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Physiological Responses of Distance Runners during Normal and Warm Conditions

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ABSTRACT

AL-Nawaiseh AM, Bataynefh M, AL Nawayseh AT, ALsuod HM. Physiological Responses of Distance Runners during Normal and Warm Conditions. **JEPonline** 2013;16(2):1-11. The aim of this study was to determine the effects of elevated climate temperature on the exercise-induced physiological responses in distance runners. Ten competitive distance runners (age: 17.75 ± 0.68 yrs) participated in a counter balanced cross over design that consisted of performing a treadmill run (75% VO_2 max) for 30 min under normal (18 ± 1C°; RH 26% ± 2) and warm (40 ± 1°C; RH 12% ± 2) conditions, separated by 15 days. Measures of blood sodium, blood potassium, blood pressure, heart rate, body temperature, blood sugar, and rating of perceived exertion (RPE) were obtained at 5-min intervals (0, 5, 10, 15, 20, 25, and 30 min) from the onset of exercise. Results of this study showed an increase in sodium and potassium concentrations at the beginning of exercise that decreased towards the end of exercise and a decrease in blood sugar at the beginning and an increase at the end. Blood pressure, heart rate, body temperature, and RPE increased all the way to the end of the exercise. These findings indicate that coaches who are responsible for athletes exercising and/or training in warm dry weather should take the athletes' physiological responses seriously and recalculate their training loads according to weather conditions.

Key Words: Running, Heat, Sodium, Electrolyte Loss

INTRODUCTION

Based on a considerable body of knowledge, physical activity is an excellent means to promoting health, physical fitness, and contributes to an improved mental well-being. Regular exercise training, therefore, is the main factor in developing better health to avoid various diseases (e.g., coronary heart disease) and/or to increase the athlete's performance. Thus, increase physical activity and regular exercise have become a new lifestyle for mankind of all ages (4).

Yet, despite the importance of physical activity and regular exercise, there are many obstacles that keep people from exercising. Athletes are also confronted with a number of different obstacles. In particular, it is important that athletes get acclimatized to abnormal weather conditions. One of the most important factors that influence exercise habits and effectiveness is the environment. To be more specific, warm weather, altitude, humidity, pollution, and several other climate conditions have a significant influence on athletic performances in outdoor sports.

The fact that exercise-induced hyperthermia and climate changes may hinder an athletic performance (18) imposes an obligation on stakeholders to investigate practical solutions to ease nature's effect on the general public's participation in exercise programs and, similarly, on the athletes' performance in competitive sports. Unfortunately, this point has not been sufficiently examined. That is why it is very important to investigate and quantify the detrimental effects of weather on exercise. The outcome of such research should help to provide specialists with the "physiological" roadmap to structure and schedule safe and productive training sessions that take into account safety precautions and preventive measure in accordance with the athletes' hydration needs (8).

Heat, humidity, and weather in general were the main problems accounted for during the 1996, 2004, and 2008 summer Olympic Games in Atlanta, Athens, and Beijing, respectively. In fact, in the 2008 Beijing Olympics, the organizers struggled with the effects of weather on the athletes' performance more so than other factors. Similarly, the organizers and participants in the upcoming FIFA's World Cup 2022 (DOHA), and the 2016 Summer Olympics (Rio) will also struggle with hydration and dehydration-induced heat issues (1,6,11).

Since warm, humid weather even without physical effort has an influence on a person's ability to regulate body temperature, exercise and/or participation in any prolonged outdoor athletic event such as a marathon or playing soccer will add a significant burden to the heat regulation mechanism. This factor in itself is likely to be an important limiting consideration for either physical work or an athletic performance. Then, too, there is the possibly of serious heat illness (5) that simply would stop the work or performance.

Given these points of concern, it is important to maintain the athlete's core body temperature to allow for its normal biological and mechanical functions. One way to maintain boy temperature is to sweat, which is regulated by the autonomic nervous system (3). Moreover, the thermal effects of metabolism during exercise bring about an increase in body temperature that redistributes cardiac output to accommodate the increased demand for oxygen at the cellular level. Also, the skin helps by acting as a major heat regulating organ (21).

