〔報 文〕

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Cold Sensations by Examining Distribution of Cold spots on the Human Skin.

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體表各部位의 冷點分布 密度 및 冷感覺에 關한 硏究

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報文 要約

着衣行動을 일으키는 前段階의 感覺으로서 局所의 冷感覺과 體表 各 部位에 있어서의 冷點分布에 對하여 測定을 하였다. 被驗者는, 冷點分布 測定에 韓國人 女子 大學生 30名, 冷感覺 測定에는 韓國人과 日本人 女子 大學生 8名을 對象으로 하였으며, 環境條件은 室溫 29°C±1°C, 相對濕度 55%±5%의 人工氣候室로 하였다. 冷刺激으로서는 0°C의 冷覺이 使用되었으며, 測定部位는 冷點分布 測定의 경우 體表 20部位, 冷感覺 測定의 경우 體表 13部位로 하였고 測定結果는 다음과 같다.

(1) 體表面의 冷點分布 密度는 部位에 따라서 다르며, 體幹部와 頭部는 冷點分布 密度가 높고 末端部에 갈수록 그 分布가 낮아졌다. 特히 가장 敏感한 部位는 腹部였다. 즉 體幹部와 頭部는 中核溫을 一定하게 保持하므로서 中核部 體內溫의 變化를 防御하기 위한 溫度 受容 部位로서의 役割을 하고 있으며, 末梢部는 冷點分布가 낮아서 氣溫에 따라 體表溫(外殼溫)을 廣範圍하게 變化시키는 四肢部의 溫度情報入力의 役割을 담당하고 있다고 하겠다.

(2) 各 部位에 있어서의 冷感覺 順位는 日本人과 韓國人 被驗者間에 高度의 相關(r=0.93)이 보여져, 兩 被驗者群間에 差異는 볼 수 없었다.

(3) 冷點分布 密度가 높은 部位인 腹部는 冷感覺도 가장 敏感하였으며, 冷點分布 密度가 낮은 下腿部는 冷感覺 感受性도 낮게 나타났다.

(4) 발바닥과 손바닥은 冷感覺을 敏感하게 느끼는 部位임에도 불구하고 冷點分布 密度가 낮게나타났으며, 이는 特殊性이 있는 部位로서 注目되어지는 結果라고 하겠다.

I. INTRODUCTION

The clothing provided as protection against the natural environment, and for that matter, clothing provided for protection against occupational or extreme conditions, has its structure and features specialized for the different areas of the body. Many different alternative designs and materials are available for each area and most environments.

It is no wonder that to clarify the above stat-

ements, we have prefered to study the differential thermal sensitivity of different skin areas in the determination of a physiological thermoregulatory response. Indeed it is necessary, as a first step, to learn more about the temperature regulation of human body.

Blix,[1] Rein,[4] Zotterman[5] have described thermosensitive receptors in the skin. Apart from their role in temperature sensation, thermosensitive receptors in the skin are also known to be implicated in autonomic thermoregulation. According to Rein,[4] these peripheral thermal sensors are differently distributed on the human body, and specially the face, lips and eyelids have the greatest cold spots distribution areas.

With these in mind, we thought it worthwhile to examine the distribution of cold spots on the human skin in Asian subjects and mainly to examine the differences between the trunk and the limbs. We therefore examined the distribution of cold spots on 40 sites of the human body by using a conical shaped probe containing 0°C ice water and compared the correlation between the cold spots distribution and cold sensations felt really by the subjects.

Ⅱ. METHODS

The methods for the two types of experiments are separately described.

A-Cold spots distribution experiment :

Subjects

The subjects were thirty healthy Korean female students. Their age, weight and height were (Mean±SD) : 20±1.5yr, 49.6±3.7kg and 156.5±4.2cm. In the experiment they wore shorts and brassiere, and each subject entered a conditioning room controlled at a constant temperature (29±1°C), constant relative humidity(55±5%). The subjects were sedentary during 30min before the measuring began.

Experimental device

For examining the distribution of cold spots on the human skin, we used the device which gave a 0°C temperature irritation using a simple conical shaped probe(Fig. 1) made of phosphorous copper which has a very high thermal conductivity. The probe containing 0°C ice water was applied on the skin to examine cold spots. Constant temperature of the probe was kept by changing the ice water every 5 min.

