The Influence of High Temperature Weather on Human Body Temperature Measurement by Infrared Thermal Imaging Thermometer

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Abstract. Infrared thermography thermometer is a non-contact temperature measuring equipment, which is widely used in the stage of large-scale epidemic of the covid-19 pandemic. It is used for rapid screening of human body temperature in crowded places at the entrance and exit of airports, docks, shopping malls, stations and schools. But when the outdoor temperature approaches or exceeds the body temperature in summer, can this method of measuring body surface temperature by infrared thermal imager be used as a standard for screening fever? Under the condition of high temperature in summer, the field experiment of measuring body temperature by infrared thermal imager is carried out, the experimental results are analyzed. We recommend the use of relative temperature difference for screening patients with fever.

1. Introduction
It has been two years since the emergence of COVID-19, and the number of infected people around the world is still increasing, and the number of infected people has reached hundreds of millions of people [1]. The occurrence of COVID-19 has brought incalculable loss to mankind and threatened the safety of human life, so that governments, organizations and individuals all over the world have to attach importance to this serious problem. [2]. According to the observation of infected people, it is found that people infected with COVID-19 will cause flu-like symptoms, such as fever, sore throat, and dry cough. Most patients infected with COVID-19 will have fever [3]. Therefore, body temperature monitoring has become one of the important means of epidemic prevention, control and detection [4]. In order to prevent the spread of the epidemic, it is particularly important to monitor the body temperature of infected people and realize early detection, early isolation, early treatment and early rehabilitation. It is a very important measure to screen patients suspected of being infected with covid-19 through temperature monitoring in the access of many people to prevent the spread of the epidemic. At present, the thermometer and temperature measuring gun used in close range have slow measurement speed and the risk of cross infection [5], which are not suitable for use in areas with large passenger flow, such as high-speed railway stations, subway stations, school gates, airports, etc. In order to adapt to human body temperature measurement in crowded places, infrared thermal imaging temperature measurement is widely used in the stage of large-scale epidemic of infectious
diseases. It is a non-contact temperature measurement equipment, which has the advantages of convenience, high efficiency, intuitive and no cross pollution risk [6, 7, 8]. The use of infrared thermal imaging thermometer to detect fever is an effective way to control infectious diseases such as SARS, H1N1. It plays a very important role in the suppression of infectious diseases. Besides, due to the relative accurate temperature measurement of the infrared thermal imaging thermometer, infrared thermal imaging is being used to monitor each channel port to screen COVID-19 carries all over the world [9, 10].

The infrared thermal imager measures the temperature according to the gray level of the object, but the brightness of infrared imaging was related to the emissivity of the object surface, the distance and transmittance of infrared light transmission path, the background radiation of the object, the temperature and humidity of the environment and so on. In order not to miss the detection and misreport the patients, the temperature measurement of the thermal imager should be accurate and reduce the deviation of interference factors from the temperature measurement, so that the infrared thermal imager deployed all over the world can play a correct role.

2. Principles and Factors Affecting Temperature Measurement

2.1. Principle
In the material world, objects with a certain temperature are constantly emitting electromagnetic radiation. The infrared thermal imager images on the detector panel by receiving the electromagnetic radiation intensity in the infrared band, and determines the temperature of each part of the object according to the brightness level of the image. The radiation intensity received by the detector includes the radiation emitted by the target object itself and the infrared radiation of the surrounding environment, so the total radiation power received by the infrared detector $L_\lambda$ should be as follows:

$$L_\lambda = \varepsilon_\lambda L_{\lambda,0}(T_0) + \rho_\lambda L_{\lambda,0}(T_u) = \varepsilon_\lambda L_{\lambda,0}(T_0) + (1 - \alpha_\lambda) L_{\lambda,0}(T_u)$$

The first term is the infrared radiant power emitted from the surface of the target object, and the second term is the infrared radiant power of the surrounding environment of the test target. $T_0$ represents the surface temperature of the test target object (unit: degrees Celsius); $T_u$ is the ambient temperature around the target object (unit: degrees Celsius); $\varepsilon_\lambda$, $\rho_\lambda$, $\alpha_\lambda$ respectively represent the emissivity, reflectivity and absorptivity of the target surface.

The calculation formula for the actual surface temperature of the object is given [11]:

$$T_0 = \left\{\gamma_1 \left[\frac{1}{2}T_a^n - (1 - \varepsilon)T_u^n - (\frac{1}{2} - 1)T_u^n\right]\right\}^{1/n}$$

According to formula (2), we know that the ambient temperature will affect the temperature measurement of the infrared camera under certain conditions. When using different band imagers, the value of $n$ is different. Therefore, as long as the emissivity and atmospheric transmission conditions of the target object are given, the target surface temperature can be accurately calculated by formula (2).

