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Effects of Local Heating on Whole Body Skin Temperature

- Centered on the Comparison of Old Women & Female Collegians -

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Abstract

The purpose of this study was to design functional clothing based on the physical characteristics of old women. The subjects of this experiment were 5 healthy old women and 5 college women. While the subjects were exposed to the circumstances of 28±0.5°C and local heating at 7 areas (chest, abdomen, back, loin, hand, thigh and instep), their skin temperature, physiological reaction and psychological reaction were determined.

The conclusions about the effects of local heating are as follows :

1. Skin temperature before heating was in the order of head-neck> trunk> upper limbs> lower limbs (Group A: old subjects) and head-neck> trunk> lower limbs> upper limbs (Group B: young subjects).
2. The heating pad was attached and detached for 30 minutes each. The sharpest rise and fall were recorded at 5 minutes with the pad on and off. Both groups had great changes in the body parts near trunk.
3. With the pad on and off, both groups showed no change in body temperature, blood pressure, and pulse rate.
4. Concerning the pervasive effects of local heating on whole body skin temperature, loin heating greatly increased other body parts in Group A. In Group B, the effects were large in heating chest, abdomen, back, loin, and thigh.
5. The loin part of old women has the greatest pervasive effect of local body heating.

Key words: local heating, old women, skin temperature

I. Introduction

In old age, one's function of maintaining constant body temperature grows weak. As a result, temperature control is unsteady, reaction speed is slow, and a big response is made to a small stimulus (Nakahashi, 1990). Compared with younger people, the old have a less number of cold spots on the skin (Shimizu, 1992). So their clothes need to respond properly to the changing temperature indoors and outdoors.

The research on body protection has been limited to parts of the body and especially for youths, leaving much room for senior citizens. In this respect, the present research aims to reveal the effects of local body heating on the whole

body skin temperature and to propose the ways of expanding applications to climatic changes, eventually leading to the functional clothing design based on the physiological characteristics of old women.

II. Experimental Methods

1. Laboratory Environmental Conditions

The experiment was administered from Jan. 22 through Feb. 17, 1999 at the Clothing Hygiene Laboratory in Dong-A University. The laboratory conditions are shown in <Table 1>.

<Table 1> Laboratory environmental conditions

Environmental Temp.(°C)	Relative Humidity(%)	Air Movement (m/sec)	Effective Radiant Temp.(°C)
28±0.5*	50±10	0.1	0±0.5

* Body temperature controlling burden is minimal.

2. Subjects

The physical characteristics of the subjects are described in <Table 2> .

As healthy adults, five old women (65-72 years) and five female college students (21-24 years) were chosen. Each subject took a seat in a bra and panties.

3. Heating Pad

The common type of a heating pad, No. 827 (Mexico, 30×35cm, 50W), was used after preheating. Among three levels, middle

<Table 3> Radiation and temperature of heating pad

Level	Reading Time(sec)	Radiation (cal/cm^2)	Temperature (°C)
L	146	1.54	33
M	273	2.93	41
H	624	7.18	69

<Table 2> Physical characteristics of the subjects

Items / Subject		Age (Yr)	Height (cm)	Weight (kg)	Body surface Area(m^2)*	Röhrer Index**	Metabolic Rate (kg · cal/hr)***
Old	A-1	65	161.3	56.0	1.60	1.33	54.40
	A-2	65	152.0	45.0	1.40	1.28	51.17
	A-3	67	158.4	54.5	1.56	1.37	53.60
	A-4	68	155.0	49.0	1.47	1.32	52.05
	A-5	72	153.5	47.5	1.44	1.31	51.24
Young	B-1	21	161.0	48.5	1.49	1.16	56.65
	B-2	22	165.2	54.5	1.60	1.21	58.22
	B-3	23	156.7	48.0	1.46	1.26	55.87
	B-4	23	160.0	52.0	1.54	1.27	57.03
	B-5	24	158.2	47.5	1.47	1.20	55.87

* Body surface area(calculated by Takahira's equation) = $W^{0.425} \times {}^{0.725} \times 72.46/10^4$

** Röhrer index(calculated by Röhrer's equation) = $W/H^3 \times 10^5$

*** Metabolic rate(calculated by Nakagawa's equation)= {591.620 + 3.815W + 2.434H - 1.689A)/24}×1.2

temperature was adopted. <Table 3> compares radiation and temperature.