Measurement sites

We considered ten areas in the human body: face, neck, upper trunk, lower trunk, upper arm, lower arm, hand, thigh, lower leg, foot. In each area, four measurement sites were chosen, of which two belonged to the front and two to the back of the body (Fig. 2). An exception was made for the head in which all four measurement sites belonged to the face: forehead, cheek, earlobe and chin. As for the hand and foot, "front" and "back" correspond respectively to "palm", "back of the hand", "dorsum" and "sole of foot". The total number of the measurement sites amounted to 40.

Procedure

After the subject was fully accustomed to the situation, 40 measurement sites were marked on the skin with a specially made 2cm×2cm square stamp containing a grid of 100 points (Fig. 3). We used an eyeliner liquid as an ink. At each of these grid points of the skin, the conical shaped probe containing 0°C ice water was lowered and the subjects were asked wheather they felt cold or not at each point. The probe was lowered slightly only for one second at each time in order to avoid any small sensation of pain which could have been taken for a sensation of coldness. The distribution of cold spots for each site was then obtained by summing up the number of positive answers,(if the subject felt the coldness of the probe at a given site, it was counted as a cold spot).

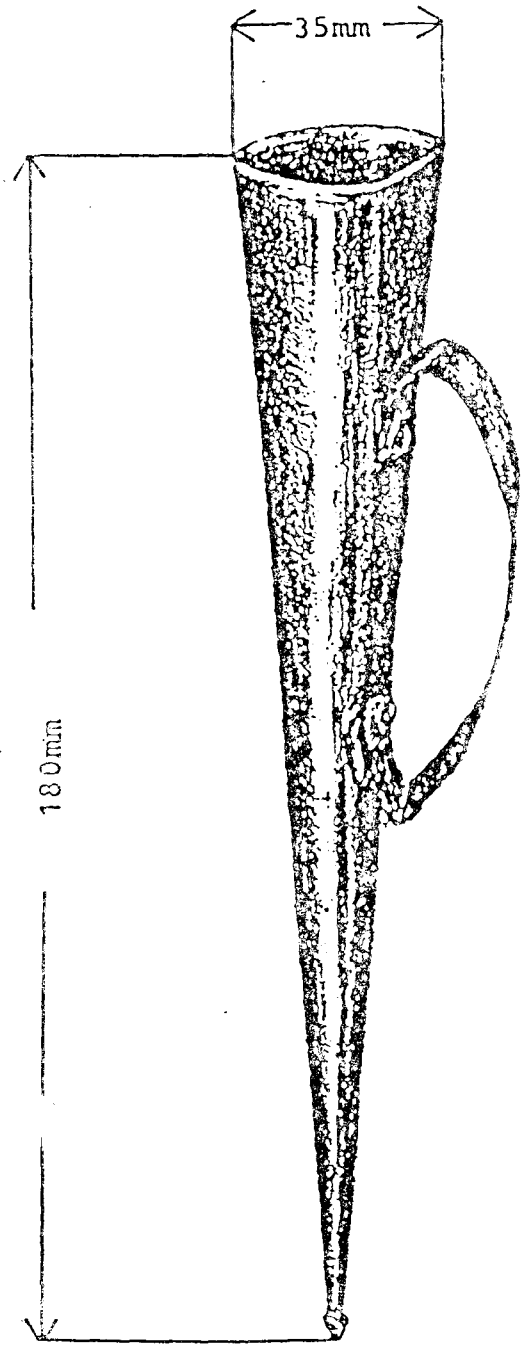


Fig. 1. A conical shaped probe for cold spots measurement.

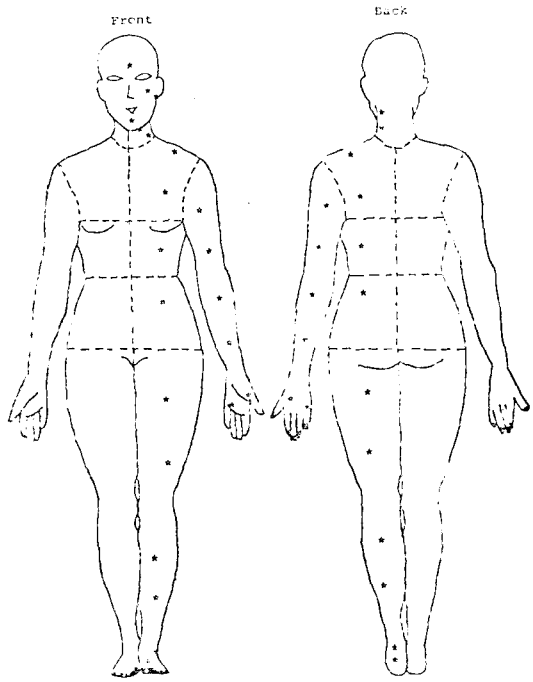


Fig. 2. Sites for cold spots measurement.

