ISSN: 1813-4890

Influence of different upper structure on heat dissipation performance of shoes

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Abstract

The heat dissipation performance of shoes is a key measure of the comfort of shoes and an important factor affecting the comfort of feet. By the choice of footwear materials and structural design, different footwear products show differences in heat dissipation, bringing different comfort to the wearer. However, the existing footwear in the evaluation of heat dissipation performance, the lack of direct detection means for heat dissipation, restricts the innovative design of footwear, and cannot meet people's needs for comfortable shoes. In this paper, the infrared thermal imaging test system was used to carry out non-contact temperature testing of foot and shoe watches, and the temperature emission rule under different upper materials and structural characteristics was quantitatively analyzed, and the influence of footwear material and structural changes on heat dissipation performance was accurately evaluated, which provided a technical reference for the formulation of footwear heat dissipation performance testing standards and the development of footwear products with better heat dissipation.

Keywords

Heat dissipation; Foot surface temperature; Thermal imaging; Temperature distribution.

1. Introduction

The heat dissipation of footwear refers to the ability of footwear products to effectively release excess heat from the foot skin to the external environment through the upper, sole, and other parts of the shoe under specific environmental conditions. Affected by the material and structure of the design of footwear products, there are significant differences in the heat dissipation of footwear products of different styles and uses, which brings difficulties to people wearing comfortable shoes. Not only that, the existing literature has found that the heat dissipation of shoes not only affects the wearing comfort of shoes but also causes the deterioration of the shoe cavity environment, which is conducive to the reproduction of microorganisms in the shoe cavity space, resulting in foot skin diseases.

In the past, the temperature test of the shoe chamber mainly relied on two kinds of test techniques. First, the detector with real-time sensing of the temperature and humidity of the shoe chamber was used to measure the temperature of the shoe chamber. Its advantage was that the humidity of the shoe chamber could be recorded while measuring the temperature, making the evaluation index more comprehensive. The disadvantage of this technology is that the tester must quickly take off the shoes during the test process to avoid the measurement error of the true temperature and humidity of the shoe cavity; The second test technology is the evaluation of the air permeability and moisture permeability of the shoe cavity. An independent test device is used to record the air permeability and moisture permeability data of the closed space of the shoe cavity in real-time, and the real wearing comfort is evaluated by

ISSN: 1813-4890

the heat dissipation index of the shoe. The test technology is an evaluation standard, with constant test conditions, but the disadvantage is that it ignores the real environment of the human body wearing, and does not consider the impact of repeated extrusion, and friction wearing footwear products on the foot surface temperature. Therefore, this study innovatively uses infrared thermal imaging non-contact foot temperature testing technology to detect the foot surface temperature distribution data of barefoot and shoe-wearing states respectively, and compares the differences between the two to judge the heat dissipation performance of footwear. Compared with previous technologies, the test results are presented in real-time, and the influence of human wearing on heat dissipation is fully considered.

2. Subjects and test equipment

2.1. Experimental subjects

In this study, 6 subjects were selected as experimental subjects, including 3 males and 3 females. The subjects were school students. After inquiry and foot morphological examination, all subjects had no history of foot type abnormality or foot injury, and no excessive secretion of foot sweat during daily wearing. The subjects underwent height and weight tests, which showed that the body composition of all subjects was normal, and the basic information was as follows:

Chart.1 Basic information of the test object

	height(cm)	weight(kg)	BMI	Shoe size(CN)
Subject 1	162.2	51.2	19.4	36
Subject 2	167.5	55.3	19.7	37
Subject 3	159.5	43.4	19.1	36
Subject 4	174.2	69	22.7	41
Subject 5	177.5	78	24.8	42
Subject 6	174.4	72	23.7	42

2.2. Test equipment

In order to accurately obtain the temperature changes of the experimental subjects' foot surface and shoe surface, without affecting the experimental subjects' wearing and walking, and reduce the test error, the MAG32mini online infrared camera produced by “Shanghai JuGe”Electronics Company was selected for temperature test in this study. The maximum resolution of the thermal camera was 640x480, and the temperature measurement accuracy was 0.1℃. The temperature measurement range is -50~150℃, and infrared images can be output in real time.

