The Method to Measure the Body’s Local Temperature: What Materials Should Be Used to Fix The iButton on the Skin

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Abstract. iButton, a wireless temperature system, is currently the most popular and inexpensive miniature temperature datalogger commercially available [1]. However, there is no any previous study to evaluate the effect of iButtons’ fixed material on the accuracy of thermal measure. This article carried an experiment to test the impacts of four different fixed materials on iButtons: transparent adhesive tape, Aluminum foil paper, black and white bandages. The result shows that transparent adhesive tape can reduce the influence of wind speed while Aluminum foil paper can prevent solar radiation effectively. As for bandages, the temperature of the black bandages group is higher than the white bandages group which indicated that black material can absorb more solar radiation. However, the function of bandages to reduce the impact of ambient heat is not obvious in this test, though it is existed.

1. Introduction
Outdoor thermal comfort is a factor of vital importance in environmental comfort evaluation. Over the last 2 decades, many scholars have been dedicated to investigating outdoor thermal comfort. And in these studies, besides the micrometeorological factors, people’s skin temperature has gradually become an important part in outdoor thermal comfort researches. As the barrier of human body, skin plays an important role in heat transfer between the human body and the thermal environment. And in order to quantify the thermal transmission between human body and environment, it’s essential to measure the human skin temperature. The temperature distribution over the body’s surface provides useful information for many research and clinical applications [2].

For the aim of skin temperature measuring, various kinds of equipment have been used by other researchers. For example, Hui Zhang et al. (2010) used an ingestible radio-thermometer pill to measure the body local temperature [3]. Andrei Claudiu Cosma and Rahul Simha [4] obtained the data by their sensor fusion which was consisted by a depth sensor and color camera combination (Kinect 2), a thermographic camera (Flir Lepton) and a point IR sensor (MLX90614). R. Califano et al. (2017) adopted the temperature measurement system which consisted of fourteen 100 Ohm Platinum RTDs (resistance temperature detectors), four RTD analog inputs, each with four channels (Type 9217, National Instruments Italy S.r.l) [5].

In this article, iButtons which showing to be valid and reliable devices [6] are being introduced for skin temperature measure. In fact, this system has already been used in many studies and participants could wear 4–8 [7] or even 26 or more iButtons attached to the skin [8] during the experiment. For example, Cong Song et al. (2010) attached the iButton (DS1922L Thermochron, Maxim, USA) to skin-
measuring sites to measure subjects’ local skin temperature and stitched the iButton (DS1923 Hygrochron, Maxim, USA) on the surface of bed covers to measure the bed climate [9]. The accuracy and precision of the data recorded by iButtons has been proved by many researchers such as E. Rubinstein et al., 1990[10], Angilletta and Krochmal, 2003[11], Dechmann et al., 2004[12] and Isaac et al., 2008[13]. Though iButton can record precise temperature data, its accuracy may be potentially affected by the materials which used to fix the devices on the skin. However, there is no any study to evaluate the accuracy of iButton when they are attached on the skin by different materials. The objective of this study is trying to compare the material’s effect on iButtons when different materials are applied to fix the devices and we hope to find out the best material for the iButtons to get the precise data.

2. Materials and Methods

Our study evaluated whether different materials which are used for fixation can affect the accuracy of iButtons and to what extent the iButtons can be affected. The fixation materials we use in this study are transparent adhesive tape, Aluminum foil paper, black and white bandages respectively. As for the reason why, we choose the four types of material above is that in order to obtain accurate skin temperature data during outdoor experiments we must eliminate the influence of the external environment factors such as wind, solar radiation and ambient heat (air temperature). And the transparent adhesive tape can reduce the impact of wind effectively. Accordingly, the Aluminum foil paper can prevent the solar radiation while the bandage can reduce the influence of air temperature.

Before we start the test, we have designed several experimental control groups for comparison, which is shown in table 1.

| Point Number | Materials      | Wind Prevention Ability | Radiation Absorption Ability | Thermal Insulation Ability |
|---------------|----------------|--------------------------|-------------------------------|---------------------------|
| 1             | black bandage (2 layers) | weak                     | strong                        | weak                       |
| 2             | black bandage (6 layers) | weak                     | strong                        | normal                    |
| 3             | black bandage (6 layers) | weak                     | strong                        | strong                    |
| 4             | white bandage (2 layers) | weak                     | normal                        | weak                       |
| 5             | white bandage (4 layers) | weak                     | normal                        | normal                    |
| 6             | white bandage (6 layers) | weak                     | strong                        | strong                    |
| 7             | white bandage (2 layers) + Aluminum foil paper | strong | weak | weak |
| 8             | white bandage (6 layers) + Aluminum foil paper | strong | weak | normal |
| 9             | white bandage (6 layers) + Aluminum foil paper | strong | weak | normal |
| 10            | white bandage (6 layers) + Aluminum foil paper | strong | weak | strong |
| 11            | white bandage (2 layers) + transparent adhesive tape | strong | normal | weak |
| 12            | white bandage (6 layers) + transparent adhesive tape | strong | normal | normal |
| 13            | white bandage (6 layers) + transparent adhesive tape | strong | normal | strong |
| 14            | Medical rubber (2 layers) | normal            | normal                        | normal                    |

Table 1. Material and Method to fix the devices AND Their Function Abilities.

The experiments were performed on a five-story room’s windowsill which is made of thick granite. And during the experiments, we made sure that there is an ideal testing condition of good quality of ventilation and sunshine. Figure 1 shows different materials and methods we used to fix the instruments.

![Figure 1. Various kinds of materials to fix iButtons.](image-url)
We collected the data on February 17th 2019 in Harbin (126.63E, 45.75N). The weather was sunny, and the air temperature ranges was between -2°C and 10°C. In order to start the devices at 0 o’clock, we fixed the iButton at February 16th night. Also, in order to make sure that the windowsill surface would be in a stable condition, we opened the windows in advance and kept it opening in the whole day during the experiment.

3. Result and Discussion

Figure 2 shows the changes of temperature in nearly a whole day. Although all of the curves have the similar trend, their values are significantly different from each other. For instance, line-1, line-2, and line-3 have the lowest temperature value in the afternoon and night while during the morning they have the highest temperature. On the contrary, the line-14 is higher than other lines during the period of afternoon and night while during the morning it turns into the lowest one. The rest of the lines are almost indistinguishable from each other in the whole day.

3.1. Result-1 (Bandage Color Analysis)

In order to find the influence of solar radiation on the function of the instrument, we compared the following sets of experimental data. As can be seen from figure 3, the six lines can be approximately divided into two parts. One part (line-1, line-2 and line-3) which uses the black bandages has a higher temperature than the other part (line-4, line-5, line-6) which uses the white bandages, that is because the black material can absorb more solar radiation than the white material.

As is shown in figure 3, there was no significant differences in all lines when there is no sunshine before the sun rose and after 1 o’clock afternoon. During the period between 7:00 a.m. and 13:00 p.m., the sunshine is stronger than other time in the whole day. The thermometers fixed by black bandages reached its peak point at 11:45am, about two degrees Celsius higher than the white bandages group, and this is because of the stronger ability of black materials to absorb the solar radiation.

3.2. Result-2 (Radiant Prevention Analysis)

In figure 4, in order to verify the conclusion of Result-1 and measure what extent of solar radiation can influence the iButton’s work, one more group data is added in the figure which used the Aluminum foil paper to prevent the impact of the solar radiation. In the morning, the white bandage group (line-4, line-5, and line-6) is in higher temperature while the Aluminum foil paper group (line-7, line-8 and line-9) is in lower temperature. At 11:45 am, the white bandage group (line-4, line-5 and line-6) reached the highest peak points which are 22.7°C, 23°C and 22.8°C respectively while the peak points of Aluminum foil paper group (line-7, line-8 and line-10) at the same time are 21.8°C, 21.6°C and 21.7°C respectively, 1.1°C less than the above group. Therefore, we can deduce that the white bandage is not prevent radiation fully, and the deviation may be more obvious than we thought before.
3.3. Result-3 (Wind Prevention Analysis)
The deviation caused by the wind is tested in the experiment and the data is shown in figure 5. In the morning, all the lines in the diagram are almost in the same level which is because the radiation impact is more obvious than wind so that the influence of the wind could be ignored. However, when the solar radiation abated gradually, the influence of wind on the experiment increased, especially at night. For instance, line-11, line-12 and line-13 are 3℃ degree lower than the others due to the lack of air ventilation. Because the indoor air temperature is about 20℃ which is higher than the windowsill surface, we can infer that the white bandage group without transparent adhesive tape (line-4, line-5 and line-6) has been heated through the way of cross-ventilation.

3.4. Result-4 (thermal isolation analysis)
Figure 6 shows the experiment data which is collected through the iButton that fixed by the white cotton bandage which have the excellent performance in heat preservation and insulation. These bandages are in different mount of layers (2, 4, and 6 respectively) and the differences among the three test are not evident. We assumed this phenomenon is due to the small span of the layers’ quantity, which will be verified in later experiments.

4. Conclusion
This study used the comparative tests to analysis the devices’ accuracy that could be affected especially when these thermometers have been fixed by the different kinds of material. Black materials can make the value significantly higher than the real temperature. However, when we add aluminum foil paper which could eliminate the radiation on the surface, the temperature value declined. In addition, windproof material can prevent the wind effect although the influence of the wind is slighter than solar radiation. Last but not the least, the influence of thermal insulation (bondage layers) on iButton’s temperature measuring was not obvious in this study.
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