The increased interest in climate is not just because of the effect on performance, but also because of the potential threat to athlete's health. In addition to the thermal effect of metabolism, exercise in the heat results in an increase in energy expenditure. It should be noted that the major limiting factor for thermal homeostasis in exercising human is the availability of sufficient intake of water to compensate for sweat fluid losses (2).

The main goal of this study was to investigate the physiological responses of trained distance runners in normal and warm conditions. The responses of heart rate, sodium and potassium concentrations, blood sugar, and rating of perceived exertion were examined at 5 min intervals.

METHODS

Subjects

Competitive distance runners (n = 10) from the top ranked athletic club in Jordan (Amman Club) were selected and recruited by a word of mouth (Table 1). The subjects in this study signed an IRB approved informed consent. They were informed of the risk associated with the study.

Table 1. Descriptive Data of the Subjects.

Conditions	Mean ± SD
Age (yrs)	17.75 ± .68
Weight (kg)	61.3 ± 4.69
Height (cm)	171 ± 0.47

Procedures

A heat chamber was designed to control the heat and humidity during exercise. The room was equipped with a treadmill. The subjects' responses to exercise in the normal (18 ± 1°C) condition (NC) and the warm (40 ± 1°C) condition (WC) were determined. Relative humidity was (12 ± 2) and (26 ± 2) in normal and warm conditions, respectively.

During the subjects' first visit (5 runners per day) to the Kinesiology Laboratory, they were introduced to the goals, design, and associated risks of the research. The subjects' signed an IRB-approved consent form and completed an exercise readiness questioner. Then, they were informed of the running uniform (shorts and an A-shirt) and the timing of gathering and food consumption. Maximum oxygen consumption and anaerobic threshold were determined during their first visit to the Laboratory. The Conconi treadmill protocol was conducted with an increase in running speed by 1 $km \cdot hr^{-1}$ after each 400 m. Since the subjects were distance runners, the running intensity was set at 75% of the VO_2 max for 30 min of exercise.

The subjects were paired to perform either a 30-min normal condition run or a 30-min warm condition run in a counterbalance cross-over design. They arrived at the Laboratory for their isocaloric meal at 8:00 am. The exercise protocol was performed at 12:00 noon. After the isocaloric breakfast, the subjects' body weight before exercise, after urination, and after exercise was measured in underwear only. The subjects then entered the testing chamber 15 min prior to the 30-min run for the purpose of acclimatization.

Blood samples were collected from the antecubital vein by certified phlebotomist 10 min before the start of the running test. During the 30-min run, the subjects were asked to stride for few seconds during which blood samples were collected every 5 min during the test. The samples were chilled in a special refrigerator before sending them to the Laboratory for analysis. Body temperature was measured orally. Blood sugar was sampled by finger venipuncture. Rating of perceived exertion (RPE) and blood pressure were determined at 5-min intervals (13) for 30 min using the Borg scale and a sphygmomanometer, respectively. Heart rate was recorded using chest-strapped heart rate telemetry (Polar; Port Washington, NY).

Statistical Analyses

Body temperature, blood sodium concentration ($mmol \cdot L^{-1}$), blood potassium concentration, systolic blood pressure (SBP), diastolic blood pressure (DBP), rating of perceived exertion (RPE), blood sugar concentration ($mg \cdot dl^{-1}$), and heart rate (HR) were measured during exercise in warm and normal conditions. Repeated measure analysis of variance was conducted for all study variables with the Statistical package for social sciences software (SPSS 19). The significance level was set at $P<0.05$.

RESULTS

Body temperature (measured orally) increased as expected during exercise in both normal and warm conditions. The difference in body temperature between the two conditions was significantly higher when exercising during the warm condition (Figure 1).