In order to limit the heat dissipation of the experimental subjects' feet, this study selected Shuhua treadmill for exercise intervention. Before the test, each experimental subject wore the designated experimental shoes to exercise on the treadmill at a speed of 1.8m/s. After the exercise, infrared thermal imaging instrument was used to collect the temperature distribution of the experimental subjects' foot surface and the experimental shoe surface respectively.

Fig 1. Test equipment infrared thermal imager and treadmill

2.3. Experimental shoes

This study mainly tested the characteristics of human foot surface temperature distribution, and further discussed the influence of different shoe topsides on foot surface temperature distribution. The experimental shoes were designed according to the daily shoe sizes worn by male and female subjects. The sample shoes were selected as sports shoes, with rubber outsole, foam EVA midsole, and suede leather top splicing with mesh fabric. Closed with shoelaces. After the experimental shoes were determined, the experimental subjects first tried them on to make them adapt to the experimental shoes.

3. Test procedure

3.1. Adapt to experimental shoes

This study selected 6 subjects to carry out sufficient temperature testing, before the formal experiments, to experiment, to make all the subjects are familiar with test content, process and the matters needing attention. The pre-experiment was conducted as follows:

According to the predetermined shoe size, the appropriate experimental sample shoes were selected, and the experimental subjects were familiar with the characteristics of the experimental sample shoes when walking at a natural speed for 3 minutes on the ground indoors. Then the subjects were asked to continue to wear the experimental shoes on the treadmill, gradually adjust the treadmill speed, and the final speed was determined at 1.8m/s. After walking on the treadmill for 3 minutes, the treadmill walking adaptation ended. When all the subjects were adapted to the experimental shoes, the subjects took off the sample shoes and waited for the formal test.

3.2. Formal experiment

After the experimental subjects were adapted to the experimental shoes and the experimental testing process respectively, the formal experiment was carried out in this study, and the experimental process was carried out according to the test of female first and then male. The first step: Before the test, the infrared thermal imager was used to collect the temperature distribution of the foot surface of the experimental subjects in the barefoot state. The second step: The experimental subjects wore the sample shoes of the corresponding size and walked on the treadmill for 5 minutes at a speed of 1.8m/s. After the walking, the infrared thermal imaging was used to test the temperature of the shoe surface. The third step: ask the subject to quickly take off the experimental shoes, and then test the temperature distribution of the foot surface. The foot surface temperature before exercise, the shoe surface temperature after exercise and the foot surface temperature after exercise were respectively recorded for each subject through the above three consecutive temperature tests. Each subject performs the above test and temperature recording separately according to the above test procedure.

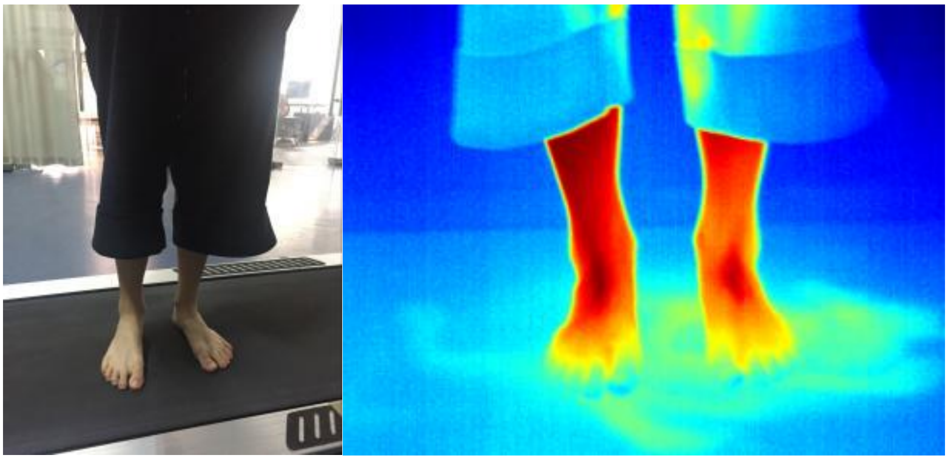

Fig 2. Foot temperature test

3.3. Data collection

The study tested the foot surface temperature and shoe surface temperature of 6 experimental subjects wearing the corresponding sample shoes respectively. The foot surface temperature was tested twice, the first time was the foot surface temperature before exercise, the second time was the foot surface temperature after exercise, and the shoe surface temperature was the shoe surface temperature after exercise. In order to accurately evaluate the distribution characteristics of foot surface temperature and further analyze the influence of vamp action on foot heat dissipation, the foot surface temperature of the experimental subjects was divided into sections, and five parts were selected respectively: toe, instep, inside foot, outside foot and heel, and the collected data were compared according to the same gender. The distribution law of foot surface temperature before and after exercise and the distribution law of shoe surface temperature after exercise were summarized.