B-Cold sensation experiment :

Eight Japanese and Korean female students(age 21±2.1Yr, weight 48.7±3.6kg, height 158.4±2.5 cm) participated in this cold sensation experiment. Wearing shorts and brassiere, the seated subjects were kept for 30 min at room temperature of 29±1°C and humidity 55±5%.

For this experiment, we used the SAMMI temperature apparatus (developped as a medical instrument by YUFU-SEIKI company of Japan), which has a big ball-pen shaped probe allowing to provide 4 kinds of temperatures: 0°C, 10°C for the coldness and 50°C, 60°C for the warm sensation (Fig. 4). We used here only the 0°C temperature and in order to keep 0°C, we always checked the batteries before and during experiments.

Measurement sites were the same ten areas of the human body, choosing only one front site per area, except for the lower arm, hand and foot. For these three areas, corresponding back sites were chosen as shown in Fig. 5. Thus a total of

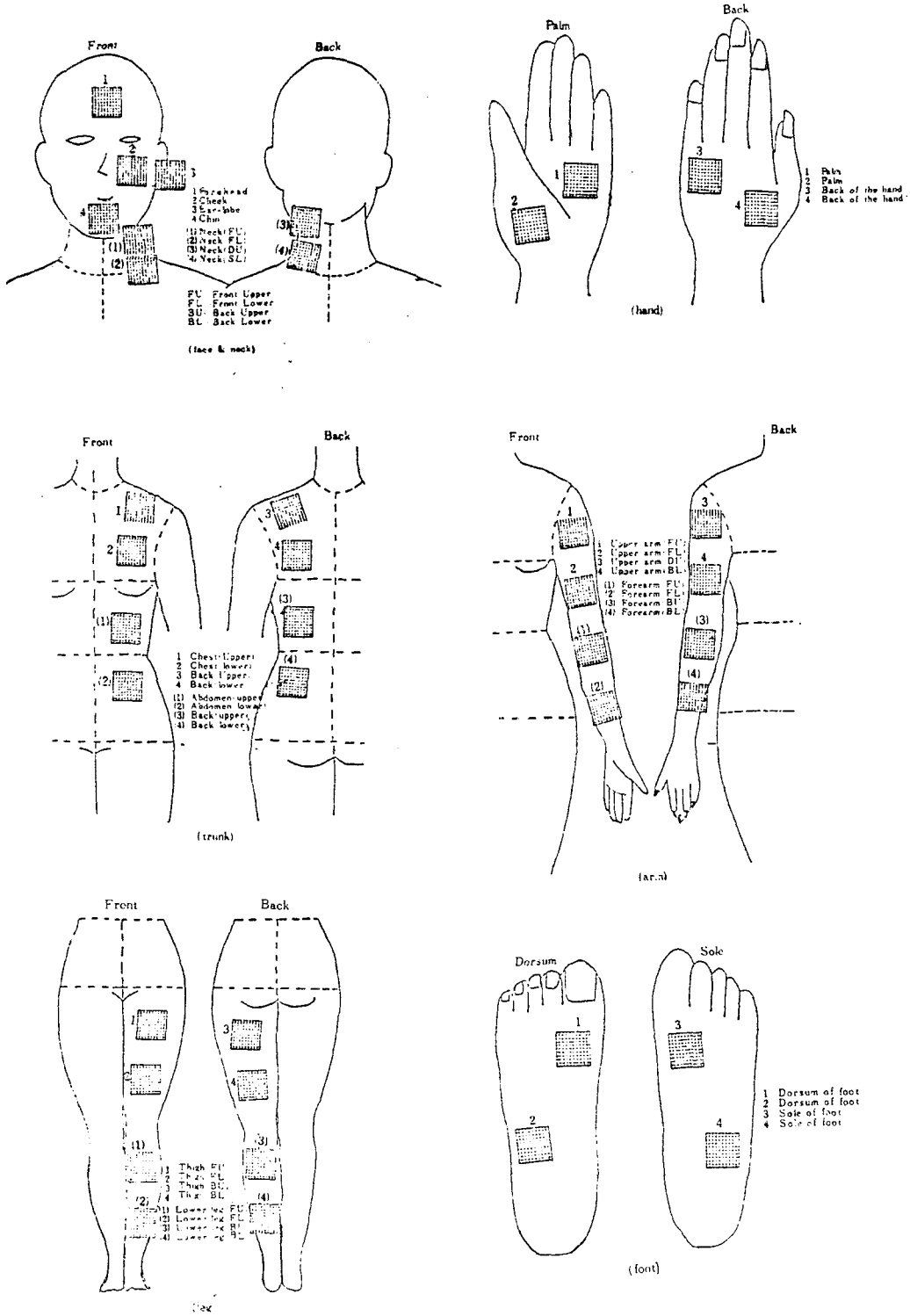


Fig. 3. Measurement sites.

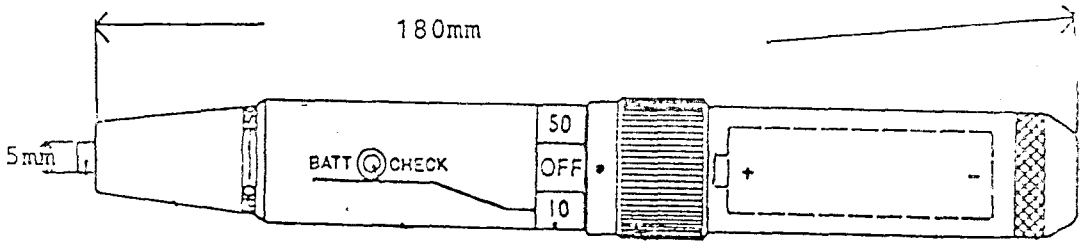


Fig. 4. SAMMI temperature apparatus for cold sensation experiment.

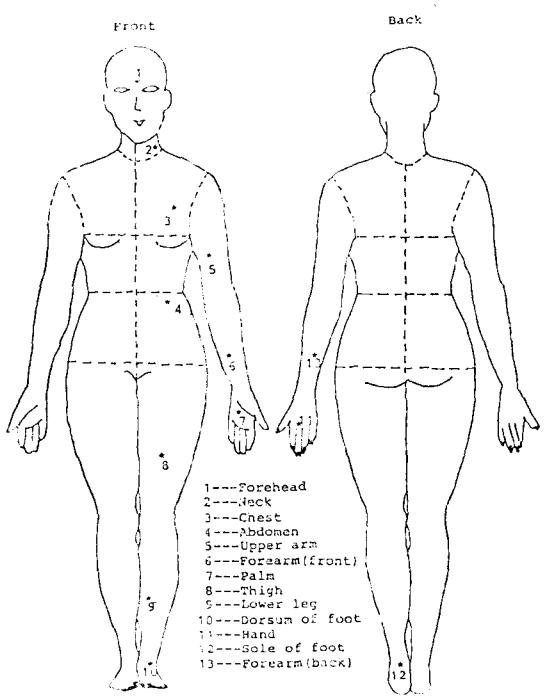


Fig. 5. Cold sensation measurement sites.

thirteen sites: forehead, neck, chest, abdomen, upperarm, lower arm(front), palm, thigh, lower leg, dorsum of foot, hand, sole of foot, lower arm(back) were used. This addition of three sites was made for the simultaneous front-back comparison of cold sensation in those three areas which may be considered somehow special.

Each subject entered a conditioning room and thirteen measurement sites were marked with a sign pen. The subjects were asked which area they feel colder between two areas with the one-pair comparative method, using the SAMMI temperature apparatus.

Thus when the 0°C stimulus with the SAMMI temperature apparatus had been applied successively on the forehead and the chest, the subject had to answer "former" if she felt cooler on the forehead, "latter" if she felt cooler on the chest, and "zero" if she couldn't feel any differences between the two areas. All possible pairs of the thirteen measurement sites were examined. The results were calculated as "former : +1", "latter- : −1", "zero : 0". For each area, these data were summed up resulting in thirteen "indices of cold sensation."

Ⅲ. RESULTS

A-Cold spots distribution :

Fig. 6 illustrates the mean number of cold spots from thirty Korean female subjects. The face shows a rather high distribution of cold spots with an average of 79 spots per 4cm² for the three areas examined(forehead, cheek, chin). In the case of the ear-lobe, however, the cold spots are 56 on the average. The neck shows more or less the same level between front and back sites, but we can find a different distribution by adding the data obtained first in the upper front and back of the neck and second, in the lower front and back of the neck. We here get respectively two distributions of 81 and 61, meaning that the lower neck is less sensitive to coldness than the upper neck.

