Spring 4-27-2022

Exercise in the Heat: Perceptual Measures in Hydrated and Dehydrated Conditions

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An Honors Thesis

University of Connecticut

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Honors Scholar Program

Spring 2022

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ABSTRACT:

Introduction: Athletes, warfighters, and laborers are often exposed to extreme environmental conditions that can result in heat-related illnesses negatively impacting performance and productivity.

Purpose: To evaluate Total Mood Disturbance (TMD) from pre-trial to post-trial surrounding exercise in the heat. The secondary purpose was to compare post-trial measures between hydration status as well as environmental conditions.

Methods: Twenty-six male and female subjects performed four trials. Two trials were conducted in temperate conditions (24 ℃, 55% relative humidity) and two in extreme heat conditions (35 ℃, 55% relative humidity), in both hydrated and dehydrated conditions. The Profile of Moods States survey was administered before and after each trial; TMD was calculated for each timepoint. Descriptive statistics (mean ± SD) were calculated, and Mann-Whitney U t-tests were utilized to compare TMD pre-trial vs. post-trial measures for each condition, post-trial hydrated vs. post-trial dehydrated for each environmental condition, and post-trial temperate vs. post-trial extreme heat for both hydration statuses.

Results: In the temperate hydrated, temperate dehydrated, and extreme heat dehydrated conditions, there were no significant differences between pre-trial and post-trial TMD ($p=0.276$; $p=0.237$; $p=0.322$). In the extreme heat hydrated condition, there were significant differences between pre-trial and post-trial TMD ($p=0.049$). There were no significant differences between post-trial TMD between environmental conditions or hydration statuses ($p>0.05$).

Conclusions: Mood disturbance was only altered from pre-trial to post-trial in the extreme heat, hydrated condition. Mood disturbance appears to be heightened post-trial, particularly when dehydrated. Additionally, dehydration may negatively impact pre-trial values compared to being hydrated.

INTRODUCTION:

Athletes, warfighters, and occupational workers are often exposed to extreme environmental conditions, with about 13.3 million people working in extreme temperatures in July 2017 alone, putting them at an increased risk for heat-related illness. The physiological effects of exercising in the heat are well known, but there is not much knowledge regarding the perceptual effects of heat exposure (2). In order to improve heat safety, it is necessary to understand the effects of heat exposure on one's perception of their physiological state as it can lend to changes in performance. The use of perceptual measure scales, such as the Profile of Moods Status (POMS) survey is an assessment used to measure the feelings and enduring effects of mood states. Through the POMS survey, Total Mood Disturbance (TMD) can be used to calculate the perceived mood status of the subject when exposed to stressful conditions, such as exercise in the heat. Understanding perceptual measures surrounding exercise in the heat may provide information to establish guidelines to increase the performance, productivity, and safety of athletes, soldiers, and laborers.

Individuals are exposed to varying levels of heat every day and some are more at risk than others for heat-related illnesses. A variety of intrinsic and extrinsic risk factors contribute to heat illness occurrence such as ambient temperature, relative humidity, wind speed, workload, and level of fitness (3). Heat stress has a number of negative effects on cognitive function and perception and has been shown to be impaired in younger adults undergoing signs of heat stress (4). Evaluating the impact of hydration status during exercise in the heat can help further understand these effects. Combining

the effects of dehydration and exercise in the hot conditions results in decreased blood volume correlated with an increased heart rate and physiological strain on the body. Dehydration results in decreased blood flow in order to help maintain energy in the body, this decreased blood flow can deprive the brain of much needed oxygen, resulting in decreased perceptual performance (5).