2.2. Factors Affecting Temperature Measurement

2.2.1. The Influence of Background Environment on the Accuracy of Temperature Measurement. All objects above absolute zero in nature are emitting infrared radiation to the surroundings. Therefore, the environment where the temperature measuring probe is located will also affect the accuracy of temperature measurement. This influence can be summarized into two parts: background factors and environmental factors. The background factor is mainly the difference between the target and the background temperature to be measured by the temperature measurement system. If the difference is large, the temperature measurement will be more accurate. The environmental factors mainly include direct solar radiation, ground radiation and wind speed in nature.
2.2.2. The Influence of Distance on the Accuracy of Infrared Temperature Measurement. The object emits infrared radiation in all directions, and the radiation energy of the target object received on the detection surface is inversely proportional to the square of the distance, so the distance has a great influence on the temperature measurement value. In addition, there are various gas molecules in the atmosphere, and the absorption wavelength is in the infrared band, which also weakens the infrared radiation energy, thus affecting the temperature measurement. Obviously, if the temperature measurement system is farther from the target object, the infrared radiation will travel farther in the atmosphere, the attenuation will be greater, and the impact on the accuracy of temperature measurement will be greater. At the same time, as the distance increases, the relative field of view area of the same object decreases, which reduces the signal-to-noise ratio of the output signal current and affects the accuracy of temperature measurement. After looking up some data, it is known that the longer the temperature measurement distance, the greater the temperature error.

2.3. Reduce Temperature Measurement Error

From the above analysis, it can be concluded that the factors affecting the accuracy of temperature measurement are mainly concentrated in four aspects: (1) the influence of the surface emissivity of the object; (2) the influence of the atmosphere on the attenuation of infrared radiation; (3) the influence of ambient temperature and humidity on the accuracy of temperature measurement; (4) The influence of temperature measurement distance on the accuracy of temperature measurement. The following four aspects will discuss measures to reduce temperature measurement errors. The measures to reduce the temperature measurement error are discussed in the following four aspects. This experiment is to study the influence of outdoor temperature change in high temperature weather on the temperature measurement of infrared thermal imaging measuring instrument at the entrance. In order to make the experimental effect obvious, the measurement is carried out in high temperature weather (outdoor temperature 39.5 ℃) in the morning, middle and evening. Through comparison, the influence of outdoor ambient temperature change on temperature measurement accuracy can be more clearly displayed. In order to improve the accuracy of temperature measurement, various influencing factors must be considered during temperature measurement, and the basic countermeasures are as follows:

- Avoid placing the measuring instrument in a place with high temperature to avoid the influence of the surrounding environment on the measurement accuracy.
- Avoid irradiating the infrared thermal imaging camera to a place with strong light. Brighter light will increase the measurement error.
- Set up a shielding device near the object to be tested to reduce interference from the surrounding environment.
- The face of the person being measured needs to face the camera to prevent incorrect temperature collected by the infrared camera.

3. Experiment

3.1. Experimental Method

In this experiment, the test locations were selected in two places, one is the laboratory building without air conditioning, and the other is the entrance of the south building of Wanfu Center Building 1 with air conditioning. An infrared thermal imaging thermometer is installed at the door of the experimental site, which can automatically measure the temperature of the entering personnel and display the temperature measurement value in time. People who enter the building are walking, riding electric cars, driving and so on. People entering the laboratory building also use different means of transportation to come to the measurement site at different time periods. The two measurement locations and the measurement environment make the data convincing.

The experimental time is September 4, 2021, and the outdoor temperature is 39.5 ℃. The experimental test records the human body temperature data in three time periods: 8:00 ~ 9:00 am, 12:00 ~ 1:00 pm and 6:00 ~ 7:00 pm of the day, and the indoor temperature and outdoor temperature
of each time period were recorded. At the same time, the body temperature of the people who came in and left after staying in the mall for a period of time was recorded. During an epidemic, masks can inhibit the spread of the epidemic, and everyone entering will wear masks. During temperature measurement, everyone entering the door will be asked to remove all objects blocking the face and forehead, and immediately stand at the fixed position of temperature measurement and aim at the infrared thermal imager for temperature acquisition, so that the collected temperature data will be more stable and accurate.