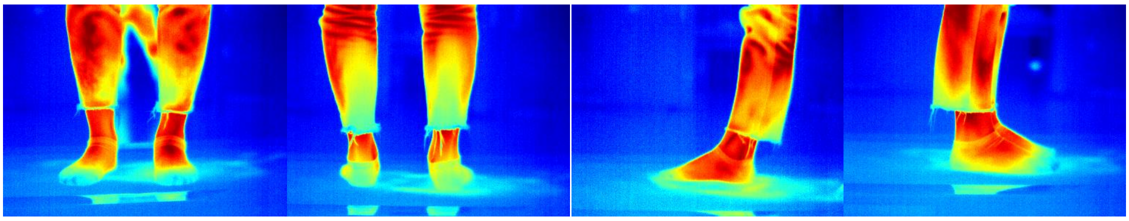

Fig 3. Foot surface temperature test zone

4. Results and discussion

4.1. Foot surface temperature distribution before exercise

The study first tested the distribution of foot surface temperature in 6 participants' barefoot state before exercise, and explored the law of foot surface temperature distribution in normal human beings. The research results showed: The foot surface temperature of 3 female subjects in the barefoot state was 34.3±1.3℃, instep temperature was 33.2±1.5℃, outer temperature was 32.6±1.7℃, heel temperature was 29.8±0.8℃, toe temperature was 26.5±2.3℃. The test results of 3 female subjects showed instep temperature > inner temperature > outer temperature > heel temperature > toe temperature. The foot surface temperature of 3 male subjects in the barefoot state, instep temperature 34.6±0.9℃, inner temperature 33.5±1.2℃, outer temperature 33.1±1.1℃, heel temperature 31.4±0.7℃, toe temperature 29.5±2.1℃, The test results of 3 male subjects showed instep temperature > inner temperature > outer temperature > heel temperature > toe temperature. However, compared with the male experiment, the temperature of the five areas of the foot surface before exercise was lower than that of the male, and the average temperature of the foot surface of the male was higher than that of the female.

Chart.2 Temperature of each area of foot surface before exercise

	Instep	Inner instep	Lateral instep	Heel	Toe
Subject 1	34.2℃	32.9℃	31.8℃	30.1℃	28.1℃
Subject 2	33.9℃	32.8℃	33.7℃	31.2℃	28.3℃
Subject 3	35.1℃	34.2℃	34.6℃	27.8℃	25.9℃
Subject 4	35.8℃	35.1℃	32.1℃	29.6℃	28.5℃
Subject 5	33.6℃	34.5℃	34.2℃	30.4℃	28.5℃
Subject 6	35.6℃	33.9℃	34.3℃	32.4℃	31.5℃

4.2. Temperature distribution of shoe surface after exercise

After testing the temperature distribution of the foot surface of 6 subjects in the barefoot state before exercise, the subjects were asked to walk on the treadmill at a speed of 1.8m/s for 3 minutes wearing the experimental shoes of the corresponding size. After the walking, the subjects stood on the ground and recorded the temperature of the five areas on the shoe surface. The test results showed: The surface temperature of 3 female subjects wearing the test shoes was 31.3±1.1℃ instep temperature, 31.8±1.3℃ inner temperature, 31.9±1.5℃ outer temperature, 27.4±1.6℃ heel temperature and 25.6±1.8℃ toe temperature. The test results of the 3 female subjects showed changes in temperature compared with that before barefoot exercise, showing as inner temperature > outer temperature > instep temperature > heel temperature > toe temperature. The surface temperature of the shoes, instep temperature of 33.6±0.7℃, inner temperature of 32.5±1.4℃, outer temperature of 32.5±1.1℃, heel temperature of 28.4±1.4℃ and toe temperature of 26.3±1.7℃ of the three male subjects changed compared with the test results before barefoot exercise. Instep temperature > outer temperature > inner temperature > heel temperature > toe temperature. Whether female subjects or male subjects, the shoe surface temperature decreased, but the overall distribution law did not change significantly, footwear products limited the dispersion of foot surface temperature, the foot and the shoe contact month is sufficient, the higher the heat transfer efficiency. The reason for the lowest toe temperature in both male and female subjects may be due to excess space at the head of the shoe.