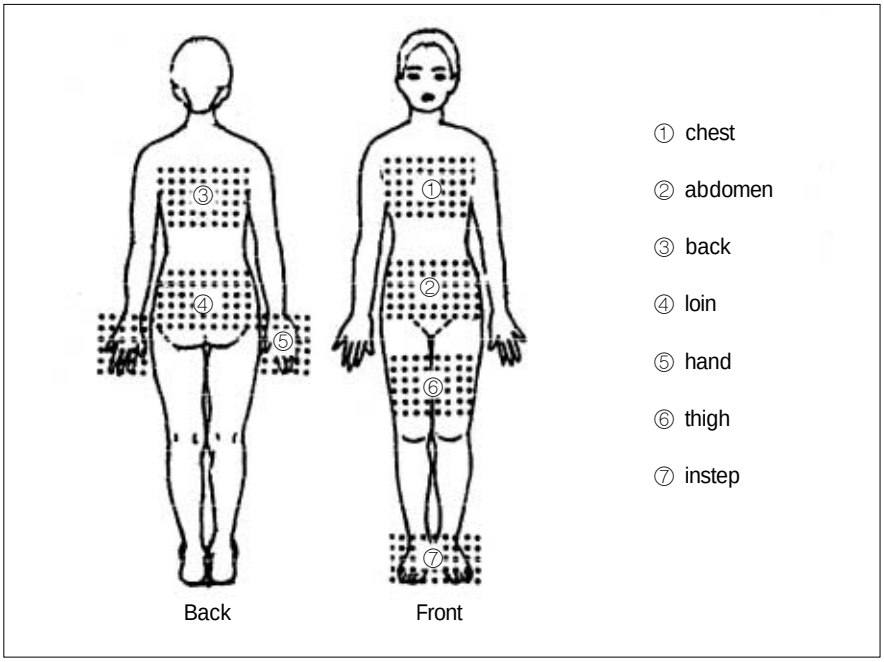
4. Heating Areas

The heating areas of the body were chest, abdomen, back, loin, hand, thigh and instep. The heating areas are shown in <Fig. 1>.

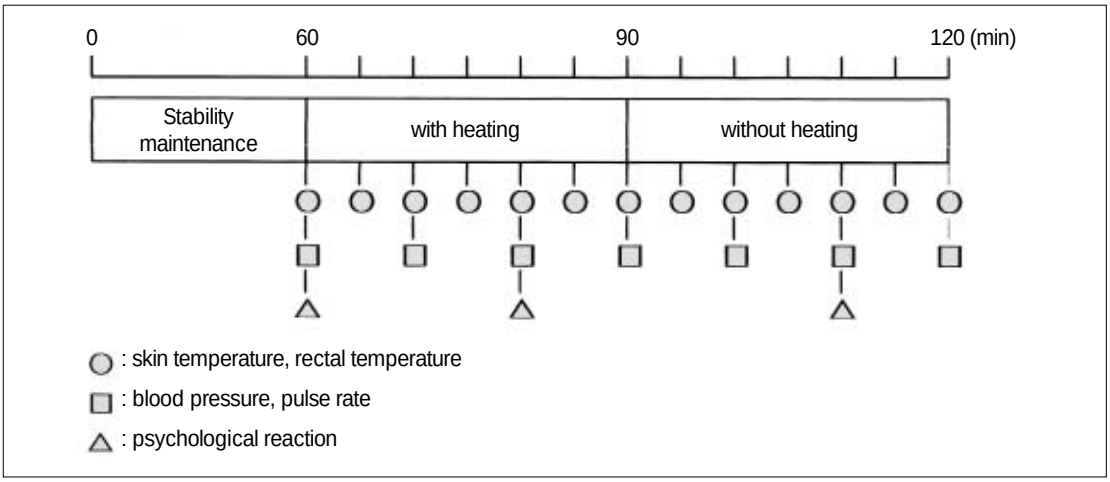
5. Measurement Items & Experimental Procedure

