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Body core temperature estimation using biometric and environmental data measured by integrated wearable device

Yuki Hashimoto, Kazuhiko Takagahara, Hiroyoshi Togo, Ryota Uematsu, Taiki Miyazawa, Akimasa Hirata, Takashi Kawahara, Hideto Tanaka

Abstract— **Monitoring body core temperature is one of the effective ways to identify heat-related risks of conditions such as heat stroke. However it is difficult to measure it directly during activity. We have developed a wearable device that can monitor a user's heart rate and the temperature and humidity inside their clothing during activity. Here, we investigated a method for estimating body core temperature from sensor data, and compared the estimated and actual values through clinical experiments.**

I. Introduction

Against the backdrop of intense heat waves, countermeasures against heat stroke have become an essential issue. The AGCIH recommends keeping the rise in body core temperature (BCT) to within 1 ℃ as a guideline for lowering of heat-related risks. However, it is difficult to measure the BCT directly during activity without burdening the user. We have so far developed an integrated wearable device with biometric and environmental sensors that measure heart rate, and temperature and humidity in clothing with little burden on the user, aiming at quantitative evaluation of heat stress on users during activity [1, 2]. Here, we demonstrate the effectiveness of estimating BCT elevation from the user's sensor data using the above wearable sensing technology.

II. Methods

An overview of the integrated wearable device is shown in Fig.1. The device can be connected to a belt with electrodes to obtain the user's cardiac potential and calculate the heart rate, and the attached sensor can measure temperature and humidity inside the user's clothes. The sensor data can then be transmitted to external devices such as smartphone via wireless communications. To estimate the BCT elevation, we use a two-layer, two-component model which considers the height, weight, gender, age, and clothing of each individual [3]. The outline of the experiment is as follows. In an artificial weather room with controlled temperature and humidity (33°C, 50% RH), subjects wearing the sensor (four subjects, height 171±1.41 cm; weight 60.8±11.2 kg; age 22.3±1.3; gender male) exercised, and sensor data were acquired as they did so. The subjects wore a long-sleeved jacket and long pants over underwear and a belt equipped with the device. Exercise was performed on a wattbike at an intensity of 50 %VO_2max for 30 min, with 15 min of standing rest before and after the exercise. Rectal temperature was measured using a temperature sensor (LT-ST08-11, Gram) as a reference value for BCT rise.

Y. Hashimoto is with NTT Device Innovation Center, NTT Corporation, 3-1, Morinosato Wakamiya, Atsugi-shi, Kanagawa, Japan, Phone: +81462402124; email: yuuki.hashimoto.zt@hco.ntt.co.jp

III. Results & Discussion

Fig. 2 shows the measurement results. Each sensor data shows gradual increase during exercise. The estimated increase in BCT had a root mean square error (RMSE) of 0.175 °C. Compared to the previous model [4] (RMSE; 0.260 °C), the accuracy was improved by increasing the number of components of the human body model, which can robustly respond to changes in the area exposed to outside air according to body size and clothing conditions.

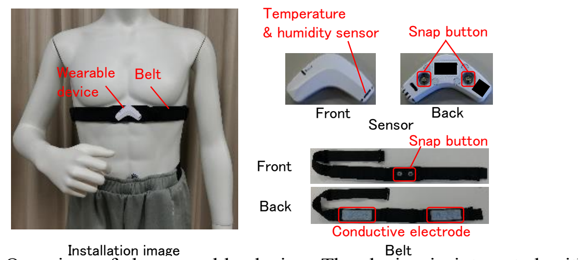

Fig. 1. Overview of the wearable device. The device is integrated with temperature and humidity sensor, and can acquire cardiac potential and calculate heart rate by connecting to a belt with electrodes through snap buttons.

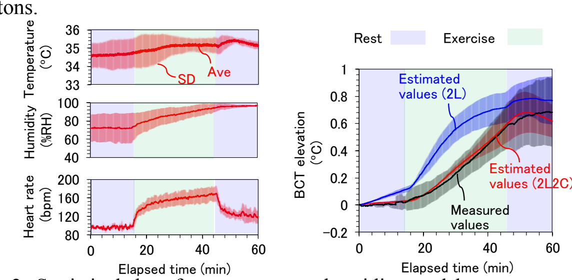

Fig. 2. Statistical data for temperature, humidity, and heart rate acquired from the sensor in the experiment, and comparison of the measured and estimated BCT elevations [two-layer model (2L) [4]; two-layer, two-component model (2L2C)].

IV. Summary

We demonstrated BCT estimation from multiple sensor data acquired by our wearable device. From the results of the experiments, we confirmed that the estimated BCT rise agreed well with measurements. In the future, we plan to conduct experiments with different variations of subjects, environments, and exercise conditions to make the estimation technique more robust.

References

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