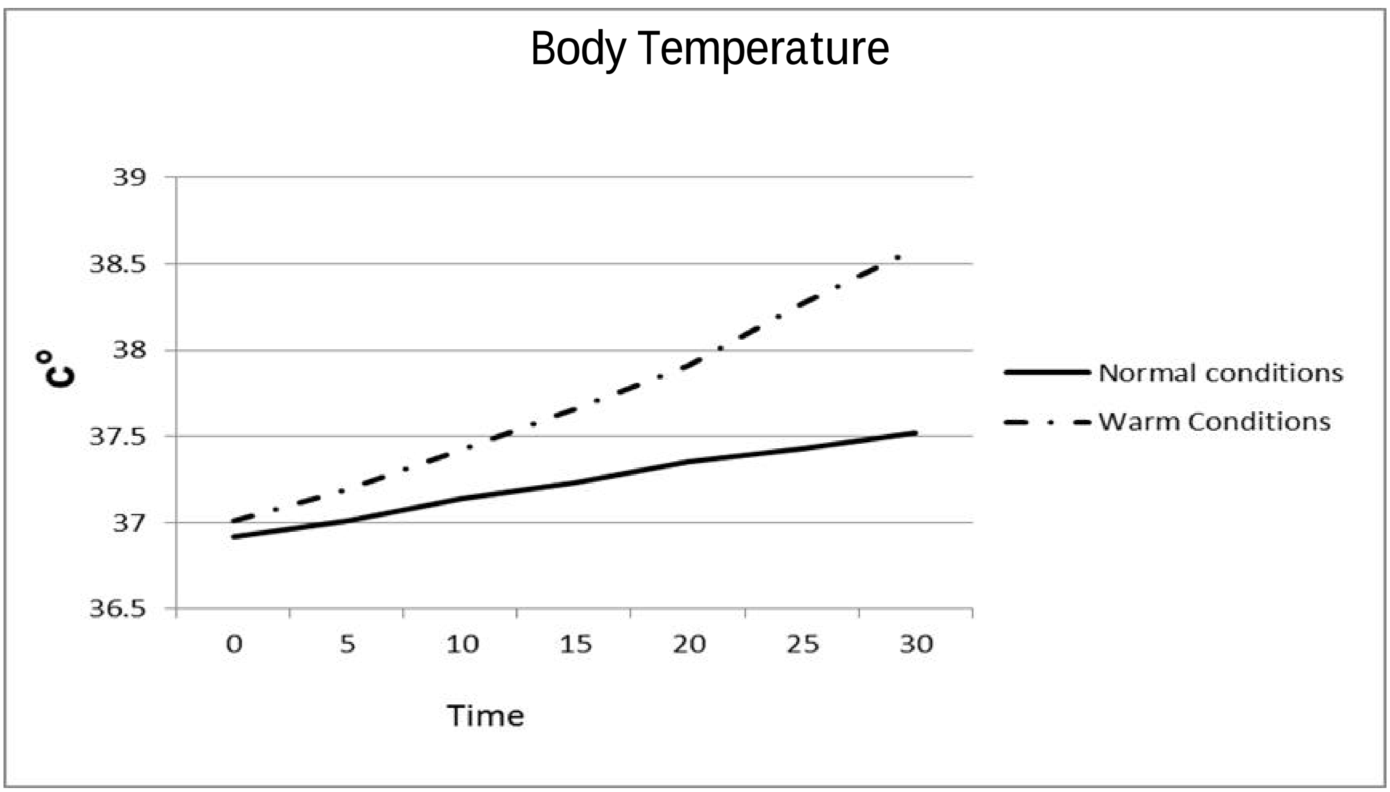

Figure 1. Body Temperature during Exercise.

The increased metabolism and exercise exertion induced a continuous increase in heart rate after the onset of exercise in the warm and normal conditions except for the period between 10 to 15 min at the normal condition where the increase was not significant (P = 0.273). The subjects' heart rate was higher in the warm condition after 10 and 15 min of the onset of exercise (P<0.001) and (P<0.001), respectively (Figure 2).