The rectal temperature was measured every 5 minutes by a rectal thermistor thermometer inserted 12cm beyond the anal sphincter of the subjects. Skin temperatures at the forehead, trunk, forearm, hand, thigh, calf, and instep were measured by thermistor thermometers taped to the skin. Mean skin temperature was calculated according to the following equation of Hardy and Dubois (1937). Other physiological measurements included blood pressure and pulse rate. The blood preassure and pulse rate were measured every 10 minutes by recorders during the experiment.

The subjects were asked to sit in chairs for at least 60 minutes while the necessary transducers were attached. When attached a heating pad on each parts, they sat for 60 minutes. After with the heating pad, they again sat without a heating pad for 60 minutes. The measurement items and experimental procedure are shown in <Fig. 2>.



< Fig. 1> Heating areas



<Fig. 2> Experimental procedure

III. Results & Discussion

1. Skin Temperature & Physiological/ Psychological Responses Before Heating

Skin temperature for the old subjects (Group A) before heating showed a descending order of head-neck, trunk, upper limbs, and lower limbs. The young subjects (Group B) had a descending order of head-neck, trunk, lower limbs, and upper limbs. The former were a little (0.39°C) lower than the latter in mean skin temperature.

In body temperature, Group A had lower means and greater individual differences. Group A held higher blood pressure and lower pulse rate. Both groups indicated the sense of comfortableness: neither cold nor hot.

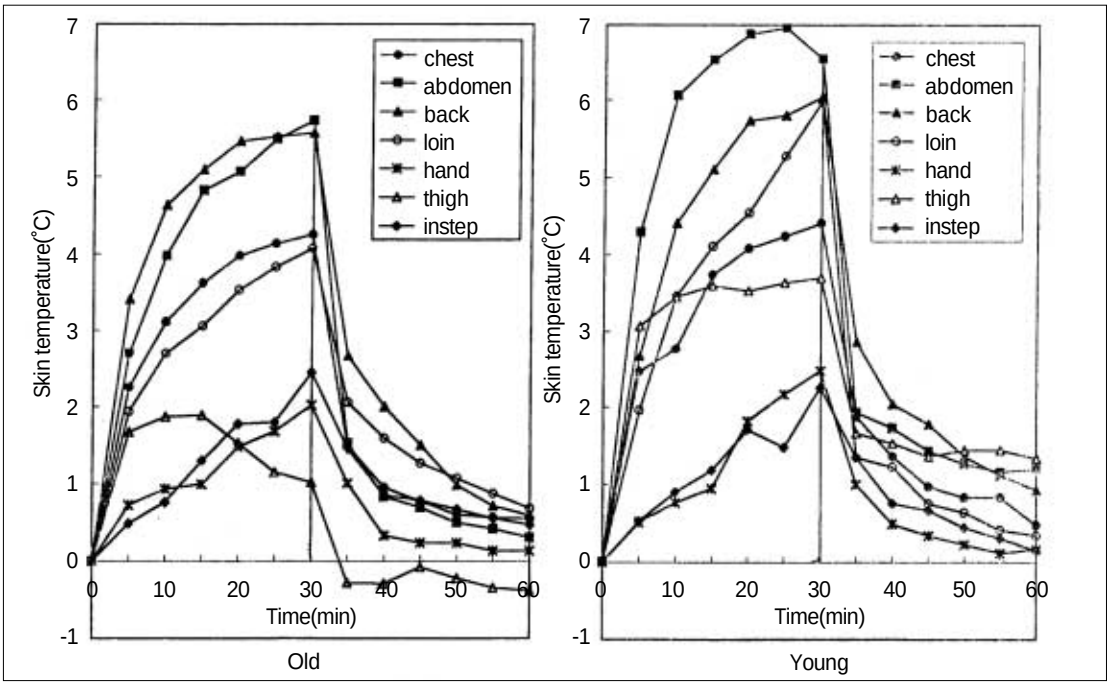
2. Tendency of Skin Temperature With/ Without the Heating Pad

