Preliminary Study On Seasonal Changes of Infrared Thermal Images of Human Body

Abstract—It is of great importance to study the manifestations and the influencing factors of the time-related changes of infrared thermal images (ITI) of human body since the variable body surface temperature distribution seriously affected the application of ITI in medicine. To explore the changes of ITI of human body in different seasons, a trial was carried out to study the skin temperature distribution of vertical and horizontal direction of the human body in winner and spring. The results showed that the temperature differences between upper and lower, left and right of the body in spring were greater than those in winter. Shengsheng capsule, one of the traditional Chinese medicine health food with immunity adjustment function, could influence the skin temperature distribution. Since the seasonal changes of human body could be reflected objectively by ITI, there are bright prospects for the application of ITI in medicine.

Keywords: infrared thermal imaging, skin temperature distribution, season, vertical distribution, horizontal distribution

I. INTRODUCTION

Detecting the natural thermal radiation from the body, Infrared thermal imaging (ITI) is noninvasive, touchless, fast and free of harmful ionizing radiations. It was first introduced by Lawson in 1956 to modern medicine and discovered the association of elevated skin temperature with breast carcinoma. This technology has revolutionized the field of temperature measurement in the last 50 years and is widely employed nowadays. So far, ITI has been used to diagnose breast cancer, rheumatism, skin lesion, fever, thyroid gland disease and eye diseases [1-2]. With the spatial resolution of ITI gets higher and the computer processing ability becomes more powerful, from the viewing of skin temperature distribution, ITI is capable of detecting more sensitive variation of skin temperature and more comprehensive information of human body [3-5].

In previous studies, people had a profound understanding of regulating laws of core temperature of human body [6-7]. But by now people had little knowledge on the regularity of the variation of the skin temperature which is susceptible to various kinds of internal or external influences and has caused difficulty to quantitative analysis and seriously affected the application of ITI in medicine. So it is of great importance to study the manifestations and the influencing factors of the time-related changes of ITI of human body.

To explore the changes of ITI of human body in different seasons, a trial was carried out to study the skin temperature distribution of vertical and horizontal direction in winner and spring. Skin temperature difference between the upper and lower of the body were used to analyze the vertical distribution while differences between the left and right of the body were used to analyze the horizontal distribution. The influences of Shengsheng capsule, one of the traditional Chinese medicine (TCM) health food with immunity adjustment function, on the ITI of human body were also studied.

II. METHODS

A. The Application Principles of ITI

Relative magnitude (temperature difference between the viewing area and the reference area) is preferred to be used as the index of the image features [8-9]. The drift or calibration error of the instrument could be decreased and more importantly relationship of the different parts of body could be reflected by relative magnitude.
Infrared thermal image of human body is influenced by the time markedly and by now we had little knowledge on the regularity of the variation. When studying the influence of trial factors, randomized control trial must be applied to guarantee reliability of the results. The acquisition time of images must be uniform. (1) The range of time for the subjects to be enrolled in the trial must be controlled, best within two weeks. (2) The images in different days for comparison must be taken in a fixed time in the day, best within two hours.

At last, non-trial factors must be controlled. Besides time, the age, gender and body mass index (BMI) are important factors to influence ITI.

B. ITI Observation

The trial was carried out in Guangzhou city, China. The climate of Guangzhou is the south subtropical oceanic monsoon climate. Images were scanned before and after the trial which lasted for one hundred and eight days from November 2005 (the beginning of winter) to March 2006 (the beginning of spring).

The images were taken by Thermal Texture Maps (TTM) made by Biowyear group. The type is TSI-21, with the spatial resolution \( \leq 3 \text{mrad} \) and temperature resolution 0.05°C. The images were scanned 7:30 to 9:30 pm in the day with room temperature 20-23°C and air humidity < 75%. Before scanning, the subjects had a rest for more than thirty minutes.

As shown in Fig. 1, altogether 18 areas were observed. Area 1 is between the left and right eyebrows, area 2 and 3 are the whole palm of two hands, area 4 and 5 are the place below the eye horizontal line and above the apex of nose horizontal line, area 6 is anterior neck area below the horizontal Mandibular line, area 8 is the surface projection limited by the sternal lines and the costal notches for the second and fourth rib, while area 7 and 9 are in the middle of the left and right sides of area 8, areas 10, 11, 12 are the same position as 7, 8, 9, area 14 is in the middle of epigastria region below the appendix ensiformis while area 13 and 15 are in the middle of the left and right sides of area 14, area 16 is the surface projection of the fourth to sixth cervical vertebra, area 17 is the surface projection of fourth to sixth thoracic vertebrae, area 18 is the surface projection of the second to third lumbar vertebrae.

\[ F_1 - F_{18} \] respectively represents the mean temperature of the area 1~18, \( I_{U\Delta} \), \( I_{L\Delta} \) represents the index of vertical and horizontal distribution and it is the difference between area A and area B.

\[ I = F_A - F_B. \] (1)

\( I_{U\Delta} \) indicates the difference value in vertical direction while \( I_{L\Delta} \) indicates the difference value in horizontal direction. Tab. I lists the indexes and their corresponding area A and B.