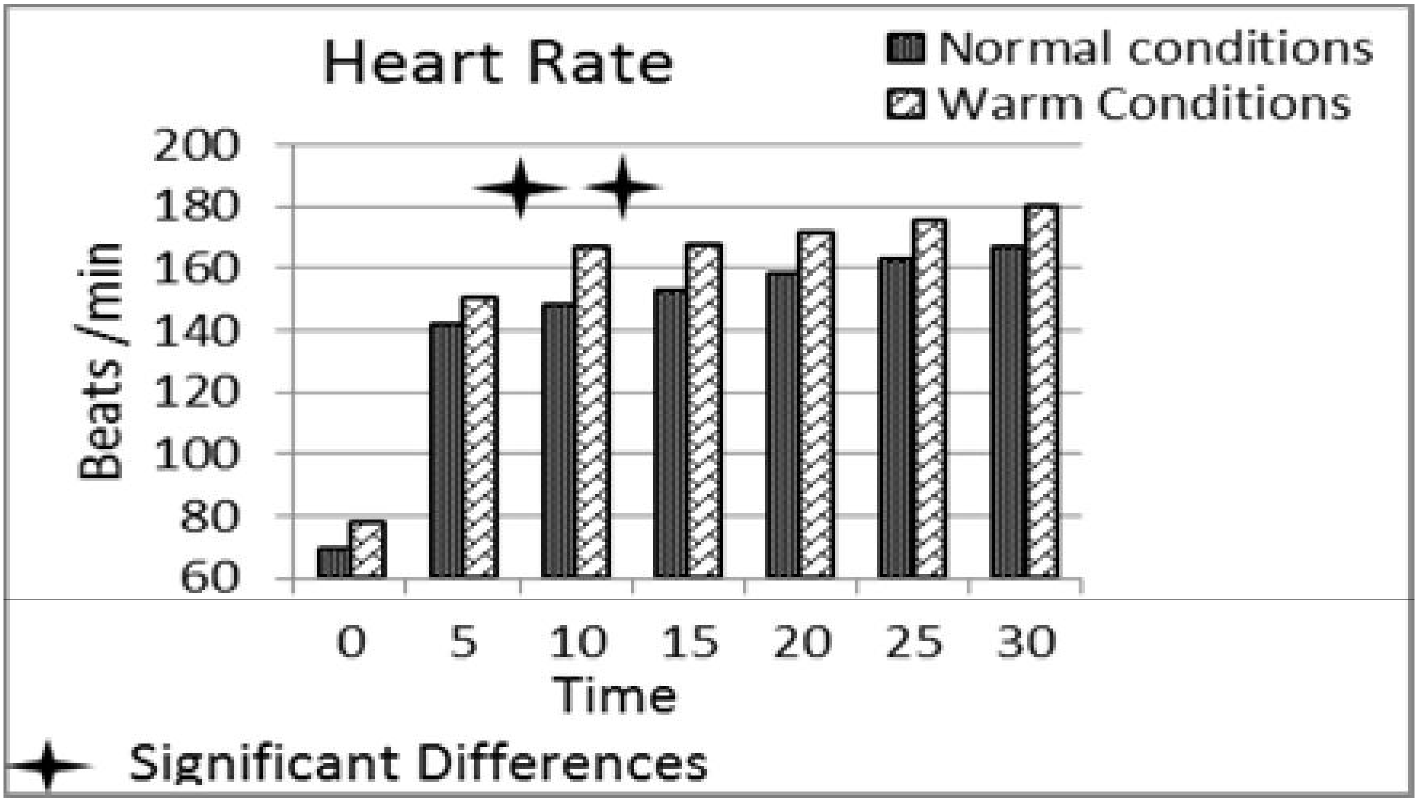

Figure 2. Heart Rate during Exercise in Hot and Normal Conditions.