Changes of skin temperatures with lapse of time are shown in <Fig. 3>.

After 5 minutes of heat pad attachment and detachment, the two groups showed a rapid rise and drop of skin temperature respectively. In 5 minutes with the pad on, skin temperature rose in the order of back> abdomen> chest> loin> thigh> hand> instep (Group A) and abdomen> thigh> back> chest> loin> hand> instep (Group B). In 30 minutes, the order was abdomen> back> chest> loin> instep> hand> thigh (A) and abdomen> back> loin> chest> thigh> hand> instep.

Among the seven heated areas, the abdomen part had the greatest change with the maximum temperature of 5.73°C (A: 30 min) and 6.96°C (B: 25 min). The average change during the 30 minutes heating was 0.96°C (A) and 1.09°C (B). Group B showed greater responses to heating. This corresponds to the research results that reaction starts late and a response size is small in cold stimuli and heat production (Wagner, 1974).

At 5 minutes with the pad off, skin temperature decreased in the order of abdomen> back>



<Fig. 3> Changes of skin temperatures with lapse of time

chest> loin> hand> instep> thigh (A) and loin> abdomen> back> chest> thigh> hand> instep (B). The lowest temperature was 4.20°C (A: abdomen) and 4.76°C (B: loin). The average change for 30 minutes of pad detachment was 0.91°C (A) and 0.79°C (B).

The correlations between skin temperature rise with the pad on after 5 minutes (x) and skin temperature fall with it off after 5 minutes (y) were as follows: A–loin (r=0.77), chest (r=0.66), abdomen (r=0.61); B–loin (r=0.99), thigh (r=0.75), abdomen (r=0.72). <Table 4>

<Table 4> Correlations between skin temperature rise and fall

Item / Heating Area	Correlation Coefficient(r)		Regression Equation		Explanation (R^2)	
	A Group	B Group	A Group	B Group	A Group	B Group
Chest	0.656	0.696	-1.08+1.70X	0.82+0.69X	43.06%	48.50%
Abdomen	0.611	0.721	2.84+0.51X	3.39+0.29X	37.34%	51.92%
Back	0.414	0.478	0.19+0.62X	0.74+0.91X	17.13%	22.86%
Loin	0.772	0.997	0.74+0.66X	-0.05+1.99X	59.57%	99.32%
Hand	0.252	-0.080	0.85+0.22X	1.64-0.28X	6.33%	0.65%
Thigh	-0.178	0.749	1.54-0.15X	0.15+0.62X	3.17%	56.08%
Instep	0.400	0.510	0.66+0.49X	0.55+0.96X	16.00%	25.99%

