Investigation and research on thermal comfort of soldiers in military tent in summer

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Abstract. In order to investigate the thermal environment of military tents in summer and the thermal comfort of soldiers, four military class tents were set up at a university of Tianjin to do the investigation. The survey results showed that the comfort temperature range of the soldiers in the tents of summer was between 26 °C and 28 °C, the proportion reached 49%. When the temperature was higher than 32 °C, the thermal sensation of soldiers was in the unbearable range, and the proportion reached 38%.

1. Introduction
Armed police forces often need to complete the task of conflict, duty, training and so on in the field. Tents are indispensable camping equipments. Because of the simple enclosure structure, the thermal environment of the tent is very bad and the internal temperature is very high in the summer. The thermal environment in the tent directly affects the physical health and work efficiency of the soldiers, thus affects the combat effectiveness of the army. In order to ensure the troops in the field training process can maintain a good state of mind into training, task, and don't waste energy to fight against natural conditions, it is necessary to study the thermal environment of the tent, to create a comfortable and healthy working and rest environment in the summer [1].

2. Investigation content and methodology
2.1. Investigation time, site and weather conditions
2.1.1. Investigation time. The time was from September 12, 2015 to September 22, 2015, and from 8 a.m. to 6 p.m. A total of 30 times investigations were conducted. The main purpose of the investigation is to study the influence of the thermal environment inside the tent on the comfort of soldiers in the summer.
2.1.2. Investigation site. The survey was conducted on the playground of a university in Tianjin. The test site is open, has no shelter. Four tents were erected far apart. The ventilation and heat dissipation are not affected by each other.
2.1.3. Weather conditions. The temperature and humidity recorder was used to record the change of temperature and humidity outside. The experimental duration is 10 days. Fig.1 and Fig.2 show the daily average temperature and humidity fluctuation outside during the experiment period.
2.2. Respondents and tents

2.2.1. Respondents. The respondents involved in the questionnaire during the experiment are police soldiers. In every experiment process, the soldiers sit down according to the specified location. Every experiment was done by a group of 10 persons. A total of nearly 100 soldiers were investigated during the whole experiment period. Because the tasks of the armed police force are carried out mostly by men, only men were selected as the experiment respondents. The objects of the survey are dressed in camouflage short sleeves + camouflage trousers + training shoes or summer short sleeves + summer trousers + leather shoes.

2.2.2. Tents. The experiment was carried out in class tents issued by the armed police force. The class tents are divided into unl ined tents and cotton tents [2]. Two unlined tents and two cotton tents were used to do the experiment, being shown in Fig.3 and Fig.4.

3. Statistics and analysis of survey results

3.1. The tent environmental parameters and questionnaire data statistics

The statistical results of the environmental parameters and questionnaires in the tent are shown in Table 1. The survey time is from 8 a.m. to 6 p.m. In Table 1, ta is air temperature, φ is relative humidity, v is wind speed, Icl is clothing thermal resistance, and TSV is thermal sensation vote value.
Table 1. Thermal environmental parameters of tent in tent

| Parameter | Mean value | Maximum value | Minimum value | Standard deviation |
|-----------|------------|---------------|---------------|--------------------|
| ta/℃      | 27.41      | 33.40         | 22.06         | 2.74               |
| φ/%       | 61.97      | 80.00         | 41.00         | 13.94              |
| v/(m/s)   | 1.50       | 0.39          | 0.01          | 0.09               |
| Icl/clo   | 0.42       | 0.62          | 0.37          | 0.09               |
| TSV       | 0.78       | 2.63          | -0.56         | 0.84               |

From Table 1, it can be seen that the maximum temperature in tents during the experiment period is 33.40 ℃, the minimum temperature is 22.06 ℃, and the average temperature is 27.41 ℃. The temperature in tents is high. During the test period, the average daily temperature outside varied from 22.8 ℃ to 26 ℃, which was lower than the average temperature in the tent. It shows that the temperature inside the tent is higher than outside, which means the tent has no heat insulation effect, it has the function of heat accumulation instead.

3.2. The change trend of internal thermal comfort of tent in summer

The main purpose of this paper is to find out the relationship between thermal sensation and temperature in summer. The thermal sensation vote scale is shown in Table 2. In September, it is relatively hot, so the thermal comfort sensation votes of soldiers are mainly concentrated in the range of (0 ~ +3) in the survey. This paper tries to find out the scope of the comfortable temperature range and the unbearable thermal critical temperature value of the soldiers in the tent, so the change trend of internal temperature of tent and thermal comfort of the soldiers need to be analyzed. According to the experimental results, the temperature range (22.06 ℃ -33.04 ℃) in the tent is divided into 12 groups, and the interval between the groups is 1 ℃. The change rules of temperature in the comfort scale 0, +1, +2 and +3 were counted respectively. Table 2 shows the thermal sensation vote scale.