Sodium concentration (mmol·L^{-1}) increased significantly in the first 15 min of exercise in the warm environment and up to 20 min in the normal condition. Then, it decreased to the end of the exercising protocol. Repeated measure analysis of variance shows significant difference between the warm and normal conditions during the exercise with higher values in the warm condition in minutes 5, 10, and 15 of exercise.

Afterwards, sodium concentration started to drop while its concentration peaked at minute 20 in the normal conditions. Sodium concentration was higher in the normal condition than in the warm condition at minutes 20 and 25 (P = 0.0) and (P = 0.0), respectively (refer to Figure 3). No significant differences in sodium concentration between the warm and normal conditions after 30 min of exercise were found. Figure 4 indicates an increased blood potassium concentration during the warm and normal conditions.

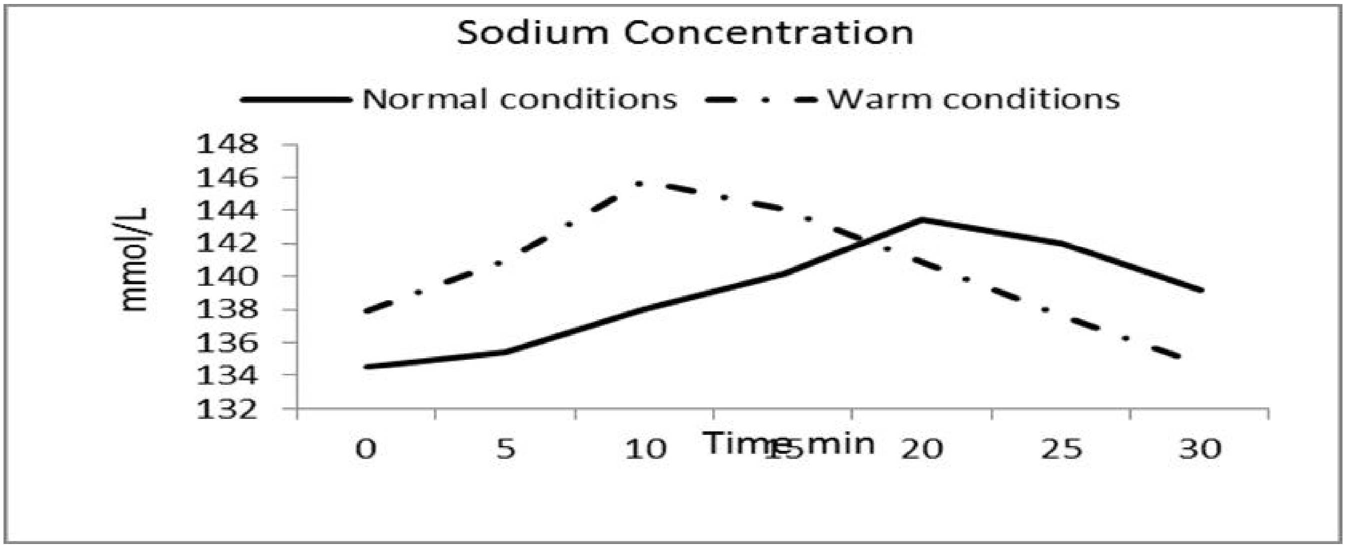

Figure 3. Blood Sodium Concentration during Exercise.