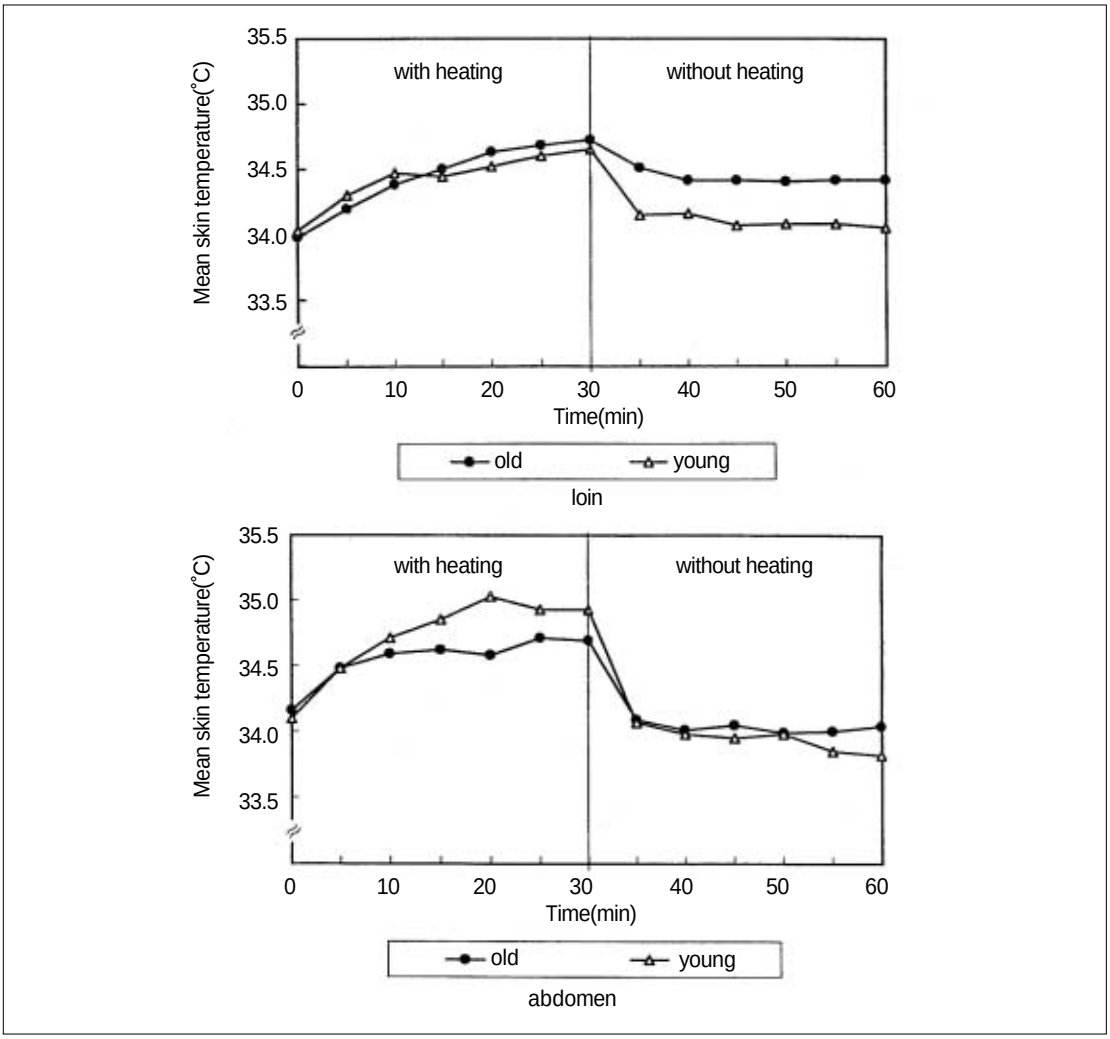
3. Changes of Mean Skin Temperature With/ Without the Heat Pad

The rising gap of mean skin temperature was 0.04-0.74°C (A) and 0.05-0.95°C (B) compared with the period before heating. In particular, the highest rise was seen in loin (A) and abdomen (B), enjoying the greatest pervasive effect on whole body skin temperature. <Fig. 4>

4. Physiological/Psychological Responses With/Without the Pad

Body temperature, blood pressure, and pulse rate stayed steady before and after the experiment. That is, physiological responses don't seem to be affected by the changes of skin temperature.

As to the heat/cold sense, Group A expressed



<Fig.4> Changes of mean skin temperature with lapse of time in the heating areas of loin and abdomen

"neither cold nor hot," while Group B reported "slightly cool" or "slightly hot" with the pad on. When the pad was removed, both groups responded "neither cold nor hot" but Group B was near the response of "slightly cool."