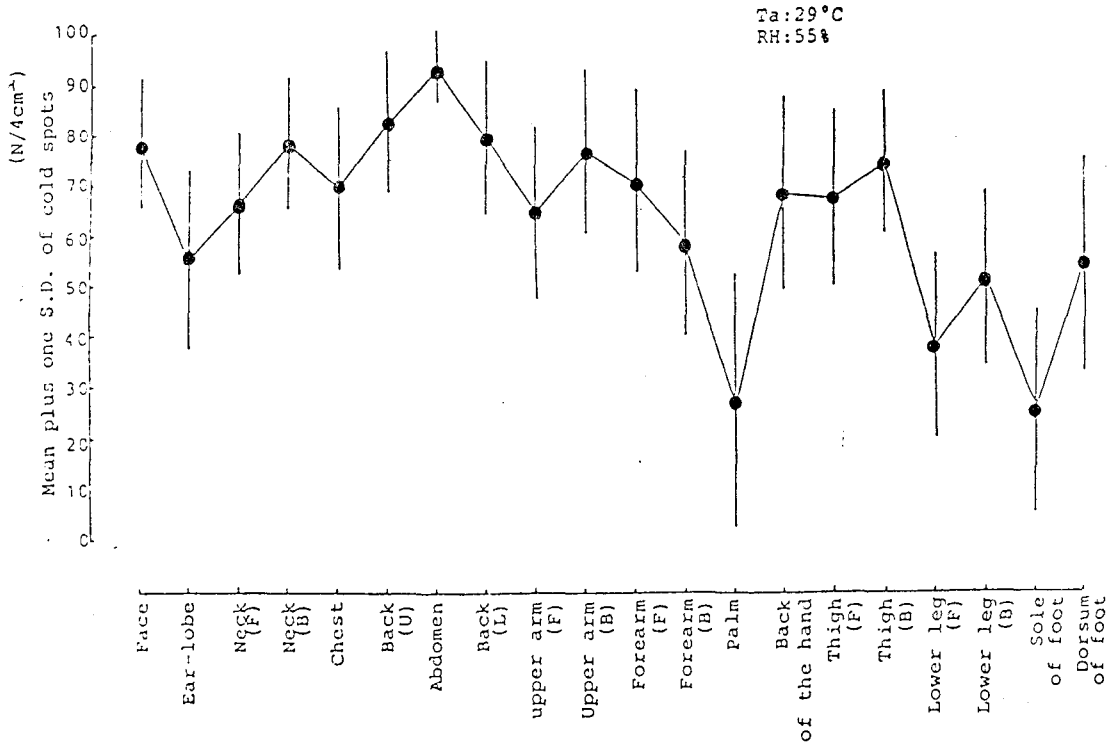


Fig. 6. Mean plus one S.D. of 30 Korean female subjects.

The trunk shows a high distribution of cold spots, the highest one being found in the abdomen(94 spots), followed by the shoulder(83 spots) and chest(70 spots).

As for the limbs, the distribution of cold spots is lower than the trunk, specially in the back of the lower leg where the distribution has a score less than half of the trunk average distribution (39 against 82). As shown in Fig. 6, the palm of the hand and the sole of the foot have quite a low cold spots distribution(respectively 28 and 26) even compared with their back side: back of the hand(69 spots), dorsum of the foot(56 spots).

The correlation coefficients of the cold spots between the 20 segments of the body surface are shown in Table 1. It was found that there was a considerable correlation between front upper arm and front forearm ($r=0.90$, $p<0.01$), and again between the palm and the sole of the foot with a level of 81%($p<0.01$). On the other hand, the coefficient between the front thigh and the front lower leg was $r=0.60$, and the coefficient between the back of the hand and the dorsum of the foot, $r=0.54$.

Principal components analysis was performed for all the 20 segments of the body, calculated from the cold spots distribution of 30 Korean female subjects. As a result, 4 principal components were obtained and interpreted(Table 2).