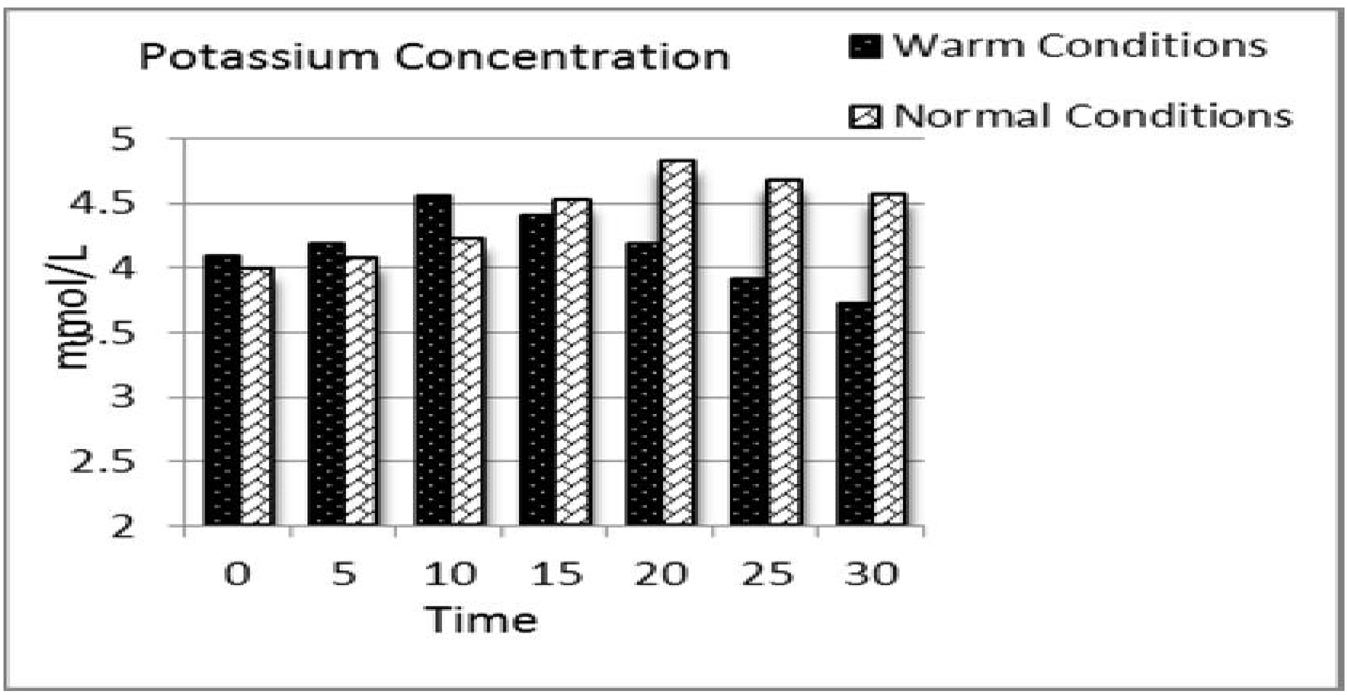

Figure 4. Potassium Concentration in the Warm and Normal Conditions.

Diastolic blood pressure (DBP) was lower in the warm condition at 5, 10, and 15 min of exercise, then, the differences in DBP were not significant, although higher than the normal condition. Systolic blood pressure (SBP), on the other hand, was higher throughout the normal condition except after 30 min of exercise.

Rating of perceived exertion (RPE) was higher in the warm condition (P=0.05) during the exercise, but the difference was not significant at 15 and 30 min of the exercising protocol (Figure 5).

Table 2. Blood Pressure in Normal and Warm Environment.

Time	Diastolic Blood Pressure (mmHg)		Systolic Blood Pressure (mmHg)	
	Normal Condition	Warm Condition	Normal Condition	Warm Condition
00 min	80 ± 0.0	77.0 ± 4.8	120.0 ± 0.0	110.5 ± 1.6§
05 min	88 ± 2.6	85.5 ± 4.4‡	154.5 ± 4.4	151.5 ± 2.4§
10 min	85.0 ± 0.0	71.0 ± 5.2‡	146.5 ± 2.4	124.0 ± 2.1§
15 min	82.0 ± 2.6	76.0 ± 2.1‡	140.0 ± 0.0	134.5 ± 3.7§
20 min	82.0 ± 2.6	83.5 ± 2.4	135.0 ± 0.0	144.5 ± 3.7§
25 min	83.0 ± 2.6	86.0 ± 2.1	138.0 ± 2.6	154.5 ± 4.4§
30 min	84.5 ± 1.6	90.5 ± 1.6	143.0 ± 2.6	164.0 ± 2.1§

‡Significant differences in diastolic blood pressure between warm and normal conditions. § Significant differences in systolic blood pressure between warm and normal conditions.

