



Heat Stress and Physical Capacity: A Case Study of Semi-Professional Footballers

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Abstract

Background: The aim of this study was to determine heat stress effect on physical capacity of semi-professional footballers in Iran by means of oxygen consumption measurement, heart rate monitoring and WBGT assessment environmental conditions.

Methods: This study compared two different thermal environmental conditions related to sub-maximal exercise and its effect on human physical capacity. Thirty two male footballers (age 25.9 ± 1.4 year; height 176 ± 2.9 cm and weight 71 ± 9.8 kg) were investigated under four workloads (50,100,150 & 200 W) in two different thermal conditions in the morning (WBGT=21 °C) and afternoon (WBGT=33 °C) in summer. Each test cycle lasted for 10 minutes with a 10 min interval for recovery and rest between every workload. In the end of each stage, the heart rate, blood pressure, skin temperature and oral temperature were measured and recorded. Expired air was collected and its volume was measured using standard Douglas bags. The WBGT index was also used to monitor the stressful heat condition.

Results: Heart rate and VO₂ consumption findings for different workload showed a significant difference between morning and afternoon ($P < 0.001$). HR and VO₂ consumption in both morning and afternoon courses showed a liner relation ($r = 0.88$, $r = 0.9$ respectively).

Conclusion: With increasing work load beside heat stress, heart rate and oxygen consumption increased. It is recommended that with $T_a > 35$ °C or $WBGT > 28$ °C, physical activities and performing exercises should be avoided in order to reduce the risk of heat stress-related conditions in athletes

Keywords: Heat stress, Physical capacity, WBGT, Football

Introduction

Nowadays physical activity is an unavoidable part in every people life. Many people take physical exercises as a daily routine for the reasons of health and fitness and many others take these exercises as a part of their profession – amateur and professional athletes and because every work environment has its own risk factors and problems

affecting health of people working in that atmosphere, these athletes are of no exception. Heat and humidity are two main physical risk factors of environment. Therefore, physical activity for reasons of occupation or recreational exercise in hot and humid environments can lead to serious harm from dehydration, heat exhaustion and heat stroke

(1-5). Work or sports participation in the heat for long periods can lead to progressive heat injury, which is associated with impaired physical and mental performance (4-6). Heat injury is a potentially lethal condition that is considered to be completely preventable. Despite expert opinion and psychological information, the amount of science and knowledge in this field is not adequate. So one can easily recognize the need for more analytical studies to be performed to evaluate intervention programs and/or identify new risk factors. Besides, a critical necessity exists in collecting and documenting new data on incidence of injuries and in assessing general attitudes and beliefs about heat stress among youth athletes, their caregivers and their coaches (7-9).

Heart rate provides an index of the degree of circulatory strain during exercise (9). It is probable that aerobic exercise can be greatly affected by heat stress and hypohydration (10, 11). The person's ability to tolerate heat strain is affected by hypohydration (10). In sports medicine heat stress from the environment is a matter of concern because of the perceived risk of heat casualties, special heat stroke. Nowadays, most sports regulating agencies propose environmental indices such as the WBGT for assessing risk and setting environmental thermal limits for exercise and competition. But the limits are not justified by evidence (7, 12). On other hand, lack of this kind of studies in developing countries such as Iran, which has a young population with a high percentage of them involving in sports activities that increases every day and knowing that the nature of the weather in this country is a hot and dry one, the need for establishing national recommendation and standards can be easily understood.

The purpose of this study was to determine heat stress effect on physical capacity of semi-professional footballers in Iran by means of oxygen consumption measurement, heart rate monitoring and WBGT assessment environmental conditions.

Materials and Methods

This study was of a descriptive-analytic nature and also a cross-sectional one. This study was per-

formed on 32 semi-professional male footballers playing for one of Iran's medical universities, with at least 3 days a week routine exercise and for a period of time not less than 2 hours. The age average was 25.9 ± 1.4 year; average height was 176 ± 2.9 cm and mean weight was 71 ± 9.8 Kg. The process and purpose of the study were described fully and clearly to the participants and they took part in the study with their willingness and were free to leave the tests whenever they desired. The tests were performed during 2 time periods in different temperature conditions, T_a and WBGT; in the morning [(8-11:30 a.m.) ($24-25^\circ\text{C}$) ($21-22^\circ\text{C}$)] and afternoon [(15:30-18 p.m.) ($39-41^\circ\text{C}$) ($33.24-33.59^\circ\text{C}$)], while the participants were taking definite exercises in summer.