Some studies have evaluated the influence of exercise in the heat on subject perceptual measures. In one study, Szymanski et al. (2021) evaluated hydration status in kids and how it affects their mood state with the POMS survey. This study focused on measuring children's hydration levels based on their access to a beverage. The POMS survey was administered to see if there was a change in mood between two different beverages. This study found no significant differences in the mood states for their trials when using the POMS survey following the intervention. Similarly, a different study used the POMS survey to assess TMD after exercise. Kannin et al. (2005) conducted a study utilizing the POMS survey on subjects after multiple exercise sessions. Participants in this study completed either short or long bouts of exercise outside in the heat for eight weeks. Subjects were given the POMS survey before and after the eight weeks of exercise. The pre-trial results of this study established baseline values for participants and the post-trial results did not deviate from this. Therefore, this study demonstrated no significant difference in mood states between exercise modalities identified by the POMS survey. Both these studies sought to better understand the degree to which TMD that is associated with stressors such exercise and dehydration, but through the use of the POMS survey were unable to accurately depict this.

Although perceptual measures have been evaluated in exercise, the comparison between timepoints within trials as well as comparisons across varying environmental conditions and hydration status have yet to be clearly compared. Therefore, the purpose of this study was to evaluate Total Mood Disturbance surrounding exercise in the heat in hydrated and dehydrated states through administration of the POMS survey.

MATERIALS AND METHODS

Baseline:

Data was collected from 26 healthy adults. All testing was completed at the Korey Stringer Institute. The baseline testing was comprised of an assessment for height and weight, body composition, and aerobic fitness (VO_2max). All of the baseline measurements were tested in a thermoneutral environment.

Experimental Conditions:

In a crossover design, all subjects were randomized to complete for experimental conditions. Two trials were completed in temperate environment conditions (24 °C, 55% relative humidity) and two trials were completed in extreme environmental conditions (35 ℃, 55% relative humidity). For each environmental condition, the trial was conducted in both a hydrated and dehydrated state. Exercise intensity was kept consistent among all trials between all participants and was prescribed as follows based

on the participants VO_2max: 3 bouts of exercise lasting 45 minutes with 15 minutes of rest; the 45-minute bouts of exercise consisted of 15 minutes of walking (40% VO_2max), 15 minutes of running (60% VO_2max), 15 minutes of walking (40% VO_2max)

Hydrated Trials

The subjects arrived at the Korey Stringer Institute hydrated and remained hydrated throughout the entirety of the trial. This was verified by collecting by analyzing urine specific gravity and urine color; nude body mass collected prior to beginning the trial. After the first bout of exercise, nude body mass was reassessed and amount of body mass lost (kg) was prescribed in water to consume during each rest block for the remainder of the trial. Body mass and hydration status were assessed again at the end of the trial to confirm that all subjects were in a hydrated state.

Dehydrated Trials

The subjects arrived at the laboratory 20-24 hours before their dehydrated trials to provide a nude body mass and urine sample. For this visit subjects arrived hydrated, but upon leaving the laboratory their fluid consumption was restricted. The following day subjects arrived at the laboratory in a dehydrated state and maintained the dehydrated state throughout the entirety of the trial. Nude body mass was collected, and a urine sample was provided prior to the trial beginning. Fluid was restricted during exercise for both trials. Nude body mass was collected, and a urine sample was provided upon completion of the trial.

Profile of Moods Status Survey

The Profile of Moods Status Survey (POMS) was administered before and after each trial. The survey consisted of sixty-five moods with values for the POMS survey ranging from 0-4 and each survey was calculated to show a Total Mood Disturbance (TMD). TMD was calculated by subtracting the vigor score from the five negative sub scores (tension-anxiety, depression, anger-hostility, vigor, fatigue, and confusion).

STATISTICAL ANALYSIS:

Descriptive statistics (mean and standard deviation) were calculated for subject characteristics, the independent variables (environmental conditions), and the dependent variables (TMD). Mann-Whitney U comparative analysis was conducted to compare pre-trial TMD to post trial TMD for all four experimental conditions. Mann-Whitney U comparative analysis was conducted to compare post-trial TMD between the environmental conditions, as well as hydration status. All analyses were performed using IBM SPSS Statistics 28 (Version 28.0 for Apple MacOS; IBM Corporation, Armonk, NY, USA).

RESULTS:

Subject characteristics and environmental conditions for each trial are presented in *table 1 and table 2*. Total Mood Disturbance was calculated for each subject pre-trial

and post-trial for each experimental condition. For the total sample, the TMD averages and standard deviations at each time point are presented in *table 3*.

Pre-Trial vs. Post-Trial: In the temperate hydrated condition, there were no significant differences between pre-trial TMD and post-trial TMD (p=0.276; u=278.5). In the temperate dehydrated condition, there were no significant differences between pre-trial TMD and post-trial TMD (p=0.237; u=273.5). In the extreme heat hydrated condition, there were significant differences between pre-trial TMD and post-trial TMD (p=0.049; u=230.5). In the extreme heat dehydrated condition, there were no significant differences between pre-trial TMD and post-trial TMD (p=0.322; u=284.0).

Temperate vs. Extreme Heat: In the hydrated conditions, there were no significant differences between post-trial temperate TMD and post-trial extreme heat TMD (p=0.700; u=317.0). In the dehydrated conditions, there were no significant differences between post-trial temperate TMD and post-trial extreme heat TMD (p=0.389; u=219.0).

Hydrated vs. Dehydrated: In the temperate conditions, there were no significant differences between post-trial hydrated TMD and post-trial dehydrated TMD (p=0.379; u=290.0). In the extreme heat conditions, there were no significant differences between post-trial hydrated TMD and post-trial dehydrated TMD (p=0.776; u=322.50).

Subjects (n=26)	Mean ± Standard Deviation
Age (years)	23 ± 4
Height (cm)	167.5 ± 8.8
Body Mass (kg)	67.90 ± 11.04
Body Fat Percent (%)	18.6 ± 9.1
Fat Mass (kg)	12.51 ± 6.45
Fat-Free Mass (kg)	57.41 ± 14.63
VO2 Max (ml/kg/min)	43.5 ± 5.9

Table 1: Subject characteristics (mean ± standard deviation)

Environmental Conditions (mean ± standard deviation)	Baseline	Temperate (Hydrated)	Temperate (Dehydrated)	Extreme Heat (Hydrated)	Extreme Heat (Dehydrated)
Temperature (°C)	24.4±1.4	26.0±1.2	25.6±1.0	35.0±1.2	36.1±4.3
Relative Humidity (%)	49.9±7.5	52.4±6.6	49.0±3.9	48.9±6.6	47.9±7.0
Wet Bulb Globe Temperature (°C)	19.8±1.3	21.6±0.6	20.8±1.1	28.9±1.5	29.2±1.8

Table 2: Environmental conditions (mean ± standard deviation) for each trial

Total Mood Disturbance (mean ± standard deviation)	**Temperate Hydrated**	**Temperate Dehydrated**	**Extreme Heat Hydrated**	**Extreme Heat Dehydrated**
Pre-Trial	12 ± 7	14 ± 10	11 ± 8	14 ± 11
Post-Trial	15 ± 9	18 ± 12	18 ± 12 *	20 ± 18

Table 3: Total Mood Disturbance (mean ± standard deviation) pretrial and post-trial by environmental condition. * Indicates statistical significance between pre-trial and post-trial ($p<0.05$)

DISCUSSION:

Overall, our study did not reveal major significant changes in TMD from within trials as well as post-trial between environmental conditions and hydration status. However, a small but significant change was produced in TMD from pre-trial to post-trial in the extreme heat and hydrated condition. These findings indicate that subjects perceived the stress from exercising in extreme heat to be mood-altering. The higher the score for TMD correlates with a greater degree of mood disturbance (9). This finding was expected to be seen for the extreme heat dehydrated trial as well, however, significant differences did not prevail.

In the temperate hydrated condition, we found the average TMD was 12 at pre-trial and 15 at post-trial, while not statistically significant, these values are elevated compared to the temperate dehydrated conditions (14 at pre-trial, 18 at post-trial). In the extreme heat hydrated conditions, the average TMD was 11 at pre-trial which is similar to the previous trials, however, the average at post-trial was significantly altered. In the extreme heat dehydrated condition, the average TMD pre-trial was greater (14)

compared to the hydrated trial, and although not significant, the post-trial value (20) appears elevated from all other trials. While only significant in one condition, post-trial TMD averages were elevated compared to pre-trial conditions.