Fig. 7 shows, that the first principal component greatly depends on almost all the areas of the body, that is to say that it could be interpreted as fluctuating with general cold spots distribution of the whole body, showing then individual characteristics. The second could be considered as depending on the distribution of cold spots on the head and on the limbs, and that there is a inverse relation between them. It must besides be assumed that this second principal component takes into account also the difference of cold spots distribution observed previously between the trunk and the limbs. As for the third prin-

Table 1. Correlation coefficients of cold spots between 20 segments of body surface

Segments	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Face	1.00																			
2. Ear-lobe	.69	1.00																		
3. Neck(F)	.55	.45	1.00																	
4. Neck(B)	.34	.29	.79	1.00																
5. Chest	.41	.32	.62	.56	1.00															
6. Back(U)	.33	.13	.59	.63	.74	1.00														
7. Abdomen	.33	.24	.55	.33	.57	.59	1.00													
8. Back(L)	.14	−.05	.35	.38	.42	.52	.55	1.00												
9. Upper arm(F)	.21	.21	.54	.47	.57	.47	.56	.46	1.00											
10. Upper arm(B)	.27	.21	.57	.44	.51	.47	.66	.39	.86*	1.00										
11. Forearm(F)	.25	.16	.56	.42	.55	.50	.64	.46	.90*	.96*	1.00									
12. Forearm(B)	.12	.15	.37	.35	.43	.39	.50	.48	.95*	.71	.07	1.00								
13. Palm	.31	.06	.55	.45	.51	.42	.31	.28	.56	.53	.60	.52	1.00							
14. Hand	.48	.17	.59	.43	.63	.38	.43	.46	.62	.56	.61	.48	.54	1.00						
15. Thigh(F)	.20	.20	.57	.43	.63	.48	.38	.41	.70	.45	.53	.66	.51	.61	1.00					
16. Thigh(B)	.19	.13	.60	.51	.65	.48	.42	.50	.72	.55	.59	.65	.57	.58	.90*	1.00				
17. Lower leg(F)	.12	−.09	.42	.39	.54	.35	.31	.45	.50	.38	.37	.44	.50	.54	.60	.66	1.00			
18. Lower leg(B)	.28	.01	.56	.58	.64	.55	.46	.43	.56	.46	.48	.51	.68	.67	.66	.68	.76	1.00		
19. Foot sole	.32	.12	.55	.55	.40	.41	.30	.37	.66	.55	.59	.69	.81*	.52	.54	.58	.54	.60	1.00	
20. Foot dorsum	.11	.05	.48	.41	.64	.51	.60	.33	.56	.45	.50	.58	.64	.54	.62	.60	.65	.82*	.55	1.00

Table 2. Principal components analysis for cold spots distribution. (Factor loadings of 20 segments)

Segment	PC1	PC2	PC3	PC4
1. face	0.409	0.608	0.236	0.372
2. ear-lobe	0.263	0.600	0.371	0.243
3. neck(F)	0.781	0.437	−0.016	−0.029
4. neck(B)	0.710	0.483	−0.266	−0.429
5. chest	0.759	0.142	−0.063	0.239
6. upper back	0.710	0.483	−0.266	−0.429
7. abdomen	0.634	−0.004	0.273	0.132
8. lower back	0.473	−0.110	−0.089	−0.047
9. upper arm(F)	0.861	−0.253	0.332	−0.134
10. upper arm(B)	0.772	−0.123	0.455	−0.166
11. forearm(F)	0.811	−0.210	0.462	−0.163
12. forearm(B)	0.759	−0.358	0.277	−0.123
13. palm	0.724	−0.087	−0.112	0.018
14. hand	0.741	0.015	−0.007	0.222
15. thigh(F)	0.768	−0.141	−0.121	0.164
16. thigh(B)	0.813	−0.151	−0.137	0.069
17. Lower leg(F)	0.670	−0.238	−0.402	0.155
18. Lower leg(B)	0.811	−0.096	−0.390	0.169
19. sole of foot	0.761	−0.073	−0.068	−0.157
20. dorsum of foot	0.754	−0.202	−0.240	0.211
Eigen values	10.21	1.83	1.45	0.93
contribution ratios(%)	67.4	12.1	9.6	6.2

cipal component, it could be interpreted as depending on the distribution of cold spots on the upper limbs and the lower limbs.

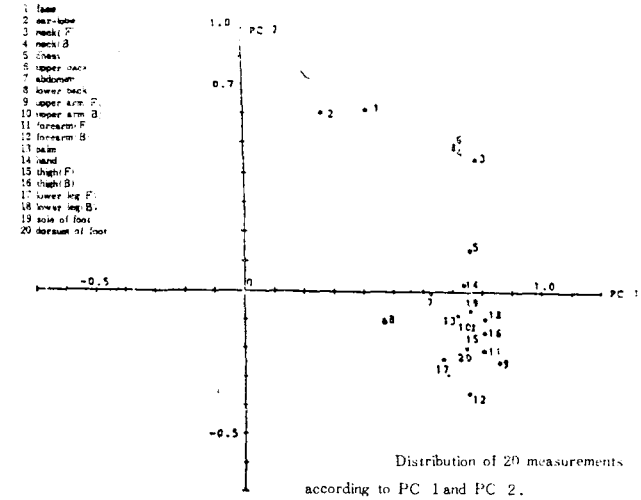
The high contribution ratio of 67.4% related to the first principal component could be interpreted as showing not so much the differences in the distribution of cold spots between different areas of the body, but as showing the tendancy of the whole body of the individuals to have a high or a low cold spots distribution.

B-The local sensations :

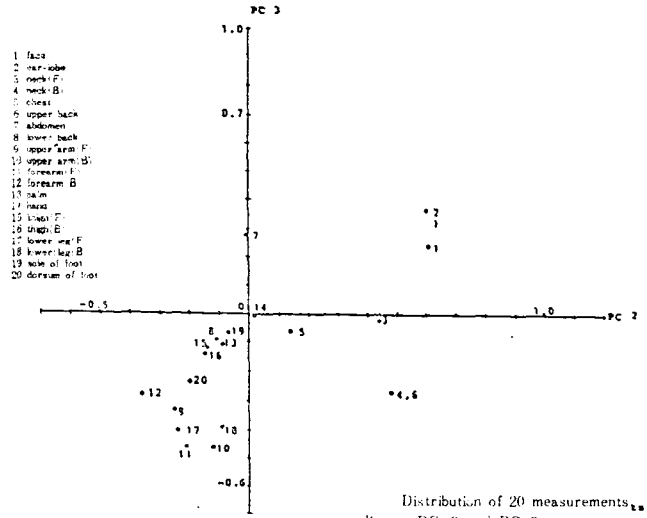
In Fig. 8, the highest sensitive areas are in order the abdomen, forehead, thigh, chest, sole of foot and palm, whereas the least sensitive area is the lower leg. It was found again that the trunk is more sensitive than the limbs.

Fig. 9 shows the correlation of cold sensations of 13 measurement sites between Korean and Japanese subjects. The correlations between the two groups were found to be linear ($r=0.93$, $p<0.01$). Although it could be suggested that the Koreans are used to endure a colder winter than Japanese dwelling in Tokyo, we could not find any distinguishable differences in cold sensations between Korean and Japanese groups.

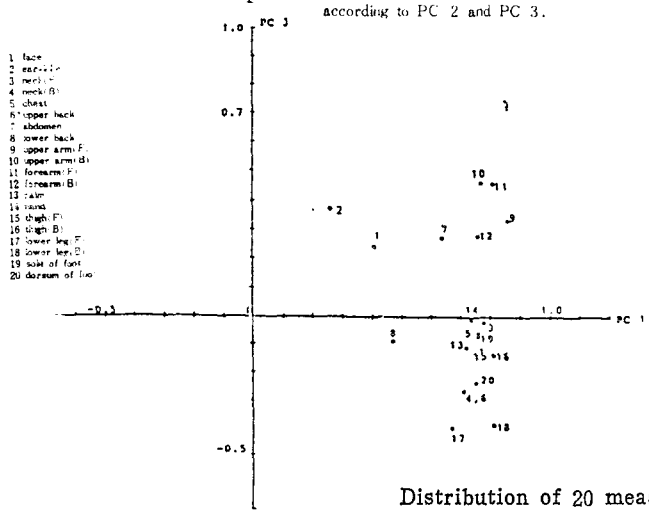
About the relation between cold spots and cold sensations, in most areas, higher cold sensations correspond to higher cold spots density. This is true specially for the forehead, neck, chest, abdomen and thigh. In the same way, coldness sensation is not much felt in the lower leg because of a low density of cold spots. However the palm and the sole of foot are exceptions: there, a rather high cold sensation corresponds to a rather low cold spots density. This difference of response in palm and sole of foot may be due to some peculiarities that these two areas



Distribution of 20 measurements according to PC 1 and PC 2.



Distribution of 20 measurements according to PC 2 and PC 3.



Distribution of 20 measurements according to PC 1 and PC 3

Fig. 7. Distribution of 20 measurements.

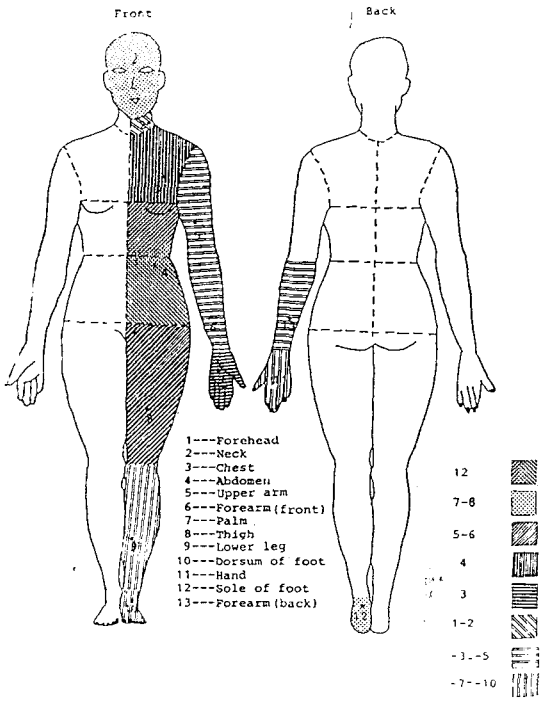


Fig. 8. Mean cold sensations of 13 measured sites.

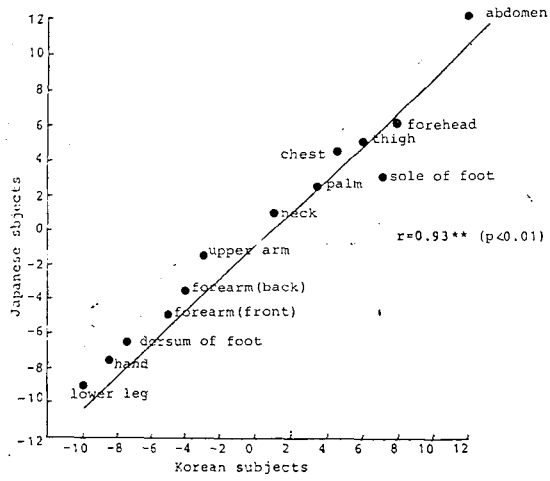


Fig. 9. Correlation of cold sensations between Korean and Japanese subjects.

happen to have (thicker skin, abundance of connective tissues, lack of subcutaneous fat, higher sweat evaporation than many other areas), all peculiarities that emerged along with the development of their function of getting more information (prehensile sensation) from the outside world, than many other areas of the body.

Ⅳ. DISCUSSION AND CONCLUSION

The various kinds of sense receptors are not evenly distributed on the skin. It is possible to map out various spots where different types of stimuli take effects in a particular skin area. There are touch spots, warm spots, cold spots, pressure spots. Certain areas of the skin are much more sensitive than others to a given type of stimulation. Here we have concentrated our attention on cold spots distribution of the skin. It has long been recognized that the face and upper body have a much greater sensitivity than the lower legs and lower arms[1~5]. Thus it may be concluded from the data presented here(Fig. 6) and the physiological data of Rein[4] and Hensel[2] that the upper body does have a greater distribution of cold spots per unit area than any other skin surface. Accordingly, the cold spots distribution on the lower leg, hand and foot is roughly half of the density found in the trunk (upper body). These uneven distribution of cold spots over the skin implies that low cold spots distributions of the body result in greater skin temperature change whereas high cold spots distribution is to be found in areas of the body where such a big temperature variation is not allowed.

It has been noticed also that cold sensations in each area of the body were well linked to cold spots density with here two exceptions concerning the palm and the sole of foot (Fig. 8).

As for these exceptions (palm and sole of foot), it must be also noticed that these areas play a special and important role in the body, in the contact with the outside world and with a greater variety of different objects and in more nu-

merous different positions. We so here state the possibility of another relation between the level of cold sensation in the palms and the soles of the feet, and their particular function (prehensile function, sense of pressure etc...), relation which would to some extent explain why the level of cold sensation is high though the density of cold spots is low.

These observations should be taken into account in evaluating the different role of each human body areas which can be predicted as specialization of the thermoregulator functions. In our experiments, we can say that the body surface is specialized by the three big functional segments of the body surface, that is, segment of the trunk, segment of the limbs, and the palms and the soles of the feet segments in the limbs.

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