<table>
<thead>
<tr>
<th>IUD1</th>
<th>IUD2</th>
<th>IUD3</th>
<th>IUD4</th>
<th>IUD5</th>
<th>IUD6</th>
<th>IUD7</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>8</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ILR1</th>
<th>ILR2</th>
<th>ILR3</th>
<th>ILR4</th>
<th>ILR5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>12</td>
</tr>
</tbody>
</table>

Difference between the baseline \( (I_B) \) and the end \( (I_E) \) of ITI index was \( \Delta I \),

\[ \Delta I = I_E - I_B. \] (2)

C. Subjects

Inclusion criteria: with more than two positive items in the inquiry part of the Table of Weak Constitution of TCM we set.

Exclusion criteria: in a state of general good health, yin deficiency with effulgent fire by TCM analysis or in need of medicine for treatment of certain diseases.

Altogether fifty-five male subjects (20.1±1.1 years) were included in the trial and divided into two groups (twenty-seven in trial group and twenty-eight in control group) in random double-blind fashion. The subjects were students of School for Information and Optoelectronic science and Engineering, South China Normal University. All of them provided written informed consent and were enrolled in the trial within three days.
D. Constitution Improving Methods

Before the trial, all subjects received the same health care education about the five principles of physical and mental health (moral, mental, behavior, diet and body).

The TCM health food Shengsheng capsule, with approval number Guo shi jian zi G20040476, is appropriate to people with low immunity ability. The capsule was taken by the trial group while placebo taken by the control group, 3 capsules twice a day.

E. Meteorological Data

Meteorological data from the Wushan meteorological station (Station designator 59287) in Guangzhou were provided by Guangzhou Central Meteorological Observatory. Meteorological factors including air temperature, humidity (vapor pressure) and station pressure were analyzed using the daily meteorological data.

F. Statistical Analysis

Grubbs criterion was used to reject the abnormal data in \( F_A, F_B, I_B, I_E \) and \( \Delta I \). So long as one of these five data of a certain feature was rejected, all the other four data would also be rejected. Two-sided independent t test was used to detect significant differences between the two groups regarding \( I_B, I_E \) and \( \Delta I \). The comparisons of \( I_B \) with \( I_E \) in the combined group were done by pairwise two-sided t test. Statistical significance was judged if \( P \leq 0.05 \). Data are expressed as mean ± SD.

The rejection of the abnormal data was performed with DPS7.05 statistical software while the other analyses were performed with SPSS16.0 statistical software.

III. RESULTS

At the end of the trial, altogether 42 subjects (19 in the trial group and 23 in the control group) were analyzed for their good compliance of taking more than 50% of the capsules. There were no significant differences between the groups regarding compliance rate, age and body mass index (BMI), \( P > 0.05 \).

TABLE II. COMPARISON OF THE METEOROLOGICAL DATA

<table>
<thead>
<tr>
<th></th>
<th>Temperature (℃)</th>
<th>Vapor Pressure (kPa)</th>
<th>Air Pressure (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>18.7±2.5</td>
<td>12.8±3.4</td>
<td>1015.0±3.2</td>
</tr>
<tr>
<td>Spring</td>
<td>18.8±4.4</td>
<td>17.7±4.7**</td>
<td>1010.3±4.4**</td>
</tr>
</tbody>
</table>

\( n^1 \): decreased n value was due to the abnormal data rejection. \(^2\): TG: trial group; CG: control group. Compared with the control group, *, \( P < 0.05 \); **, \( P < 0.01 \).

As shown in Tab. III, the indexes \( I_{UD6} \) and \( I_{UD7} \) were located on back of body. After the trial, \( I_E \) of trial group was greater than those of control group, but there was no significant difference between the groups. \( \Delta I \) of trial group was lower than those of the control group and there were significant differences between the groups regarding \( I_{UD6} (P \leq 0.01) \) and \( I_{UD7} (P \leq 0.05) \).

