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High-Risk Environmental Conditions Attenuates Performance Efficiency Index in NCAA DI Female Soccer Players

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ABSTRACT

International Journal of Exercise Science 15(6): 442-454, 2022. The purpose of this study was to evaluate the effects of environmental conditions on running performance and performance efficiency index (Effindex). Performance data recorded using Polar Team Pro sensors from eight collegiate female soccer players in nine matches were analyzed during the 2019 competitive season. Effindex and running performance, including total distance covered (TD_{REL}) and distance covered in five speed thresholds relative to minutes played, were examined for indications of fatigue with respect to environmental conditions, including ambient temperature and relative humidity. Matches were separated into three groups based on environmental conditions: Low-Risk (n = 2 matches), Moderate-Risk (n = 3 matches), or High-Risk (n = 4 matches). Speed thresholds were grouped as follows: walking ($WALK_{REL}$), jogging (JOG_{REL}), low-speed running (LSR_{REL}), high-speed running (HSR_{REL}), and sprinting ($SPRINT_{REL}$). A significant effect was observed for TD_{REL} in all environmental conditions ($\eta^2 = 0.614$). TD_{REL} was significantly lower in the High-Risk ($p = 0.002$; 95.32 ± 12.04 m/min) and Moderate-Risk conditions ($p = 0.004$; 94.85 ± 9.94 m/min) when compared to Low-Risk (105.61 ± 9.95 m/min). $WALK_{REL}$ ($p = 0.005$), JOG_{REL} ($p = 0.005$) LSR_{REL} ($p = 0.001$), HSR_{REL} ($p = 0.035$), $SPRINT_{REL}$ ($p = 0.017$), and Effindex ($p = 0.0004$) were significantly greater in Low-Risk conditions when compared to Moderate-Risk conditions. $WALK_{REL}$ ($p = 0.005$), HSR_{REL} ($p = 0.029$), $SPRINT_{REL}$ ($p = 0.005$), and Effindex ($p = 0.0004$) were significantly greater in Low-Risk conditions when compared to High-Risk conditions. High-Risk environmental conditions may result in adverse performance in female collegiate soccer players.

KEY WORDS: Effindex, ambient temperature, football, GPS

INTRODUCTION

Soccer at the National Collegiate Athletic Association (NCAA) Division I level is played outdoors in a variety of environmental conditions. The difference between victory or defeat comes down to player performance, which can be significantly affected by environmental conditions. Previous literature has shown that high-risk environmental conditions are detrimental to performance and safety during competition (8, 26). Throughout the existing literature, high-risk environmental conditions are considered to be typically around 30 °C or higher, depending on percent humidity, which may result in performance decrements (4, 17, 26).

Previous research has shown that a temperature and humidity below 22 °C and 60 %, respectively, are optimal for peak performance during professional male soccer matches (10). Nevertheless, the beginning of the NCAA soccer season occurs during the summer months in the United States, when high-risk environmental conditions are at their peak. During the summer months, athletes are not always exposed to optimal temperatures and humidity when compared to other periods in the calendar year, which may affect performance (17). For example, repeated sprint ability has been shown to be negatively impacted when competing in high thermal-stress environments (15). Less high-intensity running and shorter total distance covered has been reported in elite male soccer players playing in hot ambient conditions of 43 °C when compared to playing in temperate conditions of 21 °C (24).

In female collegiate soccer players, total distance covered in high-risk environments appears to be maintained, whereas a decrease in percent high-speed running distance has been shown in moderate and high wet bulb globe temperature (WBGT) conditions compared to low WBGT conditions (4). Another study examining 30-meter sprint speed in different ambient temperatures showed that female soccer players were negatively affected by 30 °C conditions versus 10.5°C conditions.

In soccer, decrements in performance occur during the latter stages of a match, primarily due to fatigue (14). For example, female soccer players reduce the number of tackles in the second half compared to their performance in the first half (14). Similarly, when collegiate female soccer players were required to play additional minutes towards the end of a competitive season, the total distance covered relative to minutes played declined. In contrast, distance covered during the additional minutes was performed almost exclusively within the low-intensity thresholds (33). In terms of total distance covered, players of the English Premier League displayed fatigue through shorter distances covered in the second half of a competitive match (7). Comparatively, walking distance was greater in the second half when compared to the first, but high-speed running and sprinting distances were kept consistent throughout the match (7). Jogging and running distances were higher in the first half, contributing to the decrease in the total distance during the second half of soccer matches (7). A possible explanation could be that players reserve energy in the second half to use it only when strictly needed, which is shown by a higher distance covered by walking over jogging (21). Despite attempts to preserve energy, female soccer players still demonstrate decreases in high-intensity running in the second half of their soccer matches (21).