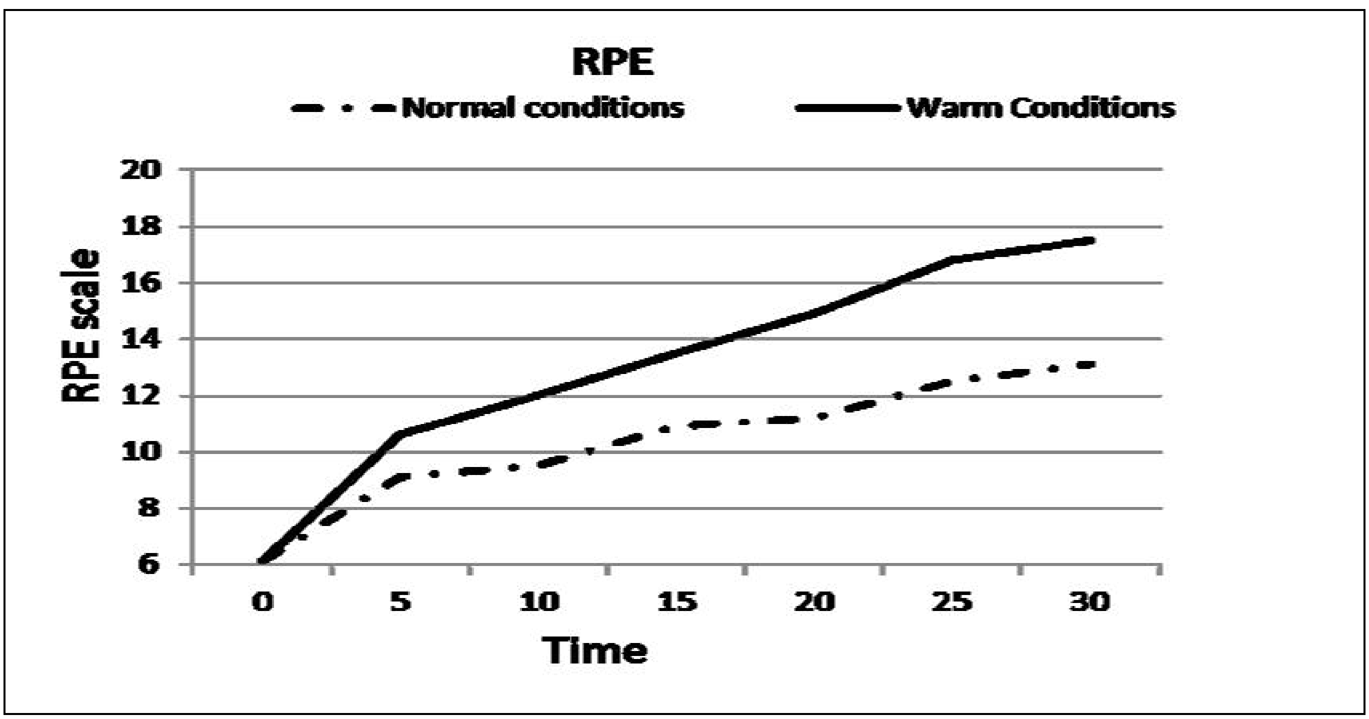

Figure 5. Rating of Perceived Exertion (RPE).

Table 3. RPE during the 30 min Run in Normal and Warm Conditions.

	Rating of Perceived Exertion (RPE)		
Time	Normal Condition	Warm Condition	P = value
00 min	±	±	
05 min	±	±	
10 min	±	±	
15 min	±	±	
20 min	±	±	
25 min	±	±	
30 min	±	±	

Blood sugar concentration dropped after the onset of exercise. Then, it started to increase after the first 15 min of exercise (Table 4).

