EFFECTS OF A SHORT, SUBMAXIMAL RUN AT DIFFERENT TIMES OF DAY ON HEAT STRAIN

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ABSTRACT

Ashley CD, Reneau PD, Roy JP, Bishop, PA. Effects of a Short, Submaximal Run at Different Times of Day on Heat Strain. \textit{JEPonline} 2006;9(1):58-63. In hot weather, radiant heat and dry-bulb temperatures are lowest and humidity is highest early and late in the day. The purpose of this study was to determine heat stress responses of running at different times of day. Moderately trained male runners (n=10) performed three 4.84 kilometer runs in the morning, noon and in the evening at a self-selected pace in a hot climate. The wet-bulb globe temperature (WBGT) was used to evaluate environmental conditions. Heart rate and rectal temperature was recorded before and after each exercise bout. The dry bulb and wet bulb temperatures were lower and humidity was higher during the morning runs (p<0.05). Running times, heart rates and rectal temperatures were not different among the trials (p>0.05). In our experienced runners, heat stress responses to a short, submaximal run were equivalent in the morning, noon and evening. Assuming an early-morning or late afternoon run obviates heat injury concerns seems unwise. However, it appears that acclimation may serve to enhance heat dissipation mechanisms and reduce heat strain.

Key Words: Exercise, Acclimation, Climate, Environment
INTRODUCTION

In the summer months, heat stress is an important consideration for runners and other outdoor athletes in terms of performance and health. The increase in metabolic load with exercise raises the temperature of exercising muscles and circulating blood transfers heat to the body core resulting in an elevated core temperature. To carry heat away from the core, peripheral vasodilation accompanied by an increase in cardiac output and thus heart rate (HR) transfers heat to the skin. To aid removal of heat from the skin, sweat production increases to enable evaporative heat loss. The loss of body water as a result of increased sweat rate results in a decreased plasma volume; increasing blood viscosity and adding to the cardiovascular strain of increased skin and muscle blood flow (1,2,3,4).

In addition to the increase in heat stress brought on by increased metabolic load, certain environmental conditions increase heat stress and impair heat dissipation. One key to safe training for endurance athletes during hot weather may be to determine the environmental conditions corresponding to time of day that minimize heat strain. Endurance performance and ambient temperature are directly related (5). Dry heat exchange, particularly convective heat loss relies on the temperature gradient between the skin and the environment. The lower the gradient, the slower heat will be dissipated. If environmental temperature is greater than skin temperature, heat storage will occur. Further, low air movement may act as a zone of insulation next to the body. Lastly, but most importantly, as relative humidity rises, evaporative heat loss will be slowed. When heat dissipation is less than heat production, core temperature rises resulting in reduced exercise capacity and increased risk of heat illness (2).

The American College of Sports Medicine (ACSM) guidelines recommend that caution should be exercised when ambient conditions approach a wet bulb globe temperature (WBGT) of 28 °C (6). During the summer months especially in southern states, the WBGT can easily exceed ACSM limits increasing the risk of a heat-related illness. However, exercising when environmental conditions yield a lower WBGT (i.e. lower ambient temperatures and lower humidity environments) will reduce heat strain and increase athletic performance and safety (5). Generally, ambient temperature is lowest during the morning hours and rises throughout the day before decreasing in the evening whereas relative humidity is highest in the morning hours and drops as the temperature increases (7). As evaporative heat loss accounts for approximately 80% of heat dissipation during exercise, exercising during times of lower relative humidity might optimize evaporative heat loss and reduce heat strain. Conversely, exercising early or late in the day reduces radiant and convective heat load. Under laboratory conditions approximating morning and evening environmental conditions, Cochrane and Sleivert (7) found equivalent HR and rectal temperature (T_r) during a two-hour run at 70 % VO_2 max under laboratory conditions designed to approximate morning and evening environmental conditions. For the morning condition, participants started the exercise bout with a T_db of 24 °C with an increase in temperature of 0.5 °C every 15 minutes until 27.5 °C had been reached. Relative humidity decreased from 78.5 to 65.5 %. The evening conditions began with a T_db of 27.5 °C with a decrease in temperature of 0.5 °C every 15 minutes to 24 °C. Relative humidity increased from 65.5 to 78.5%. However, their participants performed a long bout of continuous exercise and the researchers did not examine environmental conditions similar to mid-day conditions.

