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Corey A. Peacock
Nova Southeastern University, cpeacock@nova.edu

Ellen L. Glickman
Kent State University

Gabriel J. Sanders
Northern Kentucky University

See next page for additional authors

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Corey A. Peacock,[1] Ellen L. Glickman,[2] Gabriel J. Sanders,[3] Yong Suk Seo,[2] Brandon S. Pollock,[2] Keith J. Burns,[2] Lynn Kakos,[2] and John Gunstad[2]

[1]*Nova Southeastern University*
[2]*Kent State University*
[3]*Northern Kentucky University*

Abstract

Background: Prevention of heat illness is of considerable medical interest within the field of occupational work. There are many established methods of perceptual health assessment; however, many are rather unpractical and timely. The objective was to improve the practicality and timeliness of perceptual physiological monitoring; a Heat Thermal Sensation scale has been developed. The usefulness of the scale was assessed on its ability to monitor physiological variable. Materials and Methods: Ten apparently healthy individuals performed physically exerting activity while exposed to 37 ℃. Sensation and physiology were measured throughout. Results: The perceptual monitoring scale demonstrated weak positive correlations with human physiological variables including cardiorespiratory stresses. It demonstrated no correlation with thermoregulation stress. Conclusion: The scale needs further development to better improve heat illness practices to those commonly exposed in extreme heat during occupational work.

Keywords: environmental physiology, heated environment, thermal sensation

Introduction

Heat exposure is an essential topic of interest within the occupation work community. Further, a better understanding of the relation between heated thermal sensation and physiologic stress may contribute to improve current occupational practices. With an ever-increasing prevalence of work-related heat illness, practical perceptual monitoring research may be critical to increase timely medical safety of those occupational workers such as laborers, military personnel, and professional athletes exposed to hot agricultural environments.

Many investigations in the area of temperature regulation and thermal sensation have assessed thermal discomfort via either ratings of perceived exertion (Bassett et al., 1987; Glass, Knowlton, & Becque, 1994; Robertson, 1982; Sherman & Deutsch, 1983), modified version of the Gagge Scale (Tikuisis & Osczevski, 2002), or the physiologic strain index. All of the scales involve a perceptual interpretation of one's physiological status using different ranges and values. In an attempt to increase practicality, the Modified Glickman-Weiss scale was created to subjectively define the extreme or "0" point on a particular scale so that the subsequent thermal scores on the scale are expressed in relation to "0" (Glickman-Weiss, Hearon, Nelson, & Robertson 1994; Muller et al., 2011; Muller, Kim, Seo, Ryan, & Glickman, 2012). The scale improved the area of thermal sensation research by simplifying the interpretation process by rating one's health status using 0 as a reference point; however, the scale was particular to cold environments.

There is a lack of research and development pertaining to subjective thermoregulation monitoring in a heated work environment. Recently, a Heated Thermal Sensation Scale (HTSS) was created to monitor subjective interpretation of one's health in the heated occupational work environment. The scale was created by utilizing a semantic differential to that of the Borg CR-10 scale with a numerical end of 10 (Nobel, Borg, Jacobs, Ceci, & Kaiser, 1983). Similar to the Modified Glickman-Weiss Scale (Glickman-Weiss et al., 1994), HTSS was anchored at "0." The development of such a scale could enhance physiological health monitoring in the heated environment as it is timely if medical attention is needed.

Correspondence concerning this article should be sent to cpeacock@nova.edu.

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0	Nothing at all
1	Increase in temperature
2	Moderately warm
3	Warm
4	Very warm
5	Very, very warm
6	Somewhat hot
7	Hot
8	Very hot
9	Very, very hot
10	Unbearably hot

Figure 1. Heat thermal sensation scale.

The purpose of the preliminary thermal sensation investigation was assessing HTSS (Figure 1) while examining correlations of HTSS with multiple physiological responses during physical exertion while exposed to the heat. One may discern that HTSS could be beneficial as it may help to prevent episodes of heat illness and occupational heat injury. The researchers anticipated that HTSS will aid in the monitoring of physiological responses based on subjective thermal scaling.

Materials and Methods

Ten apparently health males volunteered for participation in the current investigation of thermoregulation and subjective scaling in the heat. The study was approved by the Kent State University Institutional Review Board prior to investigation. Participant consent was obtained prior to any physical activity. Participants were present for a 45-min screening session prior to the experimental trials. During this screening, participants were familiarized with the protocol, tested on aerobic capacity (VO_2 Max), and scheduled for two identical preliminary testing sessions separated by at least 48 h. Participants reported to the Kent State University exercise physiology laboratory between 0600 and 0700 hours for the testing sessions. The testing sessions were seasoned at an ambient environmental heat of 37 ± 0.5 ℃. The continuous ambient exposure sessions composed of resting heat exposure, physical exertion heat exposure, and recovery heat exposure lasted approximately 150 min. Prior to the experimental trials, participants were provided a standardized breakfast and water intake to minimize possible confounds. Participants avoided exercise exertion 24 h prior to experimental trials. Participants were prepared for heat exposure with a thermistor (ER 400-12, O.E. Meyer Co., Sandusky, Ohio) to examine rectal temperature (Tre). They were also equipped with a heart rate monitor (Accurex Plus, Polar Electro, Inc., Woodbury, NY) and metabolic apparatus (Parvo, Metabolic Cart, Sandy, Utah) to examine both cardiovascular physiology (HR) and aerobic physiology (VO_2), respectively.

During each identical experimental trial, participants entered an environmental chamber maintaining an ambient heat of 37℃ and remained for the duration. Each trial began with a resting heat exposure baseline thermal sensation measurement (HTSS), while the entire series of physiological measures (VO_2, HR, and Tre) were monitored for 20 min. While still exposed to 37℃, participants were then asked to exert physically in the form of leg cycle ergometery at a moderate intensity of 50% (established from VO_2 Max results). The physical exertion included 3–25 min cycling bouts, with interspersed 5 min rest periods to monitor weight loss. The 5 min periods allowed proper monitoring of safety status. Immediately following physical exertion, while remaining still in the 37℃ chamber, participants recovered from the physical exertion. They were permitted to rehydrate and rest for approximately 30 min. Thermal sensation and physiological variables remained under measurement and observation.

Results

Means and measures of variability (i.e., standard deviation) were calculated for all participant characteristics. The Pearson product–moment correlation coefficients were performed to determine correlations between thermal sensation (HTSS) and physiological parameters (HR, VO_2, and Tre). An additional thermal sensation regression per physiological variable was entered utilizing mixed effects models. Significance was set at $p \leq 0.05$. All data analyses were statistically conducted using SPSS for Windows (SPSS version 17.0, SPSS Inc, Evenston, IL).

Participant demographic characteristics are displayed in Table 1. Scale assessment analysis demonstrated a weak positive correlation ($r = 0.257$) between HTSS and VO_2, mixed model effects demonstrated that this relationship was significant ($r^2 = 0.066$, $f = 7.4$, $p < 0.01$). A weak positive correlation ($r = 0.230$) also existed between HTSS and HR, mixed model effects demonstrated this relationship was significant ($r^2 = 0.052$, $f = 4.3$, $p < 0.01$). HTSS and Tre revealed a weak negative correlation ($r = -0.245$). Mixed model effects demonstrated a non-significant relationship between HTSS and Tre ($r^2 = 0.060$, $f = 0.98$, $p = 0.49$).

Table 1
Participant demographics.

Age	Height	Weight	BMI
21.9 ± 2.0 yrs	181.4 ± 6.0 cm	90.7 ± 10.5 kg	27.5 ± 1.1

Conclusion

Thermal sensation scaling for use during rest and physical exertion during occupational heat exposure has not been examined with a modified thermal sensation scale anchored at 0 (HTSS). Also, a modified thermal sensation scale for the heat has not been directly correlated with a variety of physiological stresses elicited in a heated environment. From the data provided, HTSS could be a practical instrument for subjective scaling, although, weak correlations between thermal sensation and physiological measures may warrant additional research. The results also revealed that HTSS demonstrated no correlations with core temperature, and may show no practicality for subjective scaling in regards to Tre. This refutes previous research in the area of thermal sensation as scaling typically proves a predictor of Tre; however, previous findings were particular to the cold environment (Glickman-Weiss et al., 1994; Muller et al., 2011, 2012). Therefore, it is unclear whether HTSS is a reliable tool for assessing health status and physiological measures while exposed to a heated environment.

Although this is the first study to evaluate HTSS, it is not without limitations. The current study assessed physiologic responses to physical exertion in the form of cycling. Although this is practical for research purposes, many workers are exposed to multiple modalities of physical exertion during heat exposure. Also, humidity data were not collected during the protocol, and may also play a role in thermoregulation. Following preliminary data analysis, studies are underway further analyzing HTSS. HTSS may prove to be an effective tool for monitoring health status and physiological measures while exposed to heated environments.

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