As for the sense of comfortableness, the two groups answered "comfortable." Temperature rise was bigger and took longer time in Group A, which means that old people have an insufficient function of body temperature control (Fennel et al, 1973; Crowe et al, 1973).

5. Pervasive Effects of Local Heating on Whole Body Skin Temperature

Each skin temperature before heating and after the 30-min heating was compared in the Kruskal-Wallis Test, as shown in <Table 5>. Some significance was noticed in every part of the measured body. Individual differences appeared except in abdomen, while group differences showed up in abdomen, thigh, and instep only.

The parts of chest and loin had the greatest pervasive effect. When chest was heated <Fig. 5>, Group A maintained great individual differences and high temperature in back, abdomen (highest), hand, and instep. Group B retained high temperature except in back, upper arm, and lower thigh. Though the young subjects' abdomen temperature was the highest, too, no part of the body showed significance between the groups. The increase of blood current is thought to be responsible for the great temperature rise in the nearby abdomen part, having an additional pervasive effect on limbs.

When abdomen was heated, Group A held rather low temperature except in lower arm, thigh (0.84°C), and lower thigh. This is considered to be the insulation effect of abdomen's subcutaneous fat. Group B showed high temperature except in hand: upper arm (0.22°C), lower arm (0.38°C), thigh (3.31°C). This result is of interest in the body temperature control function, suggesting strong connection between trunk temperature increase and hand temperature rise. Yi (1988) reports the cold blood vessel change at the fingertip by way of abdomen heating, and Grayson (1949) discusses the finger temperature change through abdomen cooling.

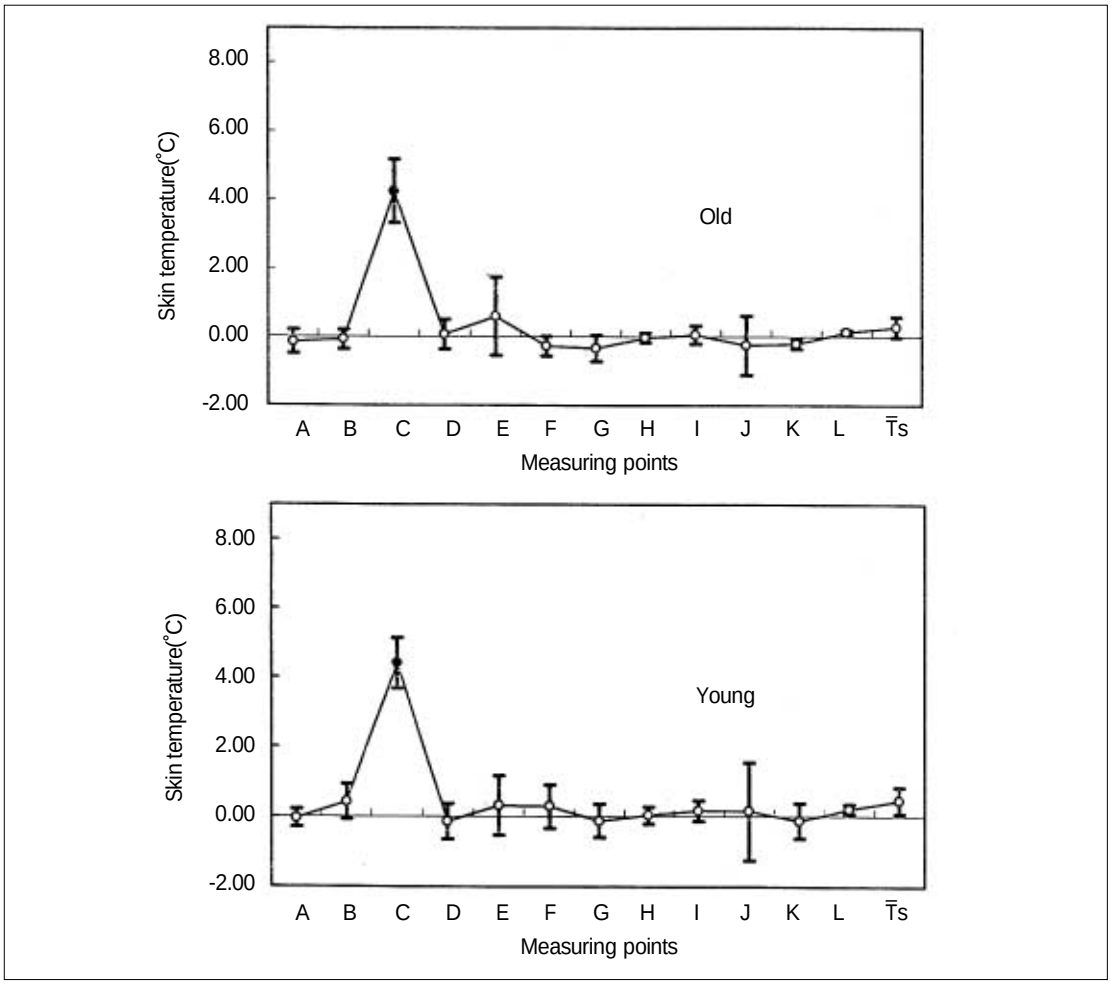
When back was heated, abdomen revealed the lowest temperature and there was no great change.