There is a lag in the onset of sweating which reaches equilibrium at approximately 30 minutes of exercise. A shorter exercise bout might rely more heavily on dry heat exchange to reduce heat strain even with higher relative humidity. Exercising in the morning or evening when the ambient temperature is lower might enhance dry heat exchange and bring about less heat strain. However, in a study that examined physiological responses during 30 minutes of cycling at 32 and 23 °C, 60 % rh,
Exercise and Heat Strain at Different Times of the Day

T\textsubscript{re} was similar for both conditions (8). Therefore, the primary purpose of this study was to determine the effects of the environmental conditions associated with different times of day on physiological responses to a short, submaximal run.

METHODS

Subjects
Ten moderately trained male runners (30.6 ± 5.6 yrs) with max VO\textsubscript{2} of 56.9 ± 7.1 ml/kg/min and body fat of 12.2 ± 3.3% volunteered to participate in this study. Average weekly mileage for the participants was approximately 32.2 km/week, with a range of 9.68 to 88.55 km/week. Before testing, all procedures were approved by the institution’s review board for the protection of human participants and informed consent was obtained.

Procedures
Prior to beginning testing, skin folds were measured at 3 sites and body fat was calculated using the generalized equations of Jackson and Pollock (9). The test protocol consisted of participants performing a test of maximal aerobic capacity (max VO\textsubscript{2}) and three submaximal 4.84 km (3-mile) runs. Prior to the max VO\textsubscript{2} test, participants performed a brief warm-up of their choosing. The protocol for the max VO\textsubscript{2} test involved participants running at a self-selected, moderate to high intensity on a motorized treadmill. They were encouraged to choose a pace that was slightly faster than their training pace. Grade was initially set at 0%, and was increased 2% every 3 minutes until participants reached exhaustion. Max VO\textsubscript{2} was assumed to be attained if any 2 of the following criteria were met: a) a HR within 10 beats/min of age-predicted maximal HR, b) a plateau of VO\textsubscript{2} (less than 150 ml/kg/min) despite an increase in workload or c) an RER greater than 1.0. Expired gases were analyzed using a Beckman Metabolic Measurement Cart and HR was assessed using a HR monitor (Polar Instruments, Brooklyn, NY) during each stage. Within two weeks of the max VO\textsubscript{2} test, each participant performed, in counterbalanced order, three submaximal 4.84 km (3-mile) runs on a grassy, non-shaded 400 m course at a comfortable pace. The tests were performed at approximately 6 A.M., noon, and 6 P.M. CDT during July, August, and September in the southeastern United States. Participants were requested to fast at least 4 hours prior to the tests, and due to the potential effects of clothing on heat dissipation, participants were requested to wear the same clothing for all tests. Tests were separated by a minimum of 48 hours and a maximum of 14 days. Pace for each 400 m was monitored so that total time for the 4.84 km run was equivalent for each participant. Participants wore heart rate monitors throughout the run and HR was recorded pre-exercise and immediately post-exercise as well as 2 and 5 minutes after the run using a HR monitor (Polar Instruments, Brooklyn, NY). Rectal temperature was assessed pre- and immediately post exercise as well as 2 and 5 minutes after the run with a thermocouple inserted 8 cm beyond the anal sphincter using an Alnor model 6629 Digitherm digital thermometer (Alnor Instrument Co., Skokie, IL). The thermometry system was calibrated prior to each test using a mercury thermometer and a hot water bath. The WBGT was assessed for each trial. Wet bulb temperature (T\textsubscript{wb}) was assessed using a mercury thermometer with a wetted cotton wick. Dry bulb temperature (T\textsubscript{db}) was assessed using a mercury thermometer. Globe temperature (T\textsubscript{g}) was assessed using a mercury thermometer inserted into a copper globe painted black. Relative humidity was calculated from wet bulb and dry bulb temperatures.

Statistical Analyses
Descriptive statistics were calculated for all data. A repeated-measures analysis of variance (ANOVA) was used to determine any differences between the submaximal runs in terms of environmental conditions or physiological responses associated with heat strain. Level of significance was set at p < 0.05.
RESULTS

Environmental conditions are shown in Table 1. Environmental conditions were significantly different between the runs (p<0.05). \( T_{wb} \) was significantly lower for the morning than the noon run (p=0.007). \( T_{db} \) was significantly lower for the morning run than for either the noon or evening run (p=0.000). \( T_{g} \) and WBGT were significantly lower for the morning and evening runs (p=0.000). Relative humidity was lower for the noon run (p=0.000).