Participants performed four consecutive workloads under sub maximal limit (50, 100, 150, 200 W) on an ergo meter bicycle (Proteus). Beginning by setting up the participant on the bike to ensure correct seat height (knee slightly bent at bottom of cycle), and then the heart rate monitor was placed on the participant's body. The test was started in 50 watt workload and the heart rate was measured each minute and this procedure continued for 3-5 min (until a steady heart rate was achieved). The test continued for 2nd, 3rd and 4th workloads. Each stage lasted for 10 minutes with a 10 min interval for recovery and rest between every workload (9). In the end of each stage, the heart rate, blood pressure, skin temperature and oral temperature were measured and recorded. (instruments applied for the measurements were as follows: blood pressure meter LAICA-Model MD6132 made in Italy, digital skin thermometer model TM-905 (Dual Channel Thermometer) made in Japan). In order to calculate average skin temperature, four point temperatures on every participant's body (chest, arm, femoral and ankle) were determined (13), and then this equation was used for calculations:

$$t_{sk} = \sum_i k_i t_{ski}$$

Where, t_{ski} is skin temperature in each point and K_i is the correction factor in each point.

The VO_2 consumption test is a measure of aerobic power in athletes. Oxygen and carbon dioxide

were analyzed by Oxycon-4 model Mijnhardtoxycon system-4 made in the Netherlands. Expired air was collected and its volume was measured using standard Douglas bags. Oxygen uptake was calculated from measures of ventilation and the oxygen and carbon dioxide in the expired air, and the maximal level was determined at or near test completion. Measuring Environmental Conditions and WBGT: The natural wet-bulb temperature (T_{nw}), the black globe temperature (T_g), the (shade) air temperature (T_a), humidity, barometric pressure and other effects were measured. Calculations: The three elements T_{nw} , T_g , and T_a are combined into a weighted average to produce the WBGT for outdoor environment (14).

$$WBGT = (0.7 \times t_{nw}) + (0.2 \times t_g) + (0.1 \times t_a)$$

WBGT measuring instrument used in this study was WBGT-meter model MTH-1 made in U.K, and at every 15 minutes all parameters were read and recorded accordingly. Statistical analyses were done with SPSS 11.5 for Windows. Generally, averages accompanied with standard deviations are presented. Paired-samples t-tests were used to determine differences between conditions (Heart rate and VO_2 consumption), and one sample t-test was used to determine differences between T_a and WBGT-index in the morning and afternoon. Two-way ANOVA was used to compare the mean differences between groups that have been split on two independent variables. Simple linear regression and correlation were used to examine

relations between the measures. A two-tailed α -level of 0.05 was used for all significance tests.

Results

Data on each workload, environmental conditions in the morning and afternoon and also WBGT values, the heart rates and blood pressures, body and air temperatures, from the graded exercise test are presented in Table 1. Heart rate was measured and subsequently recorded at the end of every 4 steps of workloads both in the morning and afternoon sessions. The recorded results (Table 1) showed a significant difference between morning and afternoon values ($P < 0.001$). VO_2 was also measured and subsequently recorded at the end of every 4 steps of workloads both in the morning and afternoon sessions. The recorded results (Table 1) showed a significant difference between morning and afternoon values ($P < 0.001$). Comparisons of the average of T_a and WBGT values measured in the morning and afternoon courses are presented in Table 1. Statistical difference between these averages was of a significant nature ($P < 0.001$). Plotting heart rate (HR) and VO_2 consumption against WBGT showed that HR and VO_2 in every workload in the morning session in comparison to the same case in the afternoon course showed a noticeable increase. This increase happened parallel to WBGT increase (Fig. 1).

Table 1: Physiological and environmental conditions in four workload in sub-maximal exercise

Workload (Watt)	Day Time	N	HR (beat/min)	VO_2 (L/min)	T_{sk} °C	T_{oral} °C	T_a °C	WBGT _{index} °C	RH %
50	Morning	32	112.6±3.5 **	0.74±0.04**	33.34±0.19	36.52±0.17	24.83±0.4	21.86±0.64	51±3
	Afternoon	32	119.8±3.5 **	0.87±0.04**	34.54±0.29	36.6±0.16	39.78±1.3**	33.24±0.41**	45±2
100	Morning	32	123±3.2 **	1.14±0.12**	34.11±0.28	36.59±0.21	24.83±0.4	21.86±0.64	51±3
	Afternoon	32	136±3.4 **	2.01±0.13**	36.11±0.28	36.89±0.18	39.78±1.3**	33.24±0.41**	45±2
150	Morning	32	148±6.9 **	1.73±0.12**	34.41±0.2	36.64±0.21	25.68±0.32	22±1.07	51±3
	Afternoon	27*	158±7.2 **	2.6±0.12**	36.5±0.12	36.75±0.25	40.7±1/03**	33.59±0.48**	45±2
200	Morning	26*	161±4 **	2.23±0.23**	35.11±0.48	36.8±0.25	25.68±0.32**	22±1.07	51±3
	Afternoon	20*	165±3.8**	2.9±0.16**	37.11±0.8	37.7±0.9	40.7±1/03	33.59±0.48**	45±2

Values are $\mu \pm SD$. VO_2 consumption; N, number of participator; HR, heart rate; T_{sk} , skin temperature; T_{oral} , mouth temperature; T_a , air temperature; RH, relative humidity. *In 150 watt workload 5 participants left the test before the completion of the due time and also in 200 watt session both in the morning and afternoon tests, 6 and 12 persons left the test respectively. ** $P < 0.001$ vs.

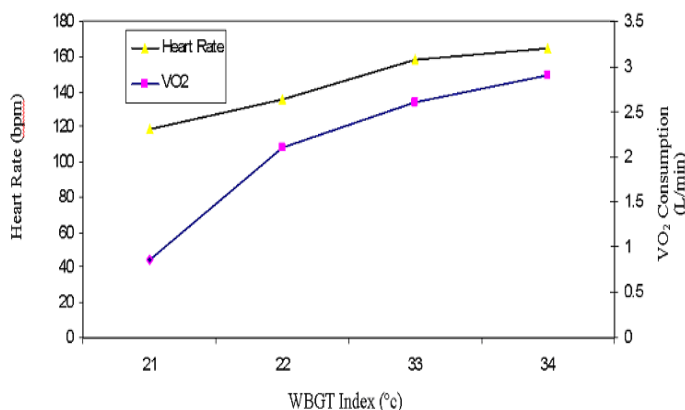


Fig. 1: Changes in heart rate and VO₂ consumption with increasing WBGT index

In another plot, HR and VO₂ consumption increased progressively in a curvilinear fashion with increasing Ta (Fig. 2). The differences between heart rate values in the morning and afternoon courses in varying workloads of 50, 100, 150 and 200 watts were 7, 13, 10 and 4 beats/min respectively. The differences between VO₂ consumption values in the morning and afternoon courses in varying workloads of 50, 100, 150 and 200 watts were 130, 870, 870 and 670 ml/min respectively.

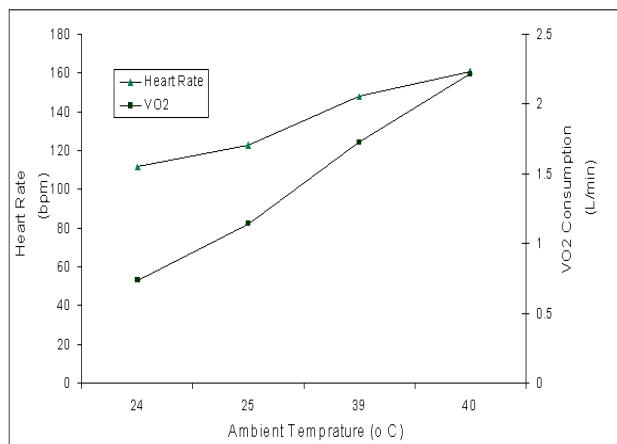


Fig. 2: Changes in heart rate and VO₂ consumption with increasing ambient temperature

Regression Analysis of the relation between HR and VO₂ consumption in both morning and afternoon courses showed a linear relation ($r=0.88$, $r=0.9$ respectively). Further analyses showed a lin-

ear regression relation between HR and VO₂ with WBGT and Ta ($r=0.79$, $r=.81$ respectively). According to the results obtained from one sample t-test, the WBGT values obtained from the tests were compared with their standards representative (28 °C) and it was made clear that the WBGT of morning course was under the standard threshold limit but its amount for the afternoon session was higher than the threshold limit of recommended standard. When WBGT and Ta from morning and afternoon sessions were compared, a significant difference was observed ($P<0.001$). It should be stated that from the participants of the 4 levels of test, some left the test because of its hardness for them to continue (in 150 watt workload 5 participants left the test before the completion of the due time and also in 200 watt session both in the morning and afternoon tests, 6 and 12 persons left the test respectively).

A two-way ANOVA test was conducted that examined the effect of temperature condition and workload intensity level on heart rate. Our dependent variable, heart rate, was normally distributed for the groups formed by the combination of the temperature condition and workload intensity level as assessed by the Shapiro-Wilk test. There was homogeneity of variance between groups as assessed by Levene's test for equality of error variances. There was a significant interaction between the effects of temperature condition and workload intensity level on heart rate, $F(2, 26) = 3.643$, $P = .014$. Simple main effects analysis showed that there the more stressful temperature condition, the more heart rate when the workload intensity was high ($P = 0.002$).

Another two-way ANOVA test was conducted to examine the effect of temperature condition and workload intensity level on Oxygen consumption. Our dependent variable, Oxygen consumption, was normally distributed for the groups formed by the combination of the temperature condition and workload intensity level as assessed by the Shapiro-Wilk test. There was homogeneity of variance between groups as assessed by Levene's test for equality of error variances. There was a significant interaction between the effects of temperature condition and workload intensity level on

Oxygen consumption, $F(2, 26) = 4.243$, $P = 0.011$. Simple main effects analysis showed that the more stressful temperature condition, the more heart rate when the workload intensity was high ($P = 0.001$).

Discussion

The findings of this study which were derived by rational and systematic methods used in this study, alongside some other studies (15, 16), proved the linear relationship between heart rate and VO_2 consumption. In other words, with increasing the workload, both heart rate and oxygen consumption progressively increase (16-19). In hot and humid environments, physical performance of the individuals decreases due to the increase in perspiration, hypohydration and losing electrolytes (18). Krstrup et al. (21) showed that when heat stress becomes uncompensable, HR during submaximal exercise increases disproportionately with increasing levels of heat stress. This finding was in accordance with the results of our study in two different thermal conditions. Whether VO_2 max is reduced as a result of heat stress has been debated (16, 22-23). The present study found that the increase in environmental heat stress is related to elevated levels of oxygen demand, that this increase in O_2 uptake was 160-870 ml/min. Some studies report no change (25-27), whereas others have reported small or modest reductions on the order of 150–350 ml/min (16, 27-29).

Regarding the unchanged nature of all four different workloads in morning and afternoon sessions the only changed parameter was environmental temperature, with a growing nature. This increase in temperature has affected the physical activity of practitioners in the form of more oxygen demand. Since our study had a different nature from the above mentioned studies, the situation and thermal condition of the tests were quite realistic. Indeed, with any increase in workload, the body will need more oxygen to perform the assumed task. Our study established that any increase in thermal stress of the environment leads to more strain and stress on cardiovascular system of the body that

results in lower performance of the participants which leaving the test during submaximal period and heavy workloads by some of them is a good evidence for this matter of fact. The WBGT index although is an established standard index in assessing occupational environments heat stress (14), can be feasibly used to monitor heat stress in sports events and environments. In this regard, the study mainly reported by Grimmer et al., (30) can be mentioned as a good practical example of using WBGT index in assessing heat stress condition sports activities environments.

Conclusion

Our study revealed that with increasing work load beside heat stress, the two physiologic indicators of body response to heat, heart rate and oxygen consumption also increased. Therefore considering ambient temperature in the form of dry bulb temperature (T_a) or WBGT index is essential for determining guidelines and permits for national or local sports events and it is recommended that with $T_a > 35^\circ C$ or $WBGT > 28^\circ C$, physical activities and performing exercises should be avoided in order to reduce the risk of heat stress-related conditions in athletes.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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