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High Risk Environmental Conditions Attenuate Distance, Speed, and Performance Efficiency Index in NCAA D1 Female Soccer Players

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HIGH-RISK ENVIRONMENTAL CONDITIONS ATTENUATE DISTANCE, SPEED, AND PERFORMANCE EFFICIENCY INDEX IN NCAA DI FEMALE SOCCER PLAYERS

by

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ABSTRACT

PURPOSE: To evaluate the effects of environmental conditions on running performance and performance efficiency index (Effindex). **METHODS:** Performance data recorded using Polar 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 relative to minutes played (TD_{REL}) and distance covered in five-speed thresholds, were examined for indications of fatigue with rising environmental conditions, including ambient temperature and relative humidity. Matches were separated into three groups based on environmental condition risk: low (Low-Risk; *n*= 2 matches), moderate (Moderate-Risk; *n*=3 matches), or high (High-Risk; *n*=4 matches). Speed thresholds were grouped as follows: walking ($WALK_{REL}$ 0.83 – 1.94 m/s), jogging (JOG_{REL} 1.94- 3.05 m/s), low-speed running (LSR_{REL}3.06-4.16 m/s), high-speed running (HSR_{REL}4.17- 5.27 m/s), and sprinting ($SPRINT_{REL}$ 5.28+ m/s). **RESULTS:** TD_{REL} was significantly lower in High-Risk conditions. $WALK_{REL}$, JOG_{REL}, LSR_{REL}, HSR_{REL} , $SPRINT_{REL}$, and Effindex were significantly greater in Low-Risk conditions when compared to Moderate-Risk conditions. $WALK_{REL}$, HSR_{REL} , $SPRINT_{REL}$, and Effindex were significantly greater in Low-Risk conditions when compared to High-Risk conditions. **CONCLUSIONS:** High-Risk environmental conditions significantly affect performance in female collegiate soccer players. Cooling and timing strategies are advised to mitigate decrements in performance.

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LIST OF ACRONYMS

NCAA	National Collegiate Athletic Association
WBGT	Wet-Bulb Globe Temperature
GPS	Global Positioning System
TD_{REL}	Total Distance
LSR_{REL}	Low-Speed Running Distance
HSR_{REL}	High-Speed Running Distance
$\%HR_{AVG}$	Average Percent of Maximum Heart Rate
LSD	Least Significant Difference
FIFA	Fédération Internationale de Football Association
RH	Relative Humidity
RPI	Rating Percentage Index

CHAPTER ONE: 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. For example, Bohner and colleagues (2015) demonstrated that matches played at moderate altitude affected high-intensity running performance in NCAA DI Women's Soccer (Bohner et al., 2015). However, high-risk environmental conditions are also detrimental to performance and safety during competition. Throughout the existing literature, high-risk environmental conditions are considered to be above 30°C and denote where performance decrements begin to occur (Benjamin et al., 2020; Girard et al., 2015; Ozgünen et al., 2010).

The optimal temperature and humidity for peak performance during soccer matches were observed below 22°C and below 60%, respectively (Chmura et al., 2017). The beginning of the NCAA soccer season is during the summer months in the United States (U.S.), when high-risk environmental conditions are at their peak. In the northern states of the U.S., high-risk environmental conditions can begin to decline during autumn in September, while southern states continue to see similar conditions in September and November. During the summer months, athletes are not always exposed to optimal temperatures and humidity, thus not performing optimally (Girard et al., 2015). Girard and colleagues (2015) explain that repeated sprint ability is negatively impacted when competing in high thermal stress environments. When playing games under the afternoon sun in high heat stress, male athletes spend more time jogging and at a low-moderate speed when compared to moderate heat stress (Ozgünen et al., 2010). Equally, less high-intensity running and shorter total distance covered was seen in elite male soccer players playing in hot ambient conditions of 43°C when compared to playing temperate conditions of 21°C (Mohr et al., 2012). When exposed to extreme conditions of 30 °C and above, male soccer athletes have seen performance decrements in the form of lower total distance covered and shorter sprint lengths after the first 15 minutes of both halves in a friendly soccer game (Mohr et al., 2010).

