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Evaluation of the impact of hot environmental conditions on physical activity among soccer players

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Abstract. – OBJECTIVE: The aim of the study was to evaluate the effect of a hot environment on several physiological variables of soccer players and suggest feasible solutions to it.

SUBJECTS AND METHODS: The study is of prospective design, considering 66 participants comprising professional soccer players. All the participants completed the Physical Activity Readiness Questionnaire (PARQ). The participants were assigned to 3 different groups. Each group was assigned 22 participants. They were made to play in three different chambers, maintained at cool, moderate and hot temperatures. Players were made to play and various variables were determined to assess the effect of hot temperature on them.

RESULTS: Several variables were determined including absolute and relative oxygen uptake, heart rate, minute ventilation, the blood concentration of lactate and time to get exhausted. All the variables of players who played in hot temperatures have revealed higher heart rate, ventilation and increased lactate concentration. Players in a hot environment ran out faster.

CONCLUSIONS: The study was concluded due to the players' dehydration and physiological deteriorated factors in a hot environment, leading to poor performances and also affecting the players' health in the long run. Further, the study suggested improving the environment around the game venues.

Key Words:
Hot environment, Physical activity, Soccer players, Sports, Temperature.

Introduction

Homeostasis is the phenomenon of maintenance of a stable environment internally including hormonal or electrolyte balance. It is a broad concept covering the maintenance of equilibrium of physiological variables like temperature and biochemical process regardless of the change in the external physical environment. Hypothalamus is primarily responsible for maintaining the temperature internally by generating or losing the body's heat[1]. Instances like performing exercise or increased physical activities, require thermoregulation which maintains the physiological mechanisms by initiating various responses. Due to the cold environment, homeostasis is maintained by increasing the heart rate and blood pressure (especially systolic). Also, the cold environment can stimulate a sympathetic response, which results in a rise in heart rate, which again, can be associated with vagal activation. It has been also said that peripheral vasoconstriction is linked to exposure to the cold environment, which increases systemic vascular resistance and blood pressure (especially diastolic pressure)[2].

A hot environment or heat stimulates the sympathetic nervous system, which leads to an increase in heart rate and due to faster beats, the stroke volume reduces significantly which decreases the preload. A hot environment also causes dehydration (called heat-induced dehydration), which results in low stroke volume, decreased cardiac output and hence, reduced blood pressure. This also decreases the blood supply and hence, reduces the peripheral distribution of nutrition and oxygen. Finally, this causes fatigue[3].

Similarly, a cold environment causes several physiological changes or responses to maintain homeostasis. A hot environment or high environmental temperature may result in an elevation of body temperature due to increased physical activities like playing soccer. With the increasing temperature, like when running a marathon or playing soccer, it has been observed in literature[3,4] that the performance of the players deteriorated

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due to the negative impact on their physiological variables like blood pressure, heart rate and respiratory rate. This is mainly due to dehydration and consequently causes fluid imbalances[4]. Due to increased physical activity, homeostasis is maintained till the physiological responses can cope with the environmental changes. But the failure of homeostasis leads to a rising in core brain temperature, causing heat stress, and finally leading to hyperthermia. This state is characterized by impairment of cardiovascular function and decreased blood pressure. The drop in blood pressure leads to reduced circulation and exchange of oxygen at the alveolar level. High-intensity exercise or physical activity lead to lowering of peripheral circulation and results in cellular dysfunction and accumulation of metabolic waste like lactate accumulation[4,5].