Table 4: Blood Sugar Concentration.

Time	Blood Sugar ($mg \cdot dL^{-1}$)	
	Normal Condition	Warm Condition
00 min	89.1 ± 9.4	95.3 ± 10
05 min	82.2 ± 10.4§	88.1 ± 9.7
10 min	78.0 ± 12.0§	88.5 ± 14.8
15 min	87.9 ± 11.8§	100.1 ± 15.4
20 min	93.5 ± 6.9§	107.2 ± 14.3
25 min	97.3 ± 4.7§	116.5 ± 11.7
30 min	99.6 ± 3.9§	124.0 ± 11.7

§Significant differences in blood sugar between normal and warm conditions.

DISCUSSION

Body Temperature

Although the increase in body temperature was not very high (38.6 ± 0.15°C) and (37.5 ± 0.6°C) for warm and normal conditions, respectively, we assume that the increase in core temperature must have been higher since it is usually higher than body temperature by 0.5°C (12). Due to cultural issues, measuring rectal body temperature was not an option.

Heart Rate

McFarlin and Mitchel (14) found differences in heart rate between hot (38°C) and cold (8°C) environments while cycling at 60% of their VO_2 Peak after 30 min of exercise. Their results contradict our results at the 30 min point of exercise, where the difference in our study was not significant. Although the subjects' level of conditioning was not reported in the McFarlin and Mitchel's study, the heart rate reported in the results while working at 60% of VO_2 Peak appears to reveal lower fitness levels. Additionally, the relative humidity in the McFarlin and Mitchel's study in the warm condition was 45% and their subjects were acclimated for warm weather by exercising 1 hr for 4 days in similar conditions prior to the study. Furthermore, our thermoneutral conditions were much warmer (18 ± 1°C) compared to the McFarlin and Mitchel study (14).

Sodium and Potassium Concentration

The attenuated increase in sodium concentration and the reversed shape in the sodium figure could be due to increased sodium secretion with increased sweat rate. With the increased secretion, it is very likely that blood concentration of sodium decreased. We assume that this also was the reason the sodium levels increased earlier in the warm condition compared to later in the warm condition (12,15,20). Similar to the increase in sodium, potassium concentration increased during warm and normal conditions, this similarity in the sodium and potassium response to exercise could be linked to changes in plasma volume and/or distribution (17).

Blood Pressure

At intense exercise, the increase in blood flow in untrained subjects often fails to match the increased demand for blood and oxygen. However, in elite athletes this is not the case. Blood flow matches the tissue demand for oxygen without having a negative effect on blood pressure regulating mechanisms. This is done without necessarily seeing an increase in cardiac output. (7) The decrease in systolic blood pressure was very likely induced by a compromised sympathetic vasoconstrictor function and the metaboreflex (9,19,21).

Blood Glucose

The increased levels of blood glucose after 10 min of exercise is likely the result of: (a) an increase in hepatic glycogenolysis and gluconeogenesis; (b) a decrease in the insulin levels during prolonged exercise; and (c) the concurrent increase in glucagon that stimulates the release of liver glucose into the blood stream (10).

CONCLUSIONS

This study revealed the concentration of blood minerals while exercising at intervals of 5 min in normal and warm weather conditions. The use of well-trained distance runners gave an insight for the study to conclude results more applicable to real life situations. The fact that sodium and potassium concentrations peaked 10 min earlier in the warm condition compared to the normal condition suggests that subsequent studies should examine fluid mineral concentration when exercising in different environmental conditions. This could also have implications regarding the timing of fluid intake for athletes who take part in prolonged exercise in warm weather conditions.

We speculate that the decrease in blood minerals concentration is not only a result of increased sweating, but also the result of blood redistribution in the body. This speculation is supported by the decrease in blood pressure when exercise was conducted in the warm condition. Additionally, it was reported in a previous study (14) that the increase in heart rate during exercising in the heat was not associated with increased oxygen consumption.

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