Heatstroke risk informing system using wearable perspiration ratemeter

Primary Researcher Toshio Ohhashi Appointed Prof Shinshu Univ Sch of Med

Co-researches: Masao Sakaguchi Honer Prof Nagano Engineering College

Hideya Momose President Skinos Co Ltd

Yoshiko Kawai Prof Tohoku Medical and Pharmaceutical Univ

Mieko Takasaka Appointed Research Associate Shinshu Univ

We constructed an informing system to users for the heatstroke risk using a wearable perspiration ratemeter and the users' thirst responses. The sweating ratemeter was constructed with a capacitive humidity sensor in the ventilated capsule. The timing point for informing heatstroke risk was decided to change from positive to negative on the second derivative of sweating curve. In addition, a wearable self-identification and -information system of thirst response was constructed with a smartphone. To evaluate the validity of wearable apparatus, we aimed to conduct human experiments of 16 healthy subjects with the step up and down physical exercises. The blood and urine samples of the subjects were collected before and after the 30-min physical exercise. The concentrations of TP, Alb, and RBC increased slightly with the exercise. In contrast, the concentrations of vasopressin in all subjects remarkably increased with the exercise. In almost subjects, they identified their thirst response until several min after the informing for heatstroke risk. In conclusion, the wearable ratemeter and self-information system of thirst response were suitable for informing system of heatstroke risk. The validity of timing point for informing heatstroke risk was confirmed with changes in the thirst response and concentrations of vasopressin in blood.

1.Aim of Research

To inform the risk to expose heatstroke to the user via a sound from the smartphone, we constructed (1) a new designed wearable perspiration ratemeter by modifying the original, (2) a wireless self-identifcation and self-information system with the smartphone for thirst response, and (3) a system that informs the heatstroke risk to the users. In addition, to evaluate the validity the timing point to inform automatically for the heatstroke risk to the user using a changing point of negative value on second diferentiation of sweating curve, we conducted human experiments with a-30 min step up and down physical exercise and simultane-ously recorded exercise-induced sweating on the neck and the thirst response. Te changes in the concentrations of vaso-pressin, blood and urine samples, body weight, and heart rate before and after the exercise are measured to evaluate the relationship between the vaso-pressin release and the self-identifcation of thirst response related to the activation of osmo-receptors in the hypothalamus.

2.Method of Research

2-1.Ethical approval

The study was approved by the Ethical Committee for Human Clinical Studies at the School of Medicine, Shinshu University (CRB3200010, approval no. 4445 on 6th August 2019). All study data and procedures were performed in accordance with the principles outlined in the Declaration of Helsinki. The study is registered in the WHO International Clinical Trial Registry Platform (13th/August/ 2022,https://www.who.int/clinical -trials-registry-platform: jRCT-1032220270, Analysis of mental and thermal sweating in human subjects using galvanic skin res-ponse and domestic-made per-spirationratemeter).

2-2.Construction of wearable perspiration ratemeter and self-information apparatus with a smart- phone.

Previously we constructed a high-sensitive perspiration ratemeter which is suitable for measuring active palmar sweating. Tus, a maximum value in the step res-ponse is obtained at appro-ximately 0.63 s. The sensitivity of the electrical performance is 0.1/1 mg water loss/1 min. With the modifcation of original per-spiration ratemeter, we constructed a wearable concise rate-meter with a capacitive humidity sensor, a small fan, and a lithium-ion battery in the venti-lated capsule. To inform the self-identifed thirst response to the observer, we also constructed a wearable self-identifcation and self-information apparatus of thirst response with a smartphone.

2-3.Subjects.

In total, 16 healthy participants (mean age: 41.6±3.3 years old; eight males and eight females) were enrolled in the present experiments. The body mass index (BMI) of the males and females were 23.7±0.7 and 21.5±0.5, respectively. The minimum number of participants was recommended by the ethical committee for the clinical obser-vation study. Hence, the minimum number we chose was suitable for obtaining a valid conclusion. All the participants provided written and oral informed consent after the detailed explanation and table showing of experimental design, methods, expected results, scientific background and value, compensatory medical tools for harmful damage, and stopping guidelines by the corresponding author. All the data and procedures were confirmed to the tenets of the Declaration of Helsinki. The collected data were stored in Shinshu University School of Medicine with responsibility. All human experiments were conducted in the afternoon from 1:00 to 4:00 pm, considering maximal and stable activity of sympathetic nerve fibers in human circadian rhythm. The temperature and moisture of the examination room were maintained within the range of 22–23 °C and 40–50%, respectively, using air condi-tioners.

2-4.Experimental protocols

This study was a randomized trial human experiments. A total of 16 healthy participants were enrolled in this study. The subjects were inhibited from water intake and excretion of urine for 1 h before and during the experiments. Immediately before a 30-min step up and down exercise, blood and urine samples were collected from the participants. A wearable per-spiration ratemeter and a self-identifcation and self-information apparatus with a smartphone for thirst response were positioned on their necks and forearms. The step up and down physical exercise lasted for 30 min. The strength of the exercise was approximately 70 Nm, that is, a moderate level, and the average of their pulse rates was approximately 120.9 beats per min. After the 30-min exercise, their blood and urine samples were collected. In addition, their body weights were measured before and after the physical exercise. To evaluate the exercise-induced hemoconcentration, the concent-rations of total protein (TP), albumin (Alb), and red blood cells (RBL) in their blood samples were measured by a clinical examin-ation laboratory in Shinshu University Hospital. In addition, to investigate the relationship between the thirst response and changes in the concentration of vasopressin, the concentrations of vasopressin in blood were measured before and after the 30-min physical exercise by SRL Co. Inc. (ISO 15189-accredited by Japan Accreditation Board, RML 00080, Tokyo, Japan). To investigate the relationship between water loss per body surface area and the decreased level of body weight, we used the formula 71.84× height0.725× weight0.425× 10−416. The body mass index (BMI) was also calculated by body weight/body height2 (kg/m^2).