Due to all these effects, many athletes today are already affected and they perform poorly. Moreover, playing in hot environment and experiencing negative impacts from it, results in poor health conditions in the long run. A potentially contaminated environment and lack of pollutant-free air aggravate the situation[6,7]. Due to all the factors combined including pollution and a hot environment, their health is affected, which goes unnoticed. Many studies[8,9] pointed out significant disturbances in the likelihood and emergence of several health conditions in this population of athletes. Due to the exposure to extreme conditions, the athletes are affected by oxidative stress in the respiratory system leading to chronic cardiovascular and respiratory conditions[8]. There are studies[8-10] which have documented the findings of oxidative stress and its effects among the population of athletes engaged in heavy sports like soccer, who have been exposed to a hot environment continuously while having a game, leading to chronic conditions. It was also observed that severe and tough training sessions affected athletes equally as well.The absence of adequate facilities, severe training, pollution, and continuous exposure to the hot environment, has resulted in several dysfunctions and increased frequency of heat stroke[11]. The accumulation of pollutants and the increase in lactate concentration also caused cell damage.This also resulted in a long-term impact on the health, performance and endurance of the athletes[12].

The study intends to find out the changes in absolute and relative VO_2, heart rate, minute ventilation, blood lactate concentration, and time to exhaustion by the players, due to higher temperature. The study further intends to suggest some feasible solutions to a hotter environment to provide a better environment for the soccer players which will eventually prevent long-term negative impacts on them.

Subjects and Methods

Study Type and Source of Data

The study has a prospective design that was conducted in Henan, China. The study considered the voluntary participation of professional soccer players. After applying the inclusion and exclusion criteria, the study finally considered only 66 participants. All the participants completed the PARQ. Everyone was explained the whole study process and their doubts were clarified.

Inclusion Criteria

The players, who were professional soccer players, aged between 18 years to 28 years old, who had no chronic conditions, cooperative about the whole study process, and players, who have been actively playing soccer are only included in this study.

Exclusion Criteria

The players who did not cooperate with the whole study process, were injured at the beginning of the study, had a recent history of injury, had a chronic condition, and players, who had a recent history of surgery are all excluded.

Experiment Design

The participants were randomly assigned to 3 different groups. Each group was assigned 22 participants. These 3 groups were made to play soccer in each chamber maintained at 8±0.5°C (cool environment), 20±0.5°C (moderate environment) and 35±0.5°C (hot environment). The groups were assigned to each chamber as group 1 (for players, who were made to play in a cool environment), group 2 (players, who were made to play in a moderate environment) and group 3 (players, who were made to play in a hot environment). The soccer match was made to play full time (90 minutes) in each chamber with 22 players (11 players in each team) and these 3 groups were exposed to cool temperature, moderate temperature, and hot temperature. The humidity was maintained at the same level in each condition using a humidifier. All the participants were made to play soccer, before which they had to fast

Table I. Basic characteristics of the participants in each group.

Characteristics	Group 1 (8 ± 0.5°C)	Group 2 (20 ± 0.5°C)	Group 3 (35 ± 0.5°C)
Number of participants	22	22	22
Age (years)*	23.32 ± 3.88	23.18 ± 2.49	24.10 ± 2.57
Height (cm)*	176.88 ± 4.25	175.35 ± 4.98	175.98 ± 4.68
Weight (kg)*	69.25 ± 6.21	70.12 ± 3.21	69.91 ± 5.26
BMI (kg/m^2)*	22.25 ±3.22	22.35 ± 3.15	22.25 ± 3.32
VO_2 max (L/min)*	3.26 ± 0.36	3.27 ± 0.35	3.25 ± 0.35
VO_2 max (mL/kg/min)*	48.32 ± 6.78	48.35 ± 6.85	48.34 ± 6.81

*Expressed as mean ± standard deviation.

for 3 hours and were asked to avoid any kind of physical activity. They were strictly controlled for the avoidance of consumption of alcohol, caffeine or tobacco or related products for the whole study period. Before the trials, all the participants underwent oxygen uptake examination (VO_2 max) under the normal environmental condition. This test was conducted to assess the exercise intensity of the participants by using the Astrand protocol.

Statistical Analysis

The study used SPSS 25 (IBM Corp., Armonk, NY, USA) for efficient statistical analysis and expressed the variables as mean±SD. The study conducted ANOVA and Tukey post-hoc test for analyzing the heart rate, minute ventilation, oxygen uptake, blood concentration of lactate and time to get exhausted. The level of significance was considered as α=0.05 for analysis.