Performance variables associated with the submaximal runs are presented in Table 2. Total times for each trial were not significantly different (p=0.757). The average heart rate during the submaximal runs was approximately 90% of maximal heart rate achieved during the max VO\(_2\) test. There was no difference in HR prior to, immediately post or 2 or 5 minutes after the runs (p=0.448, 0.371, and 0.355, respectively). The pre-exercise \( T_{re} \) was significantly lower (p=0.000) for the morning run probably due to the circadian rhythm of \( T_{re} \) (10). Also, \( T_{re} \) immediately after exercise as well as 2 and 5 minutes post did not differ among the runs (p=0.300, 0.111 and 0.103, respectively).

<table>
<thead>
<tr>
<th>Table 1. Environmental conditions for the 4.84 km (3 mile) runs.</th>
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<td><strong>Morning Run (1)</strong></td>
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<tr>
<td>Wet bulb temperature (ºC)</td>
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<td>Dry bulb temperature (ºC)</td>
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<td>Globe temperature (ºC)</td>
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<td>Wet Bulb Globe Temperature (ºC)</td>
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<td>Relative Humidity (%)</td>
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† Significantly different (1≠2)
* Significantly different (1,3≠2)
‡ Significantly different (1≠2,3)

DISCUSSION

Physiological Effects Of Heat Strain

Increased heat storage via increased heat production or gain or decreased heat loss is associated with elevated HR and \( T_{re} \), decreased performance and increased risk of heat injury. In our study, indices of environmental heat stress as evidenced by elevated \( T_{wb} \), \( T_{g} \), \( T_{db} \), and WBGT were greater during the noon run. As such, one would expect to see physiological signs of greater heat strain. However, for our participants, a short submaximal exercise bout representative of recreational outdoor exercise performed at different times of the day did not produce a significant difference in heat strain as evidenced by increased HR or \( T_{re} \) during or after the run. This supports the findings of Cochrane and Slievert (7). Tatterson et. al. (8) found similar results with cyclists although the greater relative air motion impacts the heat stress and strain responses compared with those moving slowly. Also, in the study by Cochrane and Slievert (7), the participants’ heart rates reached a plateau at approximately 20 minutes of exercise with \( T_{re} \) reaching a plateau at approximately 30 minutes, the approximate duration of our runs. The results of our study extend the earlier studies. Our
environmental conditions were more representative of actual environmental conditions incurred during outdoor exercise in the heat, as our trials were not performed under laboratory conditions. In addition, our trials provide strong ecological validity as the participants in our study were experienced, acclimatized recreational runners. It could be argued however, that our participants might not have achieved thermal equilibrium due to the short exercise bout and the relatively high intensity. Due to the relatively high intensity of their exercise bout, it also could be argued that they were in an uncompensable heat stress condition whereby they would never achieve a true equilibrium without reducing their metabolic rate.

**Acclimation And Heat Strain**

It is well established that the negative effects of heat stress on performance can be attenuated by a period of acclimation (6,11,12,13). Physiological changes of acclimation include increased plasma volume, increased sweat rate, decreased HR for a given workload, vasodilation at a lower core temperature, and decreased peripheral pooling (11,12,13). Our participants were experienced runners and were accustomed to exercising in the heat. As such they likely had undergone acclimation and experienced the associated physiological changes. This is ecologically valid because the majority of recreational outdoor athletes naturally acclimate as the weather warms. Furthermore as runners with much experience in the heat, they selected a pace that would be tolerable for 4.84 km.

It has been suggested that endurance trained individuals show some of the adaptations that accompany acclimation, and that further adaptations occur with training in the heat (11,12). The max VO$_2$ of our participants was indicative of a high level of cardiorespiratory fitness. As such, it seems logical to assume that the fitness level of our participants may have attenuated the physiological challenges of exercise in the heat.

**CONCLUSIONS**

In conclusion, the results of our study suggest that a short, submaximal exercise bout performed during different times of day during hot weather resulted in equivalent changes in HR and T$_{re}$ and therefore equivalent heat strain in fit, young men. However, it is likely that our experienced runners were acclimated, thus enhancing heat dissipation mechanisms to reduce heat strain. In planning short, submaximal workouts for trained acclimated athletes in hot weather, earlier or later times of day may not be as beneficial in reducing heat strain as we might have previously believed. Assuming that an early-morning or evening workout obviates heat injury concerns during short aerobic bouts seems ill founded. The possibility of heat strain should always be considered under these conditions.

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**REFERENCES**