All pre-trial values in both hydrated states were relatively stable between the two environmental conditions. The same values are reflected in the pre-trial dehydrated trials in both environmental conditions, potentially revealing trends in mood-alterations resulting from being dehydrated. For the post-trial values, the lowest average was produced in the least stressful condition (temperate hydrated) as anticipated, while the highest average was in the most stressful condition (extreme heat dehydrated) as anticipated.

As mentioned above, previous research utilizing the POMS survey did not find statistical significance in TMD. Szymanski et al. (year) and Kannin et al. (2005) used the POMS survey before and after bouts of exercise in either different environmental conditions or hydration states, similar to our study. Their findings from the POMS survey were similar to ours. Both studies, did not have any statistically significant data from the POMS survey; our study produced one significant change in TMD from pre-trial to post-trial in the extreme heat temperate condition. Kannin et al. (2005) reported pre-trial results as relatively normal, according to POMS surveys, which is consistent with our findings. Pre-trial results of this study declared all participants as normal and the post-trial results did not deviate from this. Szymanski et al. (year) and Kannin et al. (2005) identified a correlation between change in mood and exercise. Future analysis within

our data set should evaluate this impact to guide future research questions and statistical analysis. Our initial analysis did not reflect the thermal stress from exercise and dehydration through the POMS survey. However, this does not imply that an individual's perception is not altered from before and after exercise, but rather demonstrates that there may be more precise ways to measure mood disturbance and perceptual stress.

The question remains rather of the POMS survey's ability to accurately detect overall mood disturbance surrounding exercise in the heat. The POMS survey relied heavily on subjects' ability to accurately answer the survey questions. Our data demonstrates stress elicited from the thermal environment as seen by significant differences in core temperatures between trials, but TMD did not reflect this change. Instead of relying on the positive and negative emotions associated with exercise in these conditions, a better solution could be to utilize a rating of perceived exertion or thermal stress perceptual scale. Examples of stress tests that could be used in future studies to improve TMD scoring to be reflective of thermal stress include an exercise stress test or nuclear stress test.

There were limitations to our study that may be improved in future research. Numerous subjects did not fill out the POMS survey properly and opted to denote the score of zero for many of the questions. The response bias from some individuals may have resulted in our data not being able to provide statistical significance within the data. Another limitation in this study was the administration of the POMS survey. The

POMS survey was provided to subjects on a sheet of paper both before and after the trials. Some of these surveys were hard to read, as the text was very small, or the ink was faint. Providing these surveys to individuals on a tablet may have helped subjects read the questions more carefully and answer more truthfully and could have helped circumvent this issue. Subjects also may have been under a time restriction when filling out the POMS survey and may have resulted in improperly completed surveys and therefore inaccurate results. In dehydrated trials, subjects were not given water until after finishing the POMS survey. This may have resulted in subjects rushing through the survey and not giving it much thought to get their water faster.

CONCLUSION:

Overall, our study found that mood disturbance was only altered from pre-trial to post-trial in the extreme heat, hydrated condition. Although non-significant, some clinical relevance prevails warranting further investigation. Mood disturbance appears to be heightened post-trial, particularly when dehydrated. Additionally, arriving to an exercise trial or work shift dehydrated may negatively impact pre-trial values compared to being hydrated. While these findings were not significant, our preliminary evidence provides rationale for direction for future research to evaluate or improve on subjective perceptual assessment surveys to detect stress elicited by extreme heat and dehydration.

The discoveries made from this study may be able to serve as a form of pilot data for future research. While the POMS survey did not provide statistically significant data in all but one instance, TMD is hypothesized to be altered in different states of

dehydration. The clinical significance from this data demonstrates that while one undergoes high levels of physiological stress when exercising in these conditions, they may also be undergoing psychological stress as well. More accurate testing is needed to better understand how the mind perceives thermal stress and the data we collected shows that our TMD is affected by exercise in in the extreme heat while hydrated. With better administration of the survey and more detailed understanding of the questions that are asked, the POMS survey could be utilized to determine the TMD in individuals exercising or working in extreme condtions.

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