Table 2. Thermal sensation vote scale

| Cold | Cool | Slightly cool | Moderate | Slightly warm | Warm | Hot |
|------|------|---------------|----------|---------------|------|-----|
| -3   | -2   | -1            | 0        | 1             |      | 2   | 3   |

3.2.1. The variation trend of tent internal environment temperature relative to thermal sensation scale (0). For the results of TSV of temperature, a total of 98 questionnaires choose “moderate”. The thermal sensation vote statistical results are shown in Table 3. The frequency of thermal sensation (0) of the temperature in the tent is shown in Fig. 5 and Fig. 6.

From Table 3, Fig. 5 and Fig. 6, it can be seen that the comfort temperature in summer tent is mainly between 26 ℃ and 28 ℃, and the proportion of comfort ratio is 49%. Whether the temperature rises or decreases, the comfort ratio decreases. Therefore, it can be concluded that the comfort temperature range of soldiers in summer tent ranges from 26 ℃ to 28 ℃, which is higher than the comfort range of ordinary people, which is related to the physical and mental status of soldiers.

Table 3. Statistics of tent internal temperature to thermal sensation (0)

| No. | Group range (℃) | Group median value (℃) | Frequency | Percentage |
|-----|-----------------|------------------------|-----------|------------|
| 1   | 22.0-23.0       | 22.5                   | 1         | 1%         |
| 2   | 23.0-24.0       | 23.5                   | 3         | 3%         |
| 3   | 24.0-25.0       | 24.5                   | 10        | 10%        |
| 4   | 25.0-26.0       | 25.5                   | 12        | 12%        |
| 5   | 26.0-27.0       | 26.5                   | 22        | 22%        |
| 6   | 27.0-28.0       | 27.5                   | 28        | 29%        |
| 7   | 28.0-29.0       | 28.5                   | 9         | 10%        |
| 8   | 29.0-30.0       | 29.5                   | 3         | 3%         |
| 9   | 30.0-31.0       | 30.5                   | 4         | 4%         |
| 10  | 31.0-32.0       | 31.5                   | 2         | 2%         |
| 11  | 32.0-33.0       | 32.5                   | 3         | 3%         |
| 12  | 33.0-34.0       | 33.5                   | 1         | 1%         |
3.2.2. The variation trend of tent internal environment temperature relative to thermal sensation (+1). For the results of TSV of temperature, a total of 91 questionnaires choose “+1”. The thermal sensation vote statistical results are shown in Table 4. The frequency of thermal sensation (+1) of the temperature in the tent is shown in Fig. 7 and Fig. 8.

**Table 4.** Statistics of tent internal temperature to thermal sensation (+1)

| No. | Group range (℃) | Group median value (℃) | Frequency | Percentage |
|-----|-----------------|------------------------|-----------|------------|
| 1   | 22.0-23.0       | 22.5                   | 0         | 0%         |
| 2   | 23.0-24.0       | 23.5                   | 0         | 0%         |
| 3   | 24.0-25.0       | 24.5                   | 2         | 2%         |
| 4   | 25.0-26.0       | 25.5                   | 5         | 5%         |
| 5   | 26.0-27.0       | 26.5                   | 8         | 9%         |
| 6   | 27.0-28.0       | 27.5                   | 12        | 13%        |
| 7   | 28.0-29.0       | 28.5                   | 20        | 23%        |
| 8   | 29.0-30.0       | 29.5                   | 18        | 20%        |
| 9   | 30.0-31.0       | 30.5                   | 14        | 15%        |
| 10  | 31.0-32.0       | 31.5                   | 8         | 9%         |
| 11  | 32.0-33.0       | 32.5                   | 4         | 4%         |
| 12  | 33.0-34.0       | 33.5                   | 0         | 0%         |

**Figure 5.** Distribution frequency of tent internal temperature to thermal sensation (0)

**Figure 6.** Frequency fluctuation curve of tent internal temperature to thermal sensation (0)

**Figure 7.** Distribution frequency of tent internal temperature to thermal sensation (+1)

**Figure 8.** Frequency fluctuation curve of tent internal temperature to thermal sensation (+1)
From Table 4, Fig.7 and Fig.8, it can be seen that the temperature of thermal sensation (+1) is mainly between 28°C and 30°C, and the proportion is 43%. As the temperature rises, the comfort ratio rises. But when the temperature rises to a certain extent, (+1) proportion decreased gradually due to the enhanced thermal sensation of soldiers.