Ethics Committee Approval and Consent to Participate

This study was performed between 2021 and 2022 and in compliance with Universiti Sains Malaysia (USM), Penang, Malaysia and required informed consent was obtained from the patients before the study.

Results

The study found that the mean age of group 1, group 2 and group 3 were found to be 23.32±3.88 years old, 23.18±2.49 years old, and 24.10±2.57 years old. The characteristics of the participants are listed in Table I.

The study considered several variables to assess the effect of hot temperature on the players. Players were asked to avoid drinking water or having food during the time of the activity. The study found both the absolute and relative oxygen uptake (VO_2) in Group 2. At rest, all the groups have shown similar oxygen uptake. But with the time, oxygen uptake increased in group 3 in the first 5 minutes. After the first 5 minutes, group 2 and group 3 players have shown that their oxygen uptake increased almost in a similar pattern. Till the first 20 minutes, oxygen uptake in group 2 was lower as compared to group 1 and group 3. After 20 minutes, both the absolute and relative oxygen uptake increased and finally, group 2 had significantly higher absolute and relative oxygen uptake compared to groups 1 and 2 (p<0.05). Figures 1 and 2 show the findings of absolute and relative oxygen uptake at rest, and sub-maximal and maximal activity, respectively.

As the participants are professional's players, their heart rate was well stabilized at around 60 beats per minute, during the resting state. While they started to play, the heart rate of group 3 players starts increasing steadily and finally be-

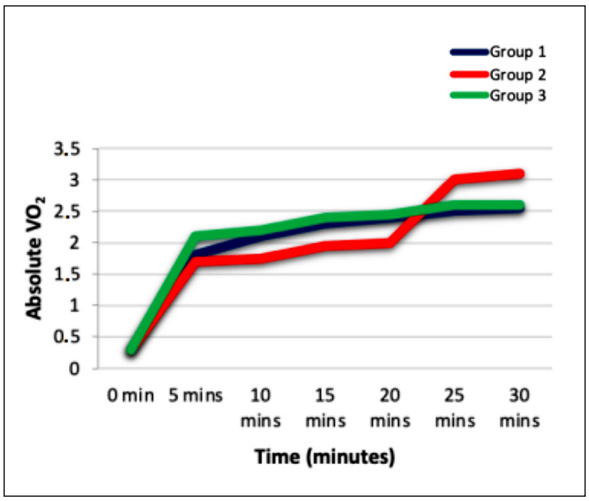

Figure 1. Variation of absolute VO_2 (*oxygen uptake*) among the three groups during the rest, submaximal and maximal activity.

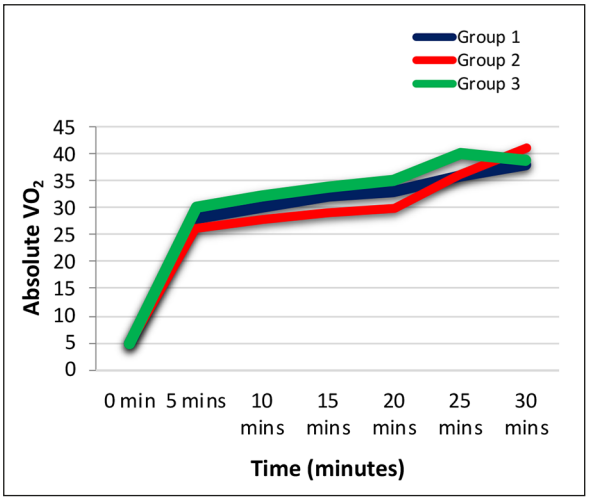

Figure 2. Variation of relative VO_2 (*oxygen uptake*) among the three groups during the rest, submaximal and maximal activity.