A relatively new measure, the performance efficiency index (Effindex), considers both internal and external loads and displays the combination of the two into a single parameter (3). In addition, this new index allows for detecting changes in athletic performance during a soccer match across all positions (31). For example, a decreased value of Effindex demonstrates a reduction in running efficiency in male soccer referees (2) and running performance in professional male soccer players (30). Unfortunately, to the best of our knowledge, there is no literature examining Effindex in female soccer players throughout an entire season and, more importantly, the effects of environmental conditions on this measure.

Therefore, the purpose of this study was to examine if environmental conditions influence running performance and if the detrimental effect on running performance measures in high-risk environments align with previous literature on collegiate women's soccer players (4). Furthermore, a secondary aim of this study was to determine if Effindex was sensitive to different environmental conditions during competitive matches. We hypothesized that High-Risk environmental conditions would affect all performance markers negatively.

METHODS

Participants

Athletic performance data from 8 NCAA Division I female soccer players was examined. The competitive season took place in the summer and fall months from August to November of 2019. Athletes that played over 30 minutes in each match were included in this analysis. In order for games to be evaluated, all eight players' playing time in the first and second halves had to exceed 30 total minutes, producing an analysis of nine matches. Of the nine matches, four were played at home, and five were played away. Participants competed on eight natural grass fields and one artificial turf field. Of the original 32 athletes on the team, 11 were removed from analysis for not having tracking equipment, and 14 were withheld from analysis for not meeting the inclusion criteria of playing 75 % of the matches, creating a final sample of 8 players. The average minutes played by the 8 players in the analysis was 83.26 ± 11.25 minutes per game. The sample included defenders (n = 4), midfielders (n = 3), and forwards (n = 1). Participants maintained their playing positions throughout the entire competitive season. All participants were cleared to participate in physical activity by the university's sports medicine staff before collecting data. A retrospective examination of the data was approved by the university's Institutional Review Board for Human Subjects.

Protocol

NCAA Division I female soccer athletes were monitored during the 2019 competitive soccer season with a heart rate monitor and global positioning system (GPS) strapped to their chest. Athletes were given Polar Team Pro GPS sensors (Polar Electro, Co, Kempele, Finland) to monitor the dependent variables which include distances and speeds covered during the competitive season. Additionally, average and maximal heart rates were considered as internal load, which is defined as the psychophysiological responses to exercise (20). WBGT was recorded from each match's start time. Running performance was measured as the distance covered relative to the minutes played in different speed thresholds. Speed thresholds included walking ($WALK_{REL}$), jogging (JOG_{REL}), low-speed running (LSR_{REL}), high-speed running (HSR_{REL}), and sprinting ($SPRINT_{REL}$).

All eight participants were equipped with Polar Team Pro sensors and a chest strap to attach the sensor. Polar Team Pro sensors record data up to 200 meters away, at 200 Hz with the accelerator, gyroscope, and magnetometer and 10 Hz for the GPS (16). Participants mounted the sensor on the chest strap at the level of the xiphoid process (16). Before starting the season, GPS sensors were assigned to each player, and player profiles were created with each player's respective anthropometric data retrieved from the university's sports medicine department. For every game, GPS sensors were given to the athletes to wear 15 minutes before the start of warm-up, and data collection started as soon as the official warm-up commenced. Data were recorded in real-time using an iPad (Apple, USA) and then uploaded to the Polar Team Pro's online database once connected to the internet. Substitutions and playing time were calculated in real-time by a team staff member controlling the iPad. Distance covered in meters, the average percent of maximum heart rate, distance in speed zones measured in meters, and speed of sprints performed in meters per minute were extracted from the database and imported into a Microsoft Excel sheet (Microsoft, USA). Previous studies (13, 16) found the Polar Team Pro sensors to be invalid in measurements of external load but valid for heart rate measures (13). Polar Team Pro sensors were found to be valid and reliable outdoors for total distance, low-speed running, and high-speed running (1).