2-5.Statistical analysis

All the data were represented as the mean ±standard errors of the mean. Statistical significance was analyzed using the Student's t-test for unpaired observations (Microsoft Excel, version 16.54). $p<0.05$ was considered statistically significant. The relationship between the wearable ratemeter output and water loss in the sweating was compared using linear regression. The Pearson correlation coefficient, r was obtained (Microsoft Excel, version 16.54).

3.Results of Research

3-1.Construction of wearable

per-spiration ratemeter
To measure large amounts of exercise-induced sweating, we constructed a new wearable perspiration ratemeter (Fig. 1). It is extremely small (55 mm×17 mm×46 mm) and lightweight (35 g). Instead of the airflow circulating system of the original ratemeter, a small fan (UB393-700, Sunon, Japan) is equipped on the top of the venti-lated capsule to perfuse air from the upper to the lower chamber. A capacitive humidity sensor (BME280, Bosch, USA) is fixed in each chamber, and a lithium-ion battery is used for the power supply. Both the difference of humidity between the lower and upper chambers and the temperature of the perfused air are calculated in the sweating rate using a microcomputer system. Thus, the absolute amount of water loss per constant time and area of the skin surface is registered on a chart recorder.

Figure 1

3-2.Wearable self‐identifcation and self‐information apparatus of thirst response.
To evaluate the relationship bet-ween thirst response and exercise-induced sweating, we constructed a self-identifcation and self-information apparatus for thirst response during physi-cal exercise using the wearable smartphone. Figure 2 shows the schematic of the apparatus. When the participants were thirsty, they selected a thirst level among three levels of thirst (mild+, middle++, and severe+++) and subsequently touched the level on the display of the smartphone. The apparatus was placed on the participants' fore-arms. By using the apparatus, both the level and timing point were recorded simultaneously on the sweating curve of the users.

Figure 2

3-3.Evaluation of the constructed system informing the heatstroke risk in human subjects with physical exercise.
To evaluate the validity of timing point for informing the heatstroke risk to users, with human experiments we investigated the relationship between the informing point for the heatstroke risk and the self-identification point of thirst response, and relationship between the self-identification of thirst response and changes in the concentration of vasopressin in blood, urine volume and urine osmolality.
Effects of physical exercise on sweating on the neck and thirst level of participants. Figure 3A illustrates the representative exercise-induced sweating curves measured using the wearable perspiration ratemeter on the necks of two participants: (a) 40-years old female and (b) 40-years old male. In addition, the timing point of the thirst levels is shown using three levels of thirst responses (grade;+, mild;++, strong;+++, severe) on the same sweating curves. The participants were thirsty for several minutes following the informing points of heatstroke risk (●), which were electrically decided as the value of the second derivative of sweating curve changed from positive

to negative.

Figure 3B demonstrates the data of 12 participants for the relationship between the informing point for heatstroke risk and the self-identification of thirst response. The rest 4 participants did not identify the thirst response during the 30 min physical exercise. The time point informed the heatstroke risk represents zero in the abscissa of Fig. 3B. The plus and minus values in the abscissa show the time identified thirst response in each participant after and before informing time for heatstroke risk (zero value), respectively. Seven participants identified their hirst response during 0–10 min after the informing time. Only 3 participants noticed the thirst response around 1–3 min before the informing time.

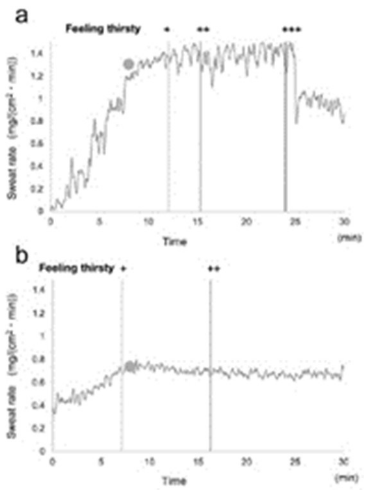

Figure 3A

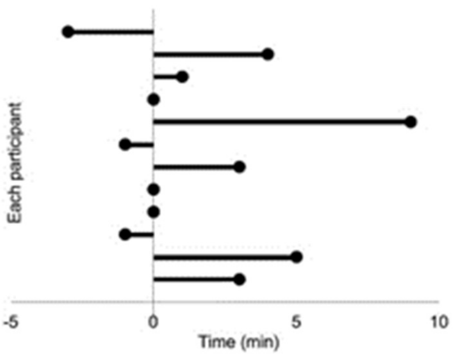

Figure 3B

4.Conclusion

Several studies on the advantages of fluid ingestion on thermoregulatory and cardiovascular responses during progressive dehydration-related hemoconcentration have been reported. However, the contribution of exercise-induced sweating in dehydration-related hemoconcentration and information systems for heatstroke risks, to the best of our knowledge, has not yet been evaluated. Therefore, we developed a wearable sweating ratemeter for informing the users of heatstroke risk.

5.Future Area to Take Note, and Going Forward

The constructed system will be needed in the future to evaluate in detail with additional clinical experiments included old persons. Especially, we should reevaluate, in the future, the suitability to decide the informing point for heatstroke risk.

6.Means of Official Announcement of Research Results

In the future, we have attempted to publish the present results in the official international journal. We also have a plan to demonstrate the present results in the newspapers or using the television system.

7.References

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