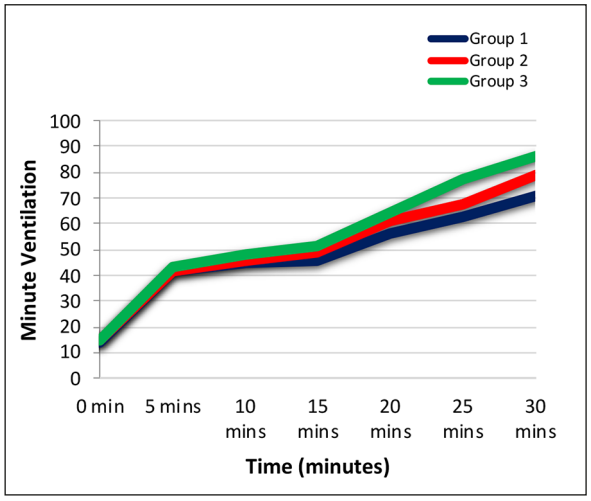

Figure 4. Minute Ventilation (*mean value*) in each group, due to the temperature at different intervals.

came significantly higher than group 1 and group 2 (p=0.000). Therefore, increased temperature is the cause behind the increase in heart rate. Figure 3 shows the variation in the heart rate of the players in each group with time.

A similar effect has been observed in minute ventilation among the players of all the groups. In the beginning, their minute ventilation was almost the same for all the groups. But, with the time and activity, minute ventilation increased in group 3 players significantly as compared to group 2 and group 1 (p<0.05). While the difference in minute ventilation between group 2 and group 1 was also found to be analytically significantly higher. Figure 4 has plotted the variation of Minute Ventilation with time, in each group.

Due to the physical activity, the accumulation of lactate and thereby, increase of the same in the blood occurred, resulting in a rising level of lactate. Group 3 players have shown to have increased levels of lactate with time, which is significantly higher as compared to group 2 and group 1 player (p<0.05). Figure 5 shows the variation of lactate concentration in the blood, in each group.

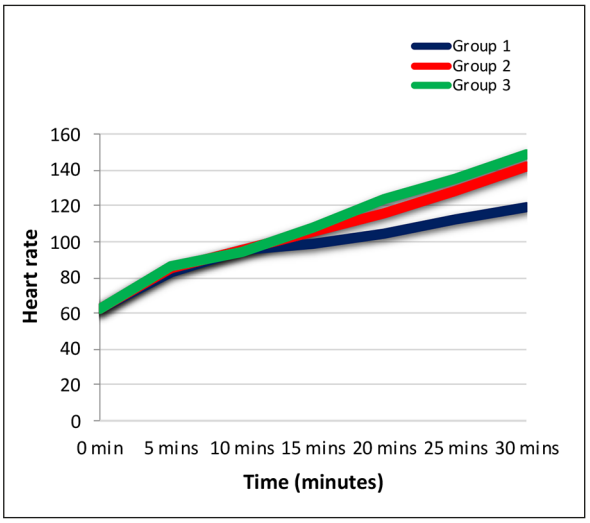

Figure 3. Heart rate (*mean value*) in each group, due to the temperature at different intervals.

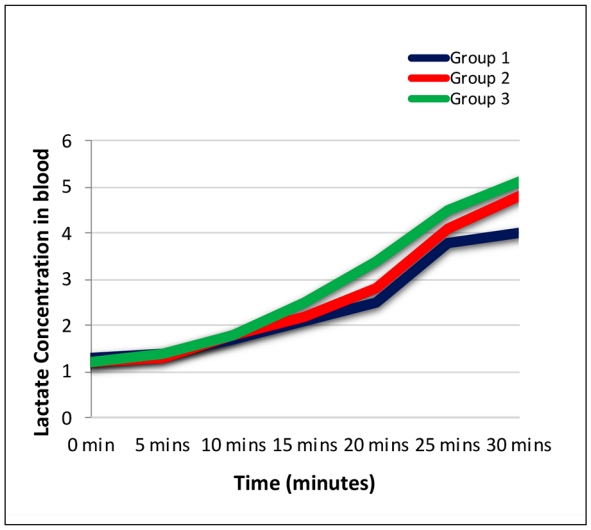

Figure 5. Lactate concentration of Blood among each group.