Distance and Time: After being exported and organized onto a Microsoft Excel sheet, minutes played and distance covered was exported to IBM SPSS Statistical software version 25.0. To analyze the performance differences for each environmental condition, the total distance (TD_{REL}) and distances covered in each speed zone were divided by each player's minutes played to determine the TD_{REL} and relative distances in each speed zone. The distance covered was expressed in meters, and sprints performed were considered any speed over 2.8 meters per second (6) or 168 meters per minute. Speed zones were separated into 5 categories via Polar Team Pro software: walking ($WALK_{REL}$ 0.83–1.94 $m \cdot s^{-1}$), jogging (JOG_{REL} 1.94-3.05 $m \cdot s^{-1}$), low-speed running (LSR_{REL}3.06-4.16 $m \cdot s^{-1}$), high-speed running (HSR_{REL}4.17-5.27 $m \cdot s^{-1}$), and sprinting ($SPRINT_{REL}$ 5.28+ $m \cdot s^{-1}$). Speed zones were then grouped further into Low-Intensity Running (LIR_{REL}) and High-Intensity Running (HIR_{REL}). LIR_{REL} consisted of distances covered at $WALK_{REL}$, JOG_{REL}, and LSR_{REL}. HIR_{REL} consisted of distances covered at HSR_{REL} and $SPRINT_{REL}$ (33).

Heart Rate: Polar Team Pro sensors, equipped with heart rate monitoring technology, worn by the eight players analyzed in this study were attached to the body by chest straps equipped with conductive electrodes touching the skin to capture data. Resting heart rate was collected at pre-season physical testing done by the university's sports medicine department and later input into each player's profile. Maximum heart rate was standardized by the equation 220-player's age but was modified manually as the season progressed during training sessions or matches, if previous maximum heart rate was exceeded, by updating the maximum beats per minute value on players' profiles in the Polar Team Pro database. The average percent of maximum heart rate ($\%HR_{AVG}$) was extracted from Polar Team Pro's online database and exported into a Microsoft Excel sheet.

Performance Efficiency Index: Performance Efficiency Index (Effindex), measured in arbitrary units (a.u.), combines mean running speed with respect to relative cardiovascular stress to create one single variable (3). Effindex was calculated by dividing speed in meters per minute by $\%HR_{AVG}$. This allowed for the analysis of the performance of all players equally, regardless of varying minutes played.

Environmental Conditions: Environmental conditions were supplied by the nearest WeatherSTEM station to the location of the match, which was on campus or less than 1.6 kilometers. Ambient temperature, humidity, and WBGT were reported via WeatherSTEM at the beginning of each match. WBGT was used to classify matches as low-risk environmental conditions (Low-Risk; n = 2 matches), moderate risk (Moderate-Risk; n = 3 matches), or high risk (High-Risk; n = 4 matches). Risk classifications of environmental conditions are shown in Table 1 (12).

Table 1. WBGT classifications

	Relative Humidity	Ambient Temperature
Low	*≤ 50 %*	*< 24 °C*
	51-75%	*< 20 °C*
	76% +	*< 18 °C*
Moderate	*≤ 50%*	*24-28 °C*
	51-75%	*20-25 °C*
	76% +	*18-23 °C*
High	*≤ 50%*	*29-33 °C*
	51-75%	*26-29 °C*
	76% +	*24-28 °C*

Rating Percentage Index Ranking: The rating percentage index (RPI) is used by the NCAA as a team ranking system by assessing the differences in the strength of each team's opponents and wins and losses of the team being assessed to their opponents (12). 50% of the RPI calculation is based on each team's strength of schedule, while one 25% accounts for wins and losses, and the other 25% accounts for the winning percentage of the team's opponent's (12). End-of-season RPI was collected directly from the NCAA's website for each team analyzed. RPI was used to analyze whether the strength of the opponent had a main effect on the amount of distance covered throughout a match.

