An Empirical Study on the Thermal Comfort of Anti-Riot Helmet

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ABSTRACT: Aiming at the thermal comfort problems brought from anti-riot helmet in high temperature, an study of measuring the temperature of head skin based in the anti-riot helmet micro environment is designed, and thermal comfort of the volunteer is evaluated through the skin temperature and the volunteer's own subjective feeling. Results show that the skin temperature of forehead, overhead, cheek and the back of the skull increase by 0.5, 0.5, 0.3 and 0.3 degrees Celsius respectively with initial time under the conditions of (25±0.1) degrees Celsius, while the rising temperature are 2.1, 3.4, 2.1 and 2.3 degrees Celsius respectively under the conditions of (35.1±0.2) degrees Celsius. The skin temperature is reduced 0.21 degrees Celsius when a vent is designed on the helmet. The final conclusion is that thermal comfort of the head is not obviously affected by the wearing of anti-riot helmet at normal temperature, while wearing anti-riot helmet under the condition of high temperature can bring serious thermal discomfort to the wearer. What's more, designing several ventilation holes on the helmet can enhance the overall thermal comfort of the head to some extent.
KEYWORD: Thermal comfort; Skin temperature; Ventilation hole

1 INTRODUCTION

Anti-riot helmet is the most frequent of individual protective equipment of the armed police, which plays an important effect in diverse tasks and guarantees the life safety of police officers effectively (Davis, G.A. 2011). At present, in the design and manufacture of anti-riot helmet, experts and producers are more inclined to its security, while usually neglect the thermal comfort problem such as heat dissipation and perspiration (David, C.V. 2012). Practice has proved that anti-riot helmet's wearing thermal comfort problem can't be ignored in most cases. It's for this very reason the paper designs an experiment for testing the head skin temperature based on the anti-riot helmet micro environment (Firoz, A. 2010), and uses thermocouples monitoring and recording the temperature of head skin's specific points under different situations, analyzes the related influencing factors of thermal comfort while wearing anti-riot helmet.

2 EXPERIMENTAL ENVIRONMENT

To make the experimental environment coincide with actual use of anti-riot helmet in troops, the experiments are all arranged in the outdoor environment. We conduct about 20 experiments, and measures the environmental parameters before the experiment to seek the period of time that meet the requirements of the experiment (Lian, Z.W. 2008) (Steven, R. 2011). If the environment parameters change a lot in the process of experiment, we stop the experiment until next time conforming to the experimental condition appears (Taher, H.M. 2012). Finally, the following there different times meet the experimental requirements within the limits of observable error.

The First Phase: August 27, 2015. 01:30-03:50 PM. Location: An training ground in Equipment Engineering College, Engineering University of CAPF, Xi'an. The ambient temperature is (35.1±0.2) degrees Celsius. The highest wind speed is 0.2m/s (similar to calm winds). The relative humidity is 52%±2%. In this phase, we measure the temperature of head skin while wearing an anti-riot helmet without ventilation hole. The experiment scene is shown in Figure 1.

Figure 1. Experiment scene in the first phase

The Second Phase: October 11, 2015. 02:20-03:50 PM. Location: The track and field in Equipment Engineering College, Engineering University of CAPF. The ambient temperature is (34.8±0.2) degrees Celsius. The wind speed is (0.2-3.6) m/s (east wind). The relative humidity is 49%±2%. Firstly, we measure the temperature of head skin while wearing an anti-riot helmet without ventilation hole, then measure the temperature of head skin while wearing an anti-riot helmet which is designed two ventilation holes on the right and the left. The experiment scene is shown in Figure 2.

Figure 2. Experiment scene in the second phase

The Third Phase: February 28, 2016. 08:10-09:00 AM. Location: The track and field in Equipment Engineering College, Engineering University of CAPF. The ambient temperature is (25.2±0.1) degrees Celsius. The relative humidity is 58%±2% and calm winds in the whole process. In this phase, we measure the temperature of head skin while wearing an anti-riot helmet without ventilation hole.

3 EXPERIMENT PROCESS

(1) Choose the volunteer. In the experiment, the volunteer is a healthy police officer. In order to ensure the experiment against accidents, we explain the purpose, steps, announcements and the fatigue response may occur in detail.

(2) Measure the environmental parameters (air temperature, wind speed, etc) and make sure that it meet the experimental requirements.

(3) Volunteer is asked to sit in the open space, then we affix the point of thermocouple probe to his head skin by using medical thin tape.

(4) In this experiment, selection of the head skin temperature measuring points are as follows: forehead (T_1), overhead (T_2), cheek (T_3) and the back of the skull (T_4). The specific location of measuring points are shown in Figure 3.