Area of \( I_{LR1} \) was located in palm of both hands. \( I_E \) was greater than \( I_B \) for trial group while \( I_E \) was lower than \( I_B \) for the control group. There were significant differences between the two groups regarding \( I_E \) and \( \Delta I (P \leq 0.01) \).

B. Comparison between the Indexes in Winter and Spring

For those indexes which showed no group difference, we combine the data of both groups to make the seasonal analysis.

As shown in Tab. IV and Fig. 2, \( I_E \) of all groups was greater than \( I_B \) except \( I_{UD2} \). There were significant differences between the seasons regarding \( I_{UD5} \), \( I_{UD5} \) (\( P \leq 0.01 \)) and \( I_{UD4} (P \leq 0.05) \).

As shown in Fig. 1 and Tab. IV, we could see that the absolute values of \( I_{UD5} \) and \( I_{UD6} \) were relatively greater than the other indexes while their upper and lower areas in vertical direction were in a smaller distances.
As shown in Tab. V and Fig. 3, all values of $I_b$ and $I_e$ were negative implying that the temperature of right is lower than left of the body. Moreover, $I_e$ was lower than $I_b$, which meant that the difference became more significant in spring. $I_{LR3}$, $I_{LR4}$ and $I_{LR5}$ showed significant seasonal differences ($P \leq 0.05$).

IV. DISCUSSION

The results showed that the temperature differences between upper and lower, left and right of the human body in spring were greater than those in winter. The seasonal changes of human body could be reflected objectively by ITI.

We are amazed to find that the results of the trial were consistent with some TCM theories. According to TCM, spring is the season of heating up in human body while winter is the season of storing energy. The liver-Qi rises from the left side of the body and liver is related to the season of spring.

ITI could also reflect the influences of TCM health food on the vertical and horizontal skin temperature distribution of human body. The anatomy, physiology and pathology basis of the influences deserves further study.

So there are bright prospects for the application of ITI in medicine.

### Table IV. INDEXES IN VERTICAL DISTRIBUTION($^\circ$C)

<table>
<thead>
<tr>
<th></th>
<th>$I_b$ (°C)</th>
<th>$I_e$ (°C)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IUD1</td>
<td>0.06±0.38</td>
<td>0.02±0.38</td>
<td>0.262</td>
</tr>
<tr>
<td>IUD2</td>
<td>0.26±0.38</td>
<td>0.28±0.31</td>
<td>0.803</td>
</tr>
<tr>
<td>IUD3</td>
<td>0.62±0.29</td>
<td>0.48±0.30**</td>
<td>0.002</td>
</tr>
<tr>
<td>IUD4</td>
<td>0.11±0.33</td>
<td>0.01±0.18*</td>
<td>0.035</td>
</tr>
<tr>
<td>IUD5</td>
<td>0.31±0.23</td>
<td>0.40±0.26**</td>
<td>0.006</td>
</tr>
</tbody>
</table>

#1: decreased n value was due to the abnormal data rejection. Comparing between two seasons, *: $P \leq 0.05$, **: $P \leq 0.01$

![Figure 2. Comparing between two seasons in vertical distribution](image)

### Table V. INDEXES IN HORIZONTAL DISTRIBUTION($^\circ$C)

<table>
<thead>
<tr>
<th></th>
<th>$I_b$ (°C)</th>
<th>$I_e$ (°C)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILR2</td>
<td>-0.10±0.29</td>
<td>-0.16±0.21</td>
<td>0.931</td>
</tr>
<tr>
<td>ILR3</td>
<td>-0.11±0.15</td>
<td>-0.16±0.17*</td>
<td>0.043</td>
</tr>
<tr>
<td>ILR4</td>
<td>-0.18±0.15</td>
<td>-0.23±0.16*</td>
<td>0.028</td>
</tr>
<tr>
<td>ILR5</td>
<td>-0.09±0.15</td>
<td>-0.15±0.18*</td>
<td>0.048</td>
</tr>
</tbody>
</table>

#1: decreased n value was due to the abnormal data rejection. Comparing between two seasons, *: $P \leq 0.05$, **: $P \leq 0.01$

![Figure 3. Comparing between two seasons in horizontal distribution](image)

As shown in Tab. V and Fig. 3, all values of $I_b$ and $I_e$ were negative implying that the temperature of right is lower than left of the body. Moreover, $I_e$ was lower than $I_b$,

### Reference

9. Li Ziru, Zhang Xusheng. “Application of infrared thermal imaging in the sleep improvement study” , IEEE iCBBE, doi. 10.1109/ICBBE.2009.5162388.