Statistical Analysis

Before statistical analyses, all data were assessed for normality using a Shapiro-Wilk test. All data were normally distributed (p's $\geq$ 0.100). Matches within each environmental condition were pooled, and the mean value for each participant for every variable was used in subsequent analyses. Repeated measures ANOVA test was used to compare each dependent variable (TD_{REL}, $WALK_{REL}$, $JOG_{REL}$$LSR_{REL}$, HSR_{REL}, $SPRINT_{REL}$, LIR_{REL}, HIR_{REL}, minutes played, and Effindex) across the three environmental conditions. In the event of a significant F value, least significant difference (LSD) post hoc tests were used for pairwise comparisons. For effect size, the partial eta squared statistic was calculated, and according to Green et al. (18). 0.01, 0.06, and

0.14 represent small, medium, and large effect sizes, respectively. Furthermore, Cohen's *d* effect sizes were used to highlight important pairwise differences, with values of 0.2, 0.5, and 0.8 corresponding to small, medium, and large effects, respectively (11). For analysis of the effect of RPI in different environmental conditions, a Kruskal-Wallis H test was used. An alpha of $p < 0.05$ was established a priori. SPSS (version 25, SPSS, Inc., Chicago, IL) was used for all statistical analyses.

RESULTS

No significant effect ($F = 1.271$; $p = 0.31$; $\eta^2 = 0.154$) was observed for minutes played across Low-Risk (84.13 ± 7.48min), Moderate-Risk (89.54 ± 19.40min), and High-Risk environmental conditions (81.44 ± 13.43min).

Kruskal-Wallis Test showed no significant differences ($p = 0.946$) between RPI across all three environmental conditions.

A significant effect ($F = 11.149$; $p = 0.001$; $\eta^2 = 0.614$), was observed for TD_{REL} across all environmental conditions (Figure 1). TD_{REL} was significantly lower during High-Risk compared to Low-Risk ($p = 0.002$; $d = 1.519$). In addition, TD_{REL} was significantly lower during Moderate-Risk compared to Low-Risk ($p = 0.004$, $d = 1.358$).

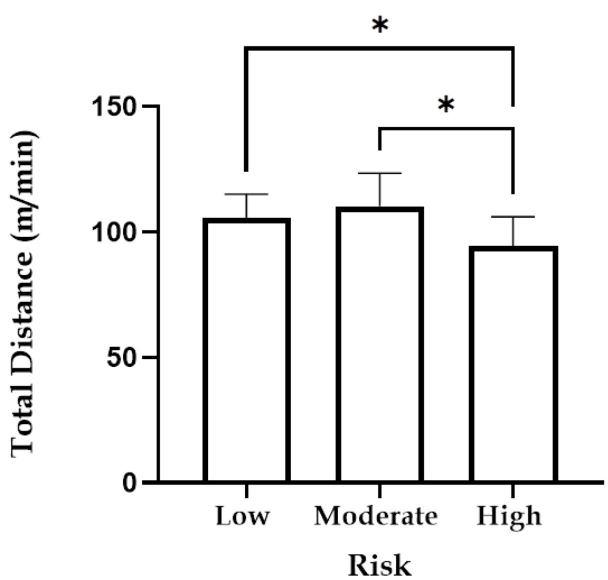

Figure 1. Effect of environmental conditions on total distance relative to minutes played; $*p < 0.05$

Total distance covered relative to minutes played across environmental conditions for each speed threshold can be found in Table 2. A significant effect ($F = 13.878$; $p = 0.002$; $\eta^2 = 0.665$) was observed for $WALK_{REL}$ in all matches played. $WALK_{REL}$ was significantly lower during

Moderate-Risk and High-Risk compared to Low-Risk (p = 0.005; d = -1.63 and p = 0.005; d = -1.63, respectively).

Table 2. TD_{REL} for environmental conditions (Mean ± SD)

	Low	Moderate	High
$WALK_{REL}$	32.60 ± 6.69*#	23.90 ± 2.23	23.71 ± 4.07
JOG_{REL}	25.41 ± 4.90*	18.52 ± 1.08	23.06 ± 3.71*
LSR_{REL}	22.41 ± 6.51*	16.35 ± 2.83$	19.18 ± 4.30
HSR_{REL}	10.37 ± 3.73*#	7.57 ± 1.62	7.83 ± 2.13
$SPRINT_{REL}$	5.97 ± 1.84*#	4.80 ± 1.41#	3.50 ± 1.45

LSR = Low-speed running; HSR = High-speed running; Mean = Meters per minute; SD = Standard deviation
* Significantly greater than Moderate-Risk; # Significantly greater than High-Risk; $ Significantly lower than High-Risk

A significant effect (F = 9.451; p = 0.003; η^2 = 0.574) was observed across environmental conditions for jogging distance. Moderate-Risk JOG_{REL} was significantly lower than Low-Risk JOG_{REL} (p = 0.005; d = 1.56). Moderate-Risk JOG_{REL} was significantly less than High-Risk JOG_{REL} (p = 0.005; d = -1.63).