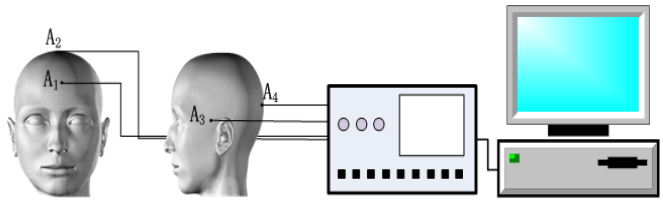


Figure 3. The arrangement of measuring points and line connection

(5) Connect the line according to Figure 3, and initialize data acquisition instrument and data recording software.

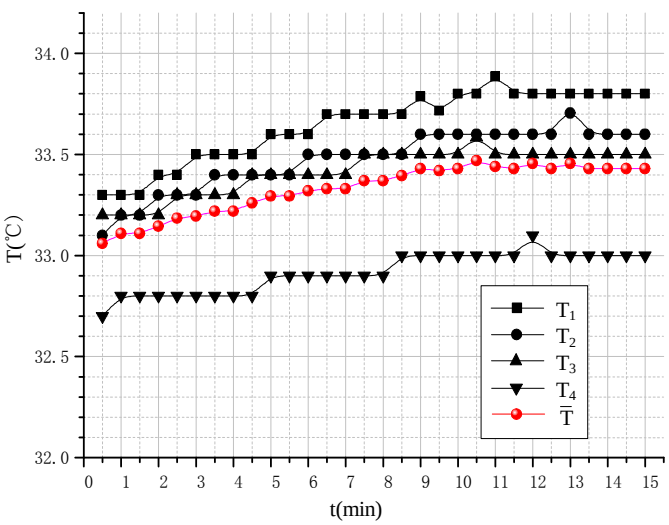
(6) Measure the temperature of head skin when the volunteer's state is stable. Set the data acquisition instrument and PC every 30 seconds to collect and record data at a time, and ask the volunteer evaluate his thermal sensation subjectively.

(7) Save the experimental data and calculate the average temperature of head skin according to the following formula:

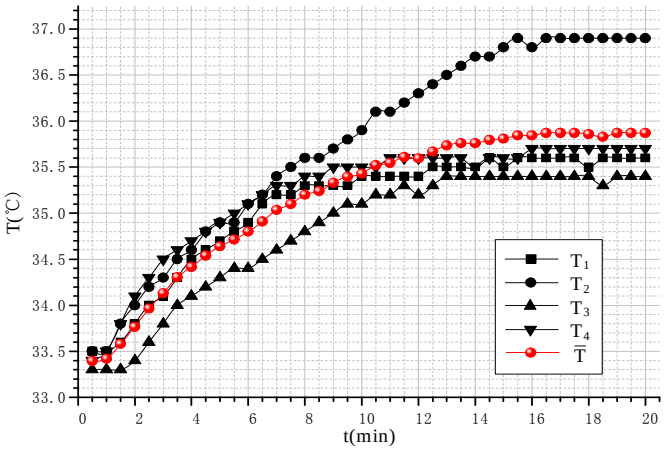
$$\overline{T} = 0.1T_1 + 0.25T_2 + 0.4T_3 + 0.25T_4$$

4 EXPERIMENTAL RESULTS AND ANALYSIS

Response curve reflecting the temperature of the four measuring points and the average temperature of head skin in the environment of (25.2±0.1) and (35.1±0.2) degrees Celsius are shown in Figure 4.



(a) 25.2±0.1 degrees Celsius

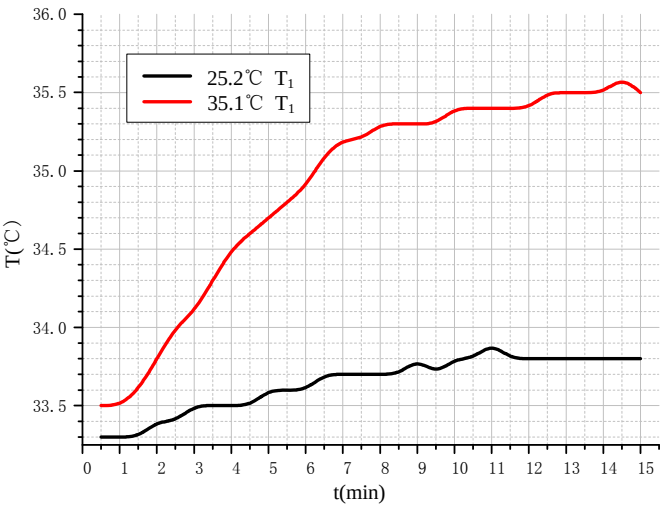


(b) 35.1±0.2 degrees Celsius

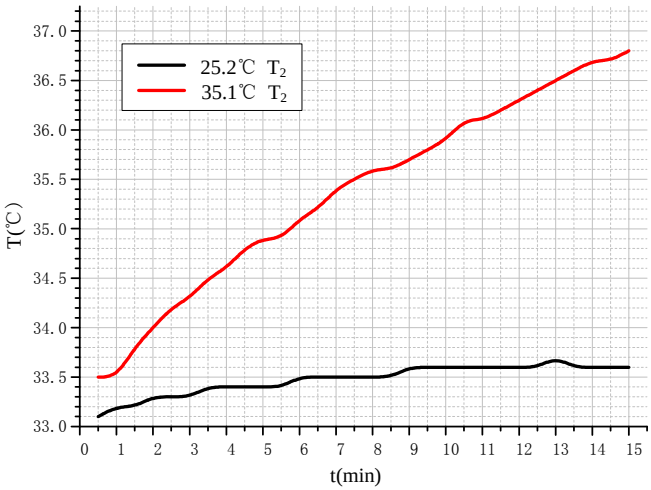
Figure 4. Response curve

Analyze of two groups of curves in Figure 4, the temperature of the four measuring points rise to some extent. In the environment of (25.2±0.1) degrees Celsius, the maximum temperature appears in the forehead, which achieves 33.8 degrees Celsius. However, the maximum steady temperature appears in the overhead in the environment of (35.1±0.2) degrees Celsius. Further analysis suggests that the overhead close contacting with the helmet has dense hair, which hinders heat dissipation of head, and hot environment will make the "blocking effect" more obvious.

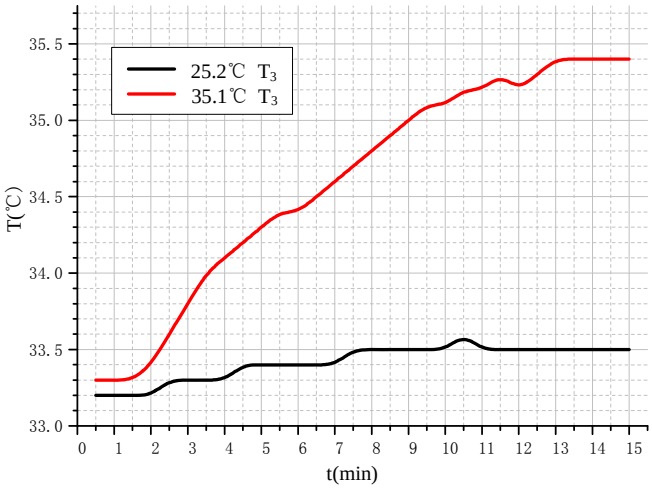
In order to further analyze the influence of ambient temperature to head while wearing anti-riot helmet, we compare the temperature of the four measuring points in (25.2±0.1) degrees Celsius with (35.1±0.2) degrees Celsius, which is showed in Figure 5.