While men have seen performance decrements in high-risk environments, Benjamin et al. (2020) did not see a decrease in total distance when examining female collegiate soccer players. The total distance covered was not affected by extreme environments, but percent high-speed running distance was lower in the low wet bulb globe temperature (WBGT) condition versus the moderate and high WBGT conditions (Benjamin et al., 2020). When looking at a 30-meter speed test in different ambient temperatures, Çakir (2019) found that female soccer players were negatively affected by 30°C conditions versus 10.5°C conditions (Çakır, 2019). Although not significant, Trewin and colleagues (2018) observed a decrease in total distance, accelerations, and low-speed and high-speed running in female soccer players when competing in a warm/hot environment > 21°C versus a cold/mild environment < 21 °C (Trewin et al., 2018).

In soccer, decrements in performance come as time passes in a match, and failure to perform at a required intensity during a match is usually the result of fatigue (Datson et al., 2014). An increase in fatigue as the clock runs can negatively impact a team and its tactics. Female soccer players are seen to reduce the number of tackles in the second half compared to their performance in the first half, and a possible explanation is due to progressive fatigue (Datson et al., 2014). When looking at total distance covered, players of the English Premier

League displayed fatigue through shorter distances covered in the second half of a competitive match (Bradley et al., 2009). Bradley and colleagues (2009) also found that 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. 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 (Bradley et al., 2009). 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 (Krustrup et al., 2005). Despite attempts to preserve energy, female soccer players still saw decreases in high-intensity running in the second half of their soccer matches (Krustrup et al., 2005).

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 (Barbero-Álvarez et al., 2012). In addition, this new index allows for detecting changes in athletic performance during a soccer match across all positions (Torreño et al., 2016). For example, a decreased value of Effindex demonstrates a reduction of running efficiency in male soccer referees (Barbero-Álvarez et al., 2012) and running performance in professional male soccer players (Suarez-Arrones et al., 2015). Subsequently, an increased value of Effindex would demonstrate an increase in performance. 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.

The purpose of this study was to examine if environmental conditions have an inverse relationship with running performance and if the detrimental effect on running performance measures in high-risk environments align with Benjamin et al. (2020) in collegiate women soccer players. Benjamin et al. (2020) is the only study using NCAA Women's Soccer that demonstrated the inverse relationship between WBGT and physical performance during soccer matches. Furthermore, to date, no one has examined the Effindex during collegiate soccer matches in different environments. Therefore, an additional aim of this study was to determine if Effindex was sensitive to different environmental conditions during competitive matches. If so, then Effindex may be a valuable performance measure because it reflects running performance, cardiovascular stress, and the effects of the two on each other.

CHAPTER TWO: REVIEW OF LITERATURE

Female Studies

Benjamin, Hosokawa, Curtis, Schaefer, Bergin, Abegg, Casa, 2020

Environmental Conditions, Preseason Fitness Levels, and Game Workload: Analysis of a Female NCAA DI National Championship Soccer Season

This study aimed to determine the effect of aerobic fitness and environmental conditions on workloads during NCAA DI Women's Soccer matches. Nineteen female soccer players from the same team were analyzed in this study. Maximal oxygen consumption (VO_2 max) was estimated before preseason training through the yo-yo intermittent recovery test. Wet-bulb globe temperature (WBGT) was recorded at the site during home matches and found at the closest weather station for all other matches. A STATSports Viper Pod unit was used to collect relative total distance (TD), relative high-speed running distance (%HSD), and relative high metabolic load (%HML) for each player. TD was significantly different between LOW WBGT and MOD WBGT. %HSD and %HML were significantly greater in LOW WBGT when compared to MOD WBGT and HIGH WBGT. The interaction between WBGT and VO2 max was significant in %HSD. These findings show that running performance is affected by an increase in WBGT, and aerobic fitness can help reduce the negative effects of WBGT on %HSD.