3.2.3. The variation trend of tent internal environment temperature relative to thermal sensation scale (+2). For the results of TSV of temperature, a total of 112 questionnaires choose “+2”. The thermal sensation vote statistical results are shown in Table 5. The frequency of thermal sensation (+2) of the temperature in the tent is shown in Fig.9 and Fig.10.

Table 5. Statistics of tent internal temperature to thermal sensation (+2)

| No. | Group range (°C) | Group median value (°C) | Frequency | Percentage |
|-----|------------------|-------------------------|-----------|------------|
| 1   | 22.0-23.0        | 22.5                    | 0         | 0%         |
| 2   | 23.0-24.0        | 23.5                    | 0         | 0%         |
| 3   | 24.0-25.0        | 24.5                    | 2         | 2%         |
| 4   | 25.0-26.0        | 25.5                    | 5         | 4%         |
| 5   | 26.0-27.0        | 26.5                    | 6         | 6%         |
| 6   | 27.0-28.0        | 27.5                    | 8         | 6%         |
| 7   | 28.0-29.0        | 28.5                    | 12        | 11%        |
| 8   | 29.0-30.0        | 29.5                    | 18        | 16%        |
| 9   | 30.0-31.0        | 30.5                    | 20        | 18%        |
| 10  | 31.0-32.0        | 31.5                    | 16        | 14%        |
| 11  | 32.0-33.0        | 32.5                    | 12        | 11%        |
| 12  | 33.0-34.0        | 33.5                    | 13        | 12%        |

From Table 5, Fig.9 and Fig.10, it can be seen that the temperature of thermal sensation (+2) is mainly between 29°C and 31°C, and the proportion is 34%. As the temperature rises, the comfort ratio decreases. Because when the temperature is higher than 32°C, most of the soldiers feel unbearable.

3.2.4. The variation trend of tent internal environment temperature relative to thermal sensation scale (+3). Although soldiers have strong heat resistance due to the long life in a difficult environment, they have a critical value of heat resistance. When the temperature is above this critical value, the soldiers will also feel hot and unbearable, so the thermal sensation vote (+3) of the soldiers should be analyzed. For the results of TSV of temperature, a total of 100 questionnaires choose “+3”. The thermal sensation vote statistical results are shown in Table 6. The frequency of thermal sensation (+3) of the temperature in the tent is shown in Fig.11 and Fig.12.

From Table 6, Fig.11 and Fig.12, it can be seen that the proportion of thermal sensation (+3) rises with the temperature. The early frequency proportion shows steady growth, when the temperature reaches
32℃, the frequency proportion rises faster. It can be seen from Table 6 that for thermal sensation (+3), the temperature higher than 32℃ captures 38% of the whole frequency proportion. It can be concluded that 32℃ is the critical value of the unbearable temperature of the soldiers.

**Table 6.** Statistics of tent internal temperature to thermal sensation (+3)

| No. | Group range (℃) | Group median value (℃) | Frequency | Percentage |
|-----|-----------------|-------------------------|-----------|------------|
| 1   | 22.0-23.0       | 22.5                    | 0         | 0%         |
| 2   | 23.0-24.0       | 23.5                    | 0         | 0%         |
| 3   | 24.0-25.0       | 24.5                    | 4         | 4%         |
| 4   | 25.0-26.0       | 25.5                    | 4         | 4%         |
| 5   | 26.0-27.0       | 26.5                    | 6         | 6%         |
| 6   | 27.0-28.0       | 27.5                    | 8         | 8%         |
| 7   | 28.0-29.0       | 28.5                    | 8         | 8%         |
| 8   | 29.0-30.0       | 29.5                    | 10        | 10%        |
| 9   | 30.0-31.0       | 30.5                    | 10        | 10%        |
| 10  | 31.0-32.0       | 31.5                    | 12        | 12%        |
| 11  | 32.0-33.0       | 32.5                    | 19        | 19%        |
| 12  | 33.0-34.0       | 33.5                    | 19        | 19%        |

![Figure 11. Distribution frequency of tent internal temperature to thermal sensation (+3)](image1)

![Figure 12. Frequency fluctuation curve of tent internal temperature to thermal sensation (+3)](image2)

4. Conclusions

Through analyzing the thermal sensation vote of the soldiers in the tent in September, it can be concluded that in summer, the comfortable temperature range of the soldiers is 26℃-28℃, the frequency is 49%. When the temperature reaches 32℃, most of the soldiers feel unbearable, the frequency is 38%.

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