3.2. No Air Conditioner

Figure 1 shows the human body temperature measured without air conditioner in the room, (a) the body temperature measured from 8 am to 9 am, the indoor temperature is 31 ℃ and the outdoor temperature is 31.3 ℃; (b) The temperature was measured from 12:00 to 1:00 at noon. The indoor temperature was 33 ℃ and the outdoor temperature was 39.5 ℃;

![Figure 1](image_url)

**Figure 1.** Human body temperature measured at different time periods without indoor air conditioning.

According to figure 1, the maximum, minimum and average temperatures in different periods of a day are counted. The results are shown in table 1.
Table 1. The results of body temperature analysis without air conditioner.

| Measurement time | Average/ ℃ | Minimum/℃ | Maximum/℃ |
|------------------|------------|-----------|------------|
| Morning          | 36.2       | 35.8      | 36.7       |
| Noon             | 37.3       | 36.5      | 38.8       |
| Afternoon        | 36.4       | 35.8      | 37.0       |

The experimental environment is to place a temperature measuring instrument at the entrance of a building without air conditioner to measure the body temperature of a person. According to the data, we can clearly see the trend of human body temperature measurement during the day. The surroundings temperature in the morning and afternoon is low, and the measured human body temperature is lower than that in the noon. When measuring human body temperature without air conditioning, there will be an obvious gap between low temperature and high temperature. The body temperature measured at noon under high temperature will have a fever. The table 1 can be used to analyze that the average body temperature of the day differs by about 1 ℃. Most of the body temperature measured at the hottest time of noon exceeded 37.5 ℃. According to the results measured by the instrument, we cannot accurately judge whether this person has a real fever or whether the person's body temperature has risen due to the influence of the high temperature environment, so that those who have been tested to have a fever can rest indoors About five minutes, we found that the person's body temperature had dropped. In this case, the body temperature measured by infrared thermal imaging in a high temperature environment cannot determine the correct result. It is impossible to quickly and accurately screen out whether the group is really feverish in a place with a large flow of people. If the relative temperature difference ($\Delta T$) is used to judge, such as $\Delta T > 1.0$ ℃, the misjudgment rate drops dramatically.

3.3. With Air Conditioner

Figure 2 shows the results of the experiment at the entrance of an air-condition room. Figure 2 (a) human body temperature is measured from 9:00 to 10:00 in the morning. The indoor temperature is 27 ℃ and the outdoor temperature is 31.3 ℃; Figure 2 (b) body temperature from 11 a.m. to 1 a.m., indoor temperature is 27 ℃, outdoor temperature 39 ℃; Figure 2 (c) body temperature from 6:00 p.m. to 7:00 p.m., indoor temperature 27 ℃, outdoor temperature 32 ℃.
According to figure 2, the maximum, minimum and average temperatures in different time periods under air conditioning conditions in a day are counted. The results are shown in table 2.

Table 2. The results of body temperature analysis with air conditioner.

| Measurement | Average value/℃ | Minimum/℃ | Maximum /℃ |
|-------------|-----------------|-----------|-------------|
| Morning     | 36.12           | 36.0      | 36.8        |
| Noon        | 36.5            | 36.0      | 37.4        |
| Afternoon   | 36.24           | 35.9      | 36.8        |

The temperature measuring instrument is placed at the entrance of the building with air conditioner to measure people's head temperature. The indoor constant temperature is about 29 ℃. According to the chart, we can see that the outdoor temperature is different in a day, which is the temperature change when people first enter the room. When the measuring environment of the infrared measuring instrument remains unchanged, the temperature change of a person in a day is measured. When the temperature is high at noon, the measured body temperature will be significantly higher than that measured in the morning and afternoon. Similarly, the relative temperature difference ($\Delta T$) is used to judge whether a fever is appropriate.

3.4. Discussion and Analysis of Experimental Results

By analyzing the two experimental conditions: infrared thermal imaging temperature measuring instrument, one is in the constant temperature air-conditioned environment, the other is in the environment without air-conditioning. Through the analysis of the two measured results, it can be seen that when the outdoor temperature exceeds a certain limit, the temperature measurement of the instrument to the human body has changed greatly. It can be seen that with the increase of outdoor environment, the temperature measured by infrared thermal imaging instrument is gradually rising. At noon, most of the measured body temperature will have a fever, which makes it difficult to distinguish the data measured by the infrared measuring instrument. Whether the data exceeding 37.5 ℃ is due to the influence of the environment or the human itself. Although those who have high temperature rest indoors for a period of time and their body temperature drops during measurement, it will still cause some trouble in some stations and airports, and even panic around people. The results of two experimental measurements form a comparison, which proves that when the outdoor ambient temperature is too high, the results of infrared thermal imaging on human body temperature measurement are not suitable for measuring human body temperature at the entrance of the building.
We believe that it is more appropriate to use the relative temperature difference method for human screening of fever.

4. Conclusions
Using the infrared thermograph thermometer to measure the temperature of the human forehead is considered to be the most economical and fastest method to screen the fever in COVID-19 epidemic. In order to minimize misjudgment rate, it must be in a standard environment and be able to use the correct measurement method. When the temperature hot, the body temperature measured by infrared thermal imaging cannot be regarded as an accurate method for measuring body core temperature to a large extent. When the outdoor ambient temperature is higher than 37.5°C, the ambient temperature has already affected the human body skin temperature. We recommend the use of relative temperature difference for screening patients with fever.

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