A significant effect (F = 7.81; p = 0.005; η^2 = 0.527) was observed across environmental conditions for low-speed running. Moderate-Risk LSR_{REL} was significantly lower than Low-Risk LSR_{REL} (p = 0.001; d = 1.4). Moderate-Risk LSR_{REL} was significantly lower than High-Risk LSR_{REL} (p = 0.024; d = -0.65).

A significant effect (F = 6.128; p = 0.012; η^2 = 0.467) was observed across environmental conditions for high-speed running distance. Moderate-Risk HSR_{REL} was significantly lower than Low-Risk HSR_{REL} (p = 0.035; d = 1.12). High-Risk HSR_{REL} was significantly lower than Low-Risk HSR_{REL} (p = 0.029; d = 1.02).

A significant effect (F = 12.009; p = 0.001; η^2 = 0.632) was observed in all environmental conditions for sprinting distance (Figure 2). Low-Risk $SPRINT_{REL}$ was significantly greater than Moderate-Risk $SPRINT_{REL}$ (p = 0.017; d = 0.82) and High-Risk $SPRINT_{REL}$ (p = 0.005; d = 1.74). In addition, High-Risk $SPRINT_{REL}$ was significantly lower than Moderate-Risk $SPRINT_{REL}$ (p = 0.035; d = 0.93).

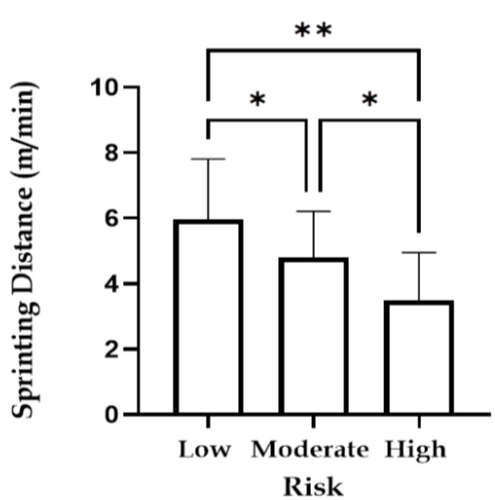

Figure 2. Effect of environmental conditions on sprinting distance relative to minutes played across all matches

**$p < 0.01$ *$p < 0.05$

A significant effect ($F = 10.988$; $p = 0.001$; $\eta^2 = 0.611$) was observed between environmental conditions for low-intensity running distance (Table 3). Low-Risk LIR_{REL} was significantly greater than Moderate-Risk LIR_{REL} ($p = 0.004$, $d = 1.46$) and High-Risk LIR_{REL} ($p = 0.032$, $d = 0.94$).

A significant effect ($F = 13.955$; $p < 0.001$; $\eta^2 = 0.648$) was found between environmental conditions for high-intensity running distance (Table 3). Low-Risk HIR_{REL} was significantly greater than Moderate-Risk HIR_{REL} ($p = 0.005$; $d = 1.45$) and High-Risk HIR_{REL} ($p = 0.003$; d = 0.1.57).

Table 3. Effect of environmental conditions on LIR and HIR distance (Mean ± SD)

	Low	Moderate	High
LIR_{REL}	28.80 ± 4.92*#	19.60 ± 1.77	21.98 ± 2.80
HIR_{REL}	8.17 ± 2.39*#	6.19 ± 1.44	5.67 ± 1.69

LIR = Low-intensity running; HIR = High-intensity running; Mean = Meters per minute; SD = Standard deviation
** Significantly greater than Moderate-Risk; # Significantly greater than High-Risk*

A significant difference ($F = 13.478$; $p = 0.001$; $\eta^2 = 0.658$) was observed for Effindex across all environmental condition risk levels (Figure 3). Low-Risk Effindex was significantly greater (p = 0.0004; $d = 1.17$) than Moderate-Risk Effindex and High-Risk Effindex ($p = 0.001$; $d = 1.82$).

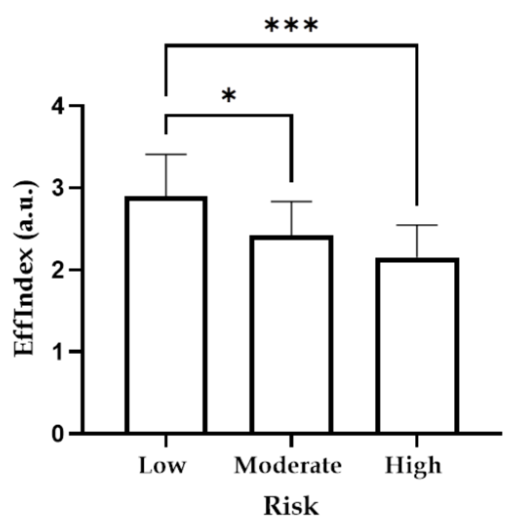

Figure 3. Effect of environmental conditions on performance efficiency index across all matches

DISCUSSION

The purpose of this study was to examine the effect of Low-Risk, Moderate-Risk, and High-Risk environmental conditions on total distance, distance run in five different speed thresholds, and performance efficiency index during a competitive female soccer season. The results of this study indicate that matches played by female soccer players in environmental conditions categorized as high-risk are detrimental to TD_{REL}, running distance in all five speed thresholds, and Effindex. Interestingly, significant differences in distance covered were shown despite the total minutes played between the three environmental conditions.

Previous research has reported performance decrements in total distance run during a match played in unfavorable or high-risk environmental conditions in professional male soccer players (10, 20, 23). Existing literature examined the players' performance measures of the 32 teams competing in Brazil's 2014 FIFA World Cup at different air temperatures and relative humidity (10). In terms of total distance in kilometers covered in a match by professional male soccer players, a significantly greater distance occurred at low temperature, low humidity (> 22 °C, < 60 %) when compared to high temperature, low humidity (> 28 °C, < 60 %) (10). Players from the 2018 FIFA World Cup in Russia ran the shortest total distance in kilometers in conditions categorized under high thermal stress, where thermal stress was any temperature over 26 °C in the Universal Thermal Climate Index (21). Previous literature has examined the physical performance of 20 professional male soccer players during experimental matches in normal environmental temperature (21 °C, 55 % relative humidity [RH]) and hot environmental conditions (42 °C, 12 % RH) (23). Total distance, in meters, was found to be 7 % shorter in hot environmental conditions compared to normal environmental conditions (23). The current study presents similar results in female soccer players.

In support of the literature examining male soccer players, High-Risk environmental conditions were shown to significantly affect total distance compared to Low-Risk conditions in NCAA female DI athletes (4). Environmental conditions were considered High-Risk under the following combinations: WBGT > 28 °C with RH < 50 %, WBGT > 25 °C with RH between 50-75 %, or WBGT > 23 °C with RH > 75 %. Although not exact, the average environmental conditions in the High-Risk category (WBGT = 30 °C) of the current study were similar to those reported by Benjamin et al. (4), and our results agreed with those of the previously mentioned study. A noted difference between the previously mentioned study and the current study is in the grouping of environmental conditions. The current study had a higher average WBGT for the High-Risk category, and the High-Risk environmental conditions were potentially more severe due to hotter temperature and humidity combinations. The significant difference in distance covered during games played in different environmental conditions in the Benjamin et al. (4) study may have been due to pacing. It has been suggested that using a pacing strategy during High-Risk environments may allow players to cover similar distances (4). For example, perhaps during High-Risk environments, more distance was covered at the lower speed thresholds.

The current study observed Low-Risk environmental conditions benefitting distances covered in all speed thresholds compared to Moderate-Risk conditions and sometimes High-Risk conditions ($WALK_{REL}$, HSR_{REL}, $SPRINT_{REL}$). Contrary to Coker et al. (12), we did not find a significant difference in $WALK_{REL}$ when comparing High-Risk conditions to Low-Risk conditions. In an attempt to find the effects of heat stress on running performance in collegiate male soccer players, existing literature shows a significant impact on running performance in $WALK_{REL}$ and JOG_{REL} when playing soccer in the same Low-Risk environmental conditions as the current study (12).