Bohner, Hoffman, McCormack, Scanton, Townsend, Stout, Fragala, Fukuda, 2015

Moderate Altitude Affects High Intensity Running Performance in a Collegiate Women's Soccer Game

The aim of this study was to observe the effects of altitude on soccer match performance on an NCAA DI Women's Soccer team. Six female collegiate soccer players were equipped with a Catapult Minimax 4.3 global positioning device under their jerseys. Data were analyzed for three games, with two being played at sea level(SL) and one being played at a moderate altitude of 1839 meters. The relative distance covered at altitude was significantly lower than SL. Relative distance covered in high-intensity runs was significantly lower at altitude during the first half and the entire match. A significant difference was detected in the percent time spent at high intensity running when playing at altitude. These results demonstrate a disadvantage in the distance covered and the percentage of the high-intensity running of teams living at SL and then competing at an altitude.

Çakir, 2019

Investigation of Female Soccer Players Performance Values Based on Ambient Temperature

The aim of this study was to observe the effect of ambient temperature on performance indicators in female soccer players. A 30-meter sprint, 20-meter shuttle, and Illinois test were conducted in different ambient temperatures (-5.5 °C, 10.5 °C, 30 °C) by 15 amateur female soccer players. A significant change was observed in all performance indicators when comparing the coldest environment (-5.5 °C) to other environments (10.5 °C and 30 °C). Performance values are increased, and high efficiency is observed when competing in hotter environments (-5.5 °C to 30 °C).

Davis, Brewer, 2012

Applied Physiology of Female Soccer Players

This review article aimed to compile the literature examining female soccer players and the game of female soccer. This review found that female soccer players cover comparable distances during competition when compared to male soccer players. Sprint times faster than average were established in elite female soccer players when compared to amateurs. Similar stress to the aerobic and anaerobic energy systems is seen in male and female soccer players.

Datson, Hulton, Andersson, Lewis, Weston, Drust, Gregson, 2014

Applied Physiology of Female Soccer: An Update

The aim of this review article was to update the new information on female soccer players as it has become more readily available. This review found that reductions in the high-speed running distance could be found between halves and during each half, pointing towards the inability to keep pace at high intensity for the entire duration of a match. There are conflicting reports on the effects the menstrual cycle has on performance, with most literature pointing towards the menstrual cycle not affecting performance. It has been found that the ingestion of oral contraceptive pills may affect performance in female soccer players. Hip and groin injuries are less common in female players, while knee and ankle injuries are the most common. Anterior cruciate ligament(ACL) injuries are 2-6 times more common in females than men. Non-contact ACL injuries are more likely to occur during the follicular phase of the menstrual cycle.

Krustrup, Mohr, Ellingsgaard, Bangsbo, 2005

Physical Demands during an Elite Female Soccer Game: Importance of Training Status

The purpose of this study was to observe the physical demands of professional female soccer players during competition and the relationship between match performance and training status. Fourteen professional soccer players were video recorded during four competitive matches. The video was then imported to a computer to code and categorize movement patterns. Categories were separated into eight groups: standing, walking, jogging, low-speed running, moderate-speed running, high-speed running, sprinting, and backward running. Total distance was recorded as the accumulation of distances covered in the groups mentioned above. Heart rate was recorded using a Polar Vantage NV heart rate monitor. After the three weeks of competition, players performed a treadmill test in the laboratory and a Yo-Yo Intermittent Recovery Level 1 test. The treadmill test involved running in 6-minute bouts at speeds of 9,11, and 13 kilometers per hour with 2 minutes of recovery between each period, followed by the exhaustive VO_2 max test. Players wore the same Polar Vantage NV heart rate monitor to record heart rate every 5 seconds. The Yo-Yo Intermittent Recovery Level 1 test was performed outside, on artificial turf, with a duration of 8-20 minutes. The Yo-Yo Intermittent Recovery test results showed that high-intensity running ability in competitive matches is correlated to performance throughout the test. The average distance covered during high-intensity running was less than two-thirds of the distance that professional male soccer players cover. High-intensity running decreased within each half and declined in the last 15 minutes of both halves. Maximum heart rate was not associated with any fitness assessment in this study. This study observed a positive connection between VO_2 max values and high-intensity running throