, thermal conductivity, water content, density, blood flow from each tissue should be studied in the future for a better understanding of the regional difference of heat pain thresholds.

Table 8 Different sensitivity of heat pain on various body sites found in the literature

Authors	**Lowest HPT**	**Highest HPT**	**Influence of sensitivity of HP**	**Test Method**
Hardy et al.(1953)	lower back, buttocks thigh	heel of the foot	tissue temperature	thermal radiation
Taylor (1993)	forearm calf	hand sole	receptor density.	39,42,45 ºC
Tracy	forearm back	shoulder leg	nociceptor density and protective mechanism:	Marstock method of limit
Hafner et al. (2015)	hand	foot	Influence of longer distances	Marstock method of limit
Harju (2002)	knee, foot	upper arm thenar	interplay of peripheral and central mechanisms	method of limit
Dyck (1993)	face (43)and volar arm(43.5)	leg sole hand	distribution of receptors	method of level
Price et al.(2013)	forehead	abdomen	subcutaneous fat thickness	
Yarnitsky et al.(1994)		thenar foot		method of limit
Hagander (1999)		thenar hand foot		method of limit
Verdugo and Ochoa, (1992)	tarsal (43.9)	thenar hypothenar		method of limit
This study	thigh, calf, sole	chest	subcutaneous fat thickness tissue temperature	method of limit method of level

4.3 Initial thermal sensation

Normally the human sensory system is capable of discriminating thermal stimuli due to the existence of different types of temperature sensors with distinct thermal sensitivities. Accumulated studies suggest that transient receptor potential (TRP) channels are the main attributor. TRP channels are activated by heating through deformation of its protein. Its activation temperatures are known to range from warm temperature (>25^{o}C for TRPV4; >31^{o}C for TRPV3), to heat (>43^{o}C for TRPV1) and noxious heat (>52^{o}C for TRPV2). In this study, most subjects felt “warm” or “none” with stimuli of 44^{o}C for 3 seconds in the calf, however, the same stimuli in the chest felt “hot”. It seems that activation of TRPV4, 3 and 1 are involved in the lower body and only TRPV1 is activated in the chest area with the same stimulus (44^{o}C for 3 sec). Thermal sensation showed regional difference and this difference was related to the heat pain thresholds measured in this study. It can therefore be inferred that the distribution of subfamilies of TRP channels may be different across various body sites.

4.4 The role of subcutaneous fat thickness

Previous studies (Zahorska Markiewicz et al., 1983, 1988; Khimich, 1997) have suggested altered pain sensitivity with obesity. Price et al.(2013) examined whether the decreased pain sensitivity of obesity is a local or global phenomenon in the various subcutaneous thicknesses of body sites. He found decreased heat pain sensitivity only on excess subcutaneous fat (the abdomen area) in obese groups compared to non obese groups. In this study, subcutaneous fat thickness was measured the relation of thickness of fat with the pain sensation was examined. The results show that it is a local phenomenon as noted by Price and colleague study. The altered pain sensitivity in various fat thicknesses showed only on the upper arm ($r=0.596$, $p=0.015$) in BMI 22.8±2.2 group. However, due to the small sample size and insufficient BMI variation it is difficult to generalize that only fat thickness in the upper arm is related to heat pain thresholds.

4.5 Limitations

Some limitations from the present study should be considered in generalization. First, participants are young healthy Korean men. Second, this study investigated the thresholds across the body with different methods. For a more detailed investigation of potential differences in heat pain perception, greater variation of method and stimuli area should be included in future studies.

Chapter 5. Summary and Conclusions

This present study investigated heat pain thresholds at the 14 body sites and compared the thresholds with the different method. Also the role of subcutaneous fat was examined.

The results show that heat pain sensitivity of human body is highest in chest area and lowest in lower body extremities. The difference of pain sensitivity is more distinct from the intermittent heat stimuli instead of continuous heat stimuli. Also subjects had a tendency to have less temperature sensation in lower body extremities. In regards to the different subjective sensation in different body area, heat pain could be somehow related to thermal sensation, warmth or hot. Heat pain sensitivity is decreased in thicker subcutaneous fat only in upper arm in the group of who had a BMI mean of 22.8±2.2.

These results confirmed that heat pain thresholds in human body vary by body site, type of heat stimuli and size of heated area. Also the results of this study suggest that the role of subcutaneous fat thickness on heat pain sensitivity could be a site specific phenomenon.

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초 록

피부의 온도 감각은 냉점, 온점, 통점 수용기를 통해 다양한 온도 범위를 감지하고 그에 따라 다양하게 반응한다. 약 13~43℃ 는 냉점 온점을 통해 냉, 온감을 느낄 수 있는 범위이며, 약 30~36℃는 피부온 중성역으로 냉온감을 느끼지 못하는 온도 범위이다. 반면 약 45℃ 이상에서는 통점을 통해 열을 통각으로 느끼게 되는데 이러한 감각을 열통증이라고 한다 (Lynette et al., 2002). 이러한 열통증의 역치는 열로부터 우리 인체를 보호하기 위한 중요한 정보를 전달하는 역할을 하게 된다. 그런데 열통증 역치는 인체의 부위별로 차이가 있어 부위별 열통증의 역치에 대한 연구가 진행 중에 있다. 하지만 Hardy et al., (1952) 연구팀은 피부접촉 가온 방식이 아닌 복사열을 이용하여 측정하여 피부 열통증 역치 온도를 제시할 수 없었으며, Yamitsky (1995) 연구팀는 손과 발의 역치만 비교하였고, Lee(2010, 2011a)와 Kim(2014) 연구팀은 부위별 열통증이 아닌 부위별 온냉감 역치에 대해 조사하였다. 이들 연구들의 공통 점은 손 부위가 발 부위보다 열통증에 민감하고 얼굴 부위의 민감도가 높음을 알 수 있었다. 하지만 인체 전체 부위별 피부의 열 통증 역치 온도를 제시한 연구는 드문 상황이다. 이에 본 연구는 건강한 20대 남성의 인체 부위별 열통증 역치 분포를 조사하여 인체 열통증 지도를 작성하는데 목적이 있으며 이는 소방관과 같이 고열환경에서 작업하는 작업자들의 1도 화상 예방을 위한 보호복 개발 및 작업지침을 제공하고 겨울철 국소 난방기구 (난로, 전기장판 등) 사용자들의 저온화상 예방을 위한 지침 마련에 기초자료로 사용될 수 있을 것이다.

주요어: 열통증, 단계법, 연속법, 피하지방 두께, 초음파, 부위별 차이

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