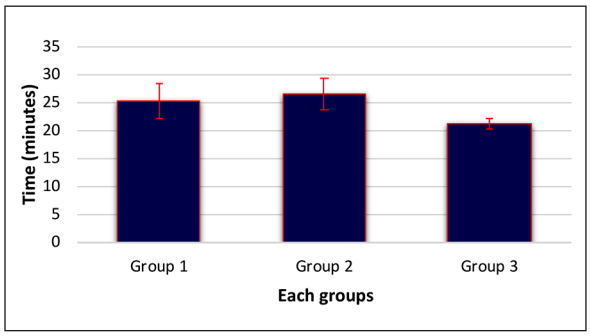

Figure 6. The time to exhaustion in minutes for each group.

The study further found that the players in group 3 exhausted significantly faster than the other groups ($p<0.05$). Group 3 players were exhausted at 21.2±0.9 minutes, followed by group 2 players at 26.4±2.9 minutes and group 1 players at 25.2±3.2 minutes. Figure 6 shows the comparison between the times required to get exhausted by the three groups.

The study employed SPSS 25 (IBM Corp., Armonk, NY, USA) for efficient statistical analysis and to find out the significance. Table II shows the *p*-value (statistical analysis) of each variable examined in this study and remarks against each variable.

Discussion

In recent times, soccer games are dynamic and played extensively. Moreover, the soccer games became economically important events. Therefore, the need to keep the game going has also risen. Hence, studies[15] have been conducted on the health of the players to keep the game going and to look after their well-being. Soccer games are played in more numbers than ever and in a hotter climate, the health of the players isaffected, leading to their poor performances. There have been many studies[14,16] that proved the hotter climate can have serious consequences on the health of the players. In this current study, it was shown that the variation of oxygen uptake increased among the players. In this current research, Group 3, which played in the hot environment (35±0.5°C) needed the most amount of oxygen due to the exhaustion from the hot temperature but due to their increased muscle fatigue in group 3 players, the oxygen uptake in group 2 surpassed those of group 3 players[13,14]. Any holistic strategy should also be considered in the assessment of performance-related and situational elements that are known to affect football players' physical and technical activity. Furthermore, another study conducted by Memmert et al[15] has shown that there are some technical as well as physical factors which can be determined for proper analytical assessment of the players' performances in a soccer game and can be used to evaluate the discrepancies between positive and negative match performances among the soccer players. Our study revealed that loss of fluid due to higher temperature was observed among group 3 players. As a result of which, group 3 players had their heart rate increase which was higher than group 2 and group 1. Time to get exhausted is also higher in group 3 players as compared to group 1 and group 2 players. Therefore, a decrease in the running speed of the group 3 players was also observed. Many experts emphasize that diverse situational elements and/or contextual variables can affect the physical activity and technical abilities of soccer players[16]. Studies[15,16] have pointed out that some factors can significantly affect the performance in a soccer game. The factors like the physical environment of the place where it

Table II. Significance tests for each variable considered for assessing outcomes.

	p-value *between groups	Remarks
Absolute VO_2	$p < 0.05$	Group 2 has significantly higher Absolute VO_2 as compared to Group 1 and Group 3
Relative VO_2	$p < 0.05$	Group 2 has significantly higher Relative VO_2 as compared to Group 1 and Group 3
Heart Rate	$p = 0.000$	Group 3 has a significantly higher heart rate as compared to Group 1 and Group 2
Minute Ventilation	$p < 0.05$	Group 3 has significantly higher Minute Ventilation as compared to Group 1 and Group 2
Lactate Concentration	$p < 0.05$	Group 3 has significantly higher Minute Ventilation as compared to Group 1 and Group 2
Time to exhaust	$p < 0.05$	Group 3 players got exhausted significantly faster as compared to Group 2 and Group 1

*Level of significance, $\alpha = 0.05$.

is being played include the average temperature of the area surrounding the stadium. The cooler environment allows the players to perform more tactics and other game techniques which can ultimately contribute to the performance of the game. Therefore, it is essential to have a cooler environment around the stadium. The current study has shown the impact on the players' health and performance due to the hotter environment. The current study also suggested some feasible solutions to this. Due to a hotter environment, the players have shown to have increased heart rate, minute ventilation oxygen uptake but still not sufficient as happened with group 3 in our study, tachycardia, increased lactate concentration in blood and muscles, resulting in muscle cramps easily and easy to get exhausted[17,18].

Several studies[17] have analytically shown that there is an association between hotter environments and negative impact on cardiovascular and respiratory consequences. Studies[16,17] have shown impacts on changes in biomarkers involving physiological and biochemical markers. This is linked to the athlete's physical performance and, as a result, their participation in sports events[19].In terms of athletes, De Wolfe et al[20] evaluated the performance of more than 100 college level and field competitors in four different green environments. They have concluded that factors like greenery can have a positive effect on the environment and due to avoidance of hotter temperatures, the performance of the players was increased. The study further concluded that players have better performance when the game is played in venues surrounded by trees and greeneries. As a result, it is important to pay attention to having as many *florae* as possible near football grounds. This is also found to have a cooler effect on the environment and eventually provide a good playing environment for the players. Roof spaces can be used in green regions where extensive tree planting in the surrounding area is not possible. According to Yang et al[21] pollutants also play an effective role in the performance of players. The solution to this particular problem is also having greeneries surrounding the venue which will eventually create a cooler environment along with decreasing the extent of pollution. In this way, not only the performance but also the long-term negative impact on the players can be minimized. It has also been found that air purifiers can be installed near stadiums or venues which can have a positive impact on the players by reducing the particle levels in the air. The study further shows that air pollution is one of the primary causes of a hotter environment, especially near the cities. Therefore, there should be an official proposal to build greeneries surrounding the venues. To keep this game more viable, it is essential to look after the health and well-being of the players. This solution can prevent the players to get fatigued and keep the dynamic nature of the game going[22].

Physiological parameters such as red-to-white muscle fibre ratio, capillary vessel density in skeletal muscles, muscle glycogen content, blood flow, oxygen transportability, and mitochondrial density and activation have been shown to affect endurance exercise capability[23]. Furthermore, as the current study revealed, environmental temperature circumstances may have a role in regulating endurance exercise ability, stressing the interplay between the body's heat-balance processes and environmental variables. Due to the heat stress, vasodilation can occur in the dermal vessels which will eventually allow the heat to escape, leading to stimulating the sweat glands. The active sweat glands contribute to evaporative heat loss. On the contrary, cold stress can lead to the vasoconstriction of the dermal vessels, leading to reduced loss of heat to the environment and hence, activation of skeletal muscle shivering can occur[24,25].

In this scenario, future research should aim to test decision-making skills during the exercise task itself, using an appropriate technique as proposed. Future studies should consider using a soccer-specific decision-making tool to improve ecological validity even more. PSCHE software, the tool employed in this study, was designed for use in a clinical context and, even though it gives useful quantitative data, it has not been widely used in sports. A soccer-specific tool that is more sensitive than the PSYCHE programme may reveal differences in decision-making that were missed in this study[26].

Conclusions

The study has concluded that the physiological characteristics like oxygen uptake, heart rate, lactate concentration in blood, ventilation, etc., became difficult to adapt in a hot environment, resulting in the faster exhaustion of the players. This may lead to a lowering of the game performance. This current study also suggested improving the surrounding of the stadium and recommended planting greeneries to create a

cool environment inside the stadium. This may help the players to improve the condition of their physical health and increase performance in the game. However, this study has only considered the temperature and studied it thoroughly while omitting the effect of humidity, which was beyond the scope of this current study. Further research should be conducted by considering more environmental variables and their effects on the players.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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None.

Authors' Contribution
Wenhao Liu, Zeyun Li and Yean Chun Loh gave substantial contribution to the conception or design of the work and in the acquisition, analysis, and interpretation of data for the work. Each author had a role in drafting the work and revising it critically for important intellectual content. Each author gave final approval of the version to be published and they agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Informed Consent
The whole procedure was explained to each patient and their correspondent. Also, written consent was obtained from each patient.

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