When loin was heated<Fig.6>, in Group A, mean skin temperature greatly increased in comparison with the heating of other body parts. Then, loin heating seems to have a peculiar effect on raising whole body skin temperature for senior

<Table 5> Results of the Kruskal-Wallis Test

Factor	Heating Area						
	Chest	Abdomen	Back	Loin	Hand	Thigh	Instep
Measuring Points	45.02***	52.89***	51.17***	58.48***	51.78***	34.86***	31.93**
Ind. Dif.	22.86***	21.01*	3.31	35.00***	18.53*	37.50***	32.76***
Group Dif.	3.31	10.64**	2.42	2.29	0.19	17.61***	12.04***

*p<0.05, **p<0.01, ***p<0.001



<Fig.5> Changes of skin temperatures measuring point during chest heating

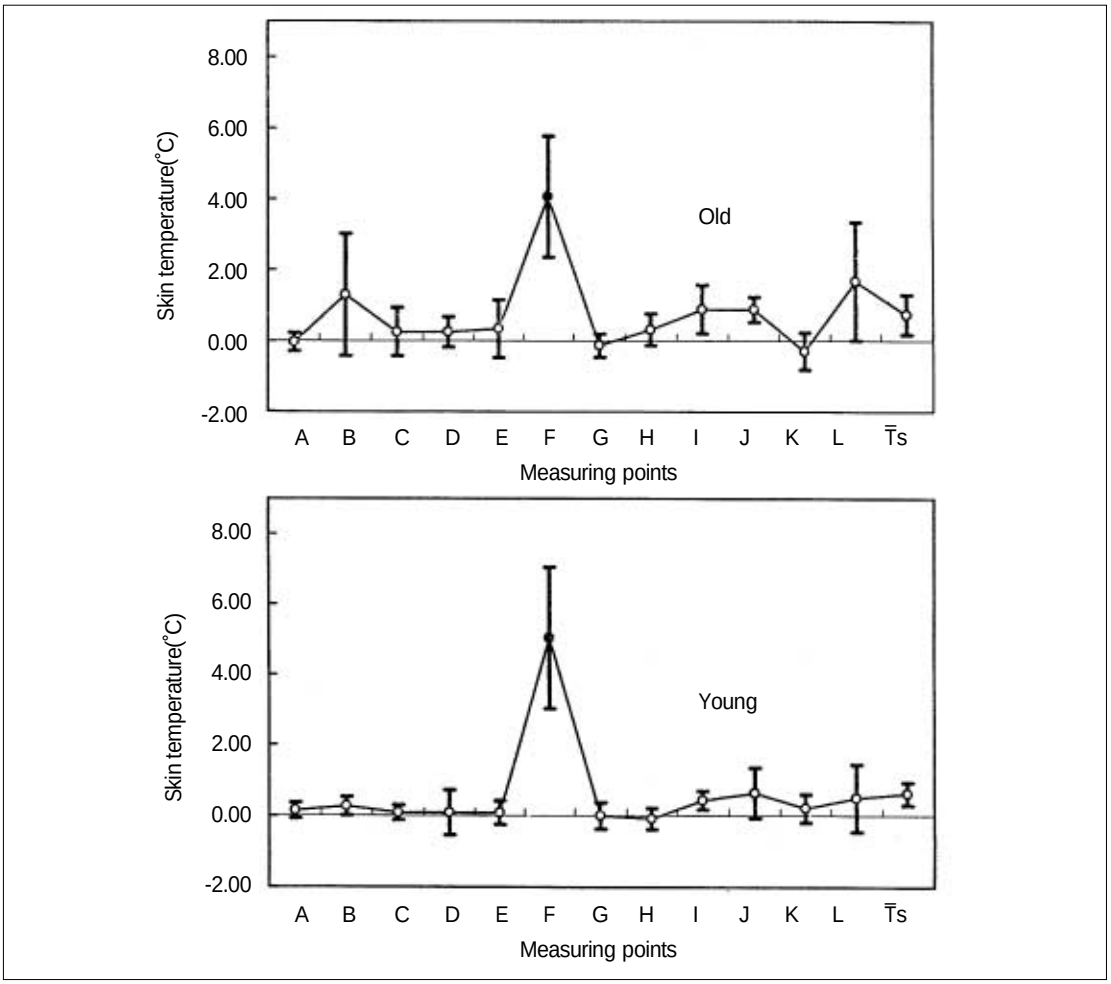
citizens.

When hand was heated, both groups showed a little increase in upper limbs, but its effect on trunk was little. When thigh was heated, Group A had low temperature except in back and abdomen, while Group B held high temperature except in loin. When instep was heated, Group A showed low degrees of temperature except in lower thigh, whereas Group B maintained high degrees.

IV. CONCLUSION

The effects of local heating on skin temperature were examined for old women and female college students. The results were as follows :

1. Skin temperature before heating was in the order of head-neck> trunk> upper limbs> lower limbs (Group A: old subjects) and head-neck> trunk> lower limbs> upper limbs (Group B: young subjects). Mean skin temperature of the former



<Fig. 6> Changes of skin temperatures measuring point during loin heating

was lower than that of the latter.

2. The heating pad was attached and detached for 30 minutes each. The sharpest rise and fall were recorded at 5 minutes with the pad on and off. Both groups had great changes in the body parts near trunk. Correlations: loin (r=0.77), chest (r=0.66), abdomen (r=0.61)–Group A; loin (r=0.99), thigh (r=0.75), abdomen (r=0.72)–Group B.

3. With the pad on and off, both groups showed no change in body temperature, blood pressure, and pulse rate.

4. With the pad attached, Group A responded “neither cold nor hot/comfortable” while Group B answered “slightly hot/comfortable” or “slightly cool/comfortable.” With it detached, both groups expressed “neither cold nor hot/comfortable” but Group A showed lower sensitivity.

5. Concerning the pervasive effects of local heating on whole body skin temperature, loin

heating greatly increased other body parts in Group A. In Group B, the effects were large in heating chest, abdomen, back, loin, and thigh. Also, for the young subjects, hand heating didn't affect any part, but leg heating affected whole body skin temperature.

6. The loin part of old people has the greatest pervasive effect of local body heating.

Therefore, clothing design for senior citizens should fully consider this point to keep warmth in the loin part. In addition, the limb parts which had no if any pervasive effects should be properly checked to prevent heat movement.

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