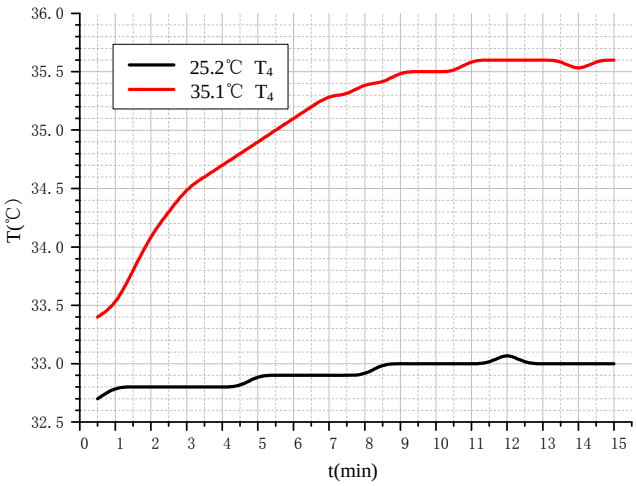
(a) Forehead



(b) Overhead



(c) Cheek



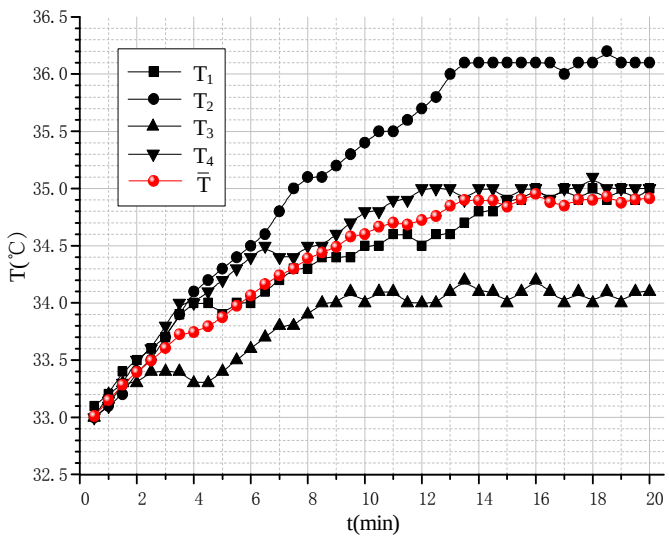
(d) The back of the skull

Figure 5. Contrast curve of environmental temperatures

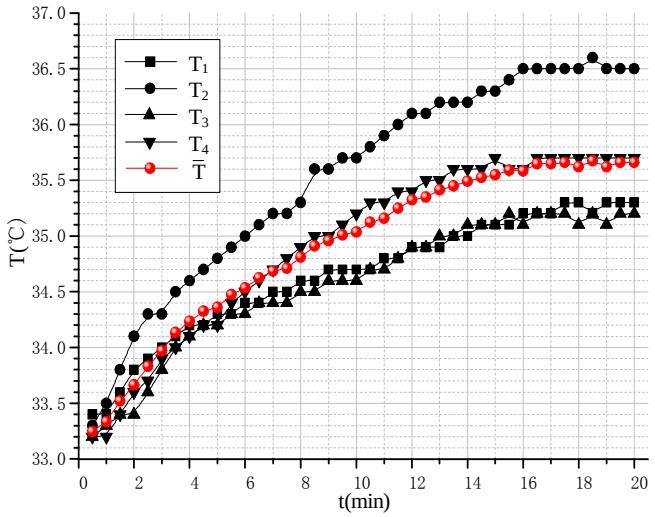
Figure 5 shows that though the temperature of the head skin increases to some extent in the two environments, the range of the rise is markedly different. In the environment of (25.2±0.1) degrees Celsius, the temperature of the forehead, overhead, cheek and the back of the skull have increased respectively by 0.5, 0.5, 0.3, and 0.3 degrees Celsius, and the volunteer feel good and has no physical and mental fa-

tigue in the process of experiment, which shows that room temperature does not much affect the thermal comfort of head. In the environment of (35.1±0.2) degrees Celsius, the temperature of the forehead, overhead, cheek and the back of the skull have increased respectively by 2.1, 3.4, 2.1, and 2.3 degrees Celsius, and the volunteer has some backlash in the same time. Therefore, we can agree that hot environment will bring serious thermal comfort problems to the wearer, and the thermal discomfort will directly affect the wearer continue to wear an anti-riot helmet.

Figure 6(a) and Figure 6(b) respective reflect the temperature changes of head skin in an anti-riot helmet without ventilation hole and in an anti-riot helmet designed two ventilation holes in the environment of (25.2±0.1) and (35.1±0.2) degrees Celsius, (0.2-3.6) m/s wind speed.



(a)



(b)

Figure 6. Response curve reflecting the effects of ventilation hole

As seen in Figure 6, the temperature of head skin in an anti-riot helmet designed two ventilation holes is different from anti-riot helmet without ventilation hole in the environment of (25.2±0.1) and (35.1±0.2) degrees Celsius, (0.2-3.6) m/s wind speed. It's mainly reflected in T_3 point and T_4 point, which are opposite the ventilation hole. The differences in this two points are 1.1 and 0.7 degrees Celsius respectively, which indicate that ventilation holes can excellently improve thermal comfort of head parts. The temperature of T_3 point and T_4 point also decrease by a smaller margin. The average temperature of head skin in an anti-riot helmet designed ventilation holes is 0.21 degrees Celsius less than anti-riot helmet without ventilation hole, which further suggest that the design of ventilation holes can promote the thermal comfort of the whole head to a certain extent.

5 CONCLUSION

This paper measures the temperature of head skin based on the anti-riot helmet micro environment, and thermal comfort of the volunteer is evaluated through the skin temperature and the volunteer's own subjective feeling. Results show that room temperature does not much affect the thermal comfort of head even wearing a helmet. However, hot environment will bring serious thermal comfort problems to the wearer, which will make the wearer resist wearing the anti-riot helmet. The wearer's thermal comfort will be greatly improved if several ventilation holes are designed on the anti-riot helmet.

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