Chart.3 Temperature distribution of shoe surface after exercise

	Instep	Inner instep	Lateral instep	Heel	Toe
Subject 1	30.6℃	31.3℃	31.9℃	26.3℃	24.6℃
Subject 2	30.3℃	30.5℃	31.1℃	27.9℃	24.7℃
Subject 3	30.3℃	32.8℃	30.8℃	26.3℃	25.1℃
Subject 4	32.4℃	31.5℃	30.3℃	26.8℃	25.3℃
Subject 5	33.1℃	31.6℃	31.4℃	27.3℃	25.5℃
Subject 6	33.1℃	31.4℃	31.7℃	27.1℃	25.7℃

4.3. Foot surface temperature distribution after exercise

After the test of shoe surface temperature after exercise, each subject quickly took off the experimental sample shoes according to the test sequence to test the changes in foot surface temperature. The test results showed: The foot surface temperature of 3 female subjects after exercise in barefoot state was 34.9±1.7℃, inner temperature was 34.2±0.9℃, outer temperature was 33.6±2.1℃, heel temperature was 30.8±0.6℃ and toe temperature was 27.5±1.3℃. The test results of 3 female subjects showed instep temperature > inner temperature > outer temperature > heel temperature > toe temperature. The foot surface temperature of 3 male subjects in the barefoot state was 35.1±0.7℃, the inner temperature was 34.5±2.2℃, the outer temperature was 34.4±1.4℃, the heel temperature was 32.3±0.9℃, and the toe temperature was 30.5±1.2℃. The test results of 3 male subjects showed instep temperature > inner temperature > outer temperature > heel temperature > toe temperature. Both male subjects and female subjects wore experimental shoes on the treadmill after exercise, the foot surface temperature increased, the foot emits more heat, but the comparison with the shoe surface temperature is low, further indicating that footwear products limit the foot surface temperature dissipation, footwear product design has a direct impact on the foot surface heat dissipation.

Chart.4 Temperature of each area of foot surface after exercise

	Instep	Inner instep	Lateral instep	Heel	Toe
Subject 1	33.6℃	34.5℃	32.8℃	31.4℃	28.6℃
Subject 2	33.7℃	35.2℃	32.9℃	31.2℃	28.3℃
Subject 3	33.3℃	33.1℃	33.9℃	31.2℃	28.5℃
Subject 4	34.3℃	35.1℃	33.7℃	33.3℃	32.2℃
Subject 5	34.2℃	35.1℃	35.2℃	33.6℃	32.5℃
Subject 6	36.2℃	34.6℃	34.9℃	33.7℃	32.4℃

5. Conclusion

The infrared thermal imaging test of foot surface temperature is of great significance for understanding the distribution of human foot temperature and designing footwear products with better heat dissipation. In this study, infrared thermal imaging technology was used to test the temperature distribution of foot surface before human movement, shoe surface temperature distribution after movement and foot surface temperature after movement. The results showed that the temperature distribution of foot surface before movement presented differences in different parts, among which the temperature of the back of the foot was the highest and the temperature of the toe was the lowest. The temperature test of the shoe surface after exercise shows that: due to the role of the shoe, the dispersion of foot temperature is limited, and the foot also presents temperature differences in different areas on the shoe surface. Limited by the material and structure of the shoe surface, the temperature of the shoe is higher on the instep, and the temperature of the shoe head is the lowest. The closer the contact between the foot and the shoe interior, the higher the heat dissipation efficiency; After taking off the test shoes quickly after exercise, the foot surface temperature increased significantly compared with the barefoot state before exercise, indicating that the foot surface temperature dissipation increased after exercise, and the foot surface temperature distribution after exercise was lower than the shoe surface temperature, which further explained the restricting effect of shoes on foot temperature dissipation. The research results are of great significance for carrying out the human foot temperature test and understanding the temperature distribution law of the human foot surface, and have reference value for developing more comfortable and better heat dissipation footwear products.

ISSN: 1813-4890

Acknowledgements

This paper is the phased results of the research project of 2021 University Domestic Visiting Engineers "School-Enterprise Cooperation Project" (FG2021021) Development and promotion of foot and ankle health shoes.

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