Conversely, in High-Risk conditions, we found a significant effect in JOG_{REL}, suggesting that players could potentially be adopting a pacing strategy when they become fatigued (15, 28). There is research (14) pointing towards players downregulating their efforts in the second half, which influences high-demand responses needed during a match. A similar study explained that players adopt a pacing strategy, regardless of consciousness towards an endpoint, to complete their physical task (28). In support of High-Risk conditions contributing to fatigue, this current study observed declines in TD_{REL}, LIR_{REL}, and HIR_{REL} when competing in such environments.

In conjunction with previous research studying professional male soccer players (9), our results can conclude that an ideal soccer environmental condition for peak running performance is below 22 °C and an RH range below 60 %. In agreement with similar research (2), the current study demonstrates higher running performance, including low-intensity ($WALK_{REL}$, JOG_{REL}, and LSR_{REL}) and high-intensity (HSR_{REL} and $SPRINT_{REL}$) distance primarily in Low-Risk environmental conditions. Further, LSR_{REL} and $SPRINT_{REL}$ performances were significantly better for Moderate-Risk environmental conditions when compared to High-Risk conditions (Table 2).

Effindex, a measure of players' work efficiency, detects fatigue and identifies the dose-response of a soccer match (19, 30). It allows for an integration of external and internal load by examining mean running speed relative to cardiovascular stress (3). A lower Effindex value indicates higher cardiovascular stress (30). Effindex was significantly greater in Low-Risk environmental conditions when compared to Moderate-Risk and High-Risk conditions (Figure 3), confirming that lower temperatures correspond to better running performance in collegiate female soccer players. To our knowledge, there is no literature examining the effects of environmental conditions on Effindex in soccer players during matches. However, there is literature examining Effindex values in soccer referees (3) and in both halves of rugby matches (29). Existing literature has found that Effindex was sensitive to time, with a reduced value in the last 15 minutes of both halves of a soccer match for referees (3). Similarly, a study found that Effindex was reduced in the second half, indicating fatigue in the latter half of a rugby match (29). Although our study did not examine different Effindex values for each half played, we can support a theory that performance, defined as a combination of internal and external load, can decrease as time goes on in a soccer match by combining results from the literature mentioned above.

One of the limitations of this study was the small sample size. Only 25% (n = 8) of the entire team was analyzed due to the lack of sufficient equipment for all players, such as the Polar Pro sensors, and an inability to meet the inclusion criteria of having played at least 30 minutes per match. However, previous studies have reported similar sample sizes (5, 12, 25, 33). An additional limitation is that we did not track factors that may affect running performance, such as sleep time, injuries, or the menstrual cycle. Literature examining the effects of menstruation on athletic performance found no significant effect on performance at the time of menstruation (14). Research looking at elite male soccer players found that lower sleep efficacy had a negative effect on the incidence of injuries (27). We also did not separate matches played in different altitudes and time zones. A lack of acclimatization for players coming from different terrains could be a cause of disruption in performance (5). A further limitation of this study was that the environmental conditions were taken from the closest weather station to the university where matches were played and not actually at the site of the match. Although weather stations were located within a 1-mile radius of the site of the match, these environmental conditions could potentially differ depending on how much distance was between the site of the match played and the nearest weather station. However, no significant difference has been found between on-site weather data and data from regional weather stations but this study emphasized topography before geographic distance (22).

The current study found that low-risk environmental conditions were more favorable for running performance and external load. Hotter environmental conditions, such as Moderate-Risk and High-Risk, could be detrimental to running performance, as observed within the currently available data. Previous research recently demonstrated that wearing a cooling vest for 15 minutes at half-time improved intermittent exercise performance in male soccer players (9). Therefore, based on our findings, we suggest that coaches or training staff may want to investigate cooling strategies that will help improve running performance when performing in high-risk environmental conditions. Furthermore, Effindex is attenuated in response to soccer matches played in Moderate-Risk and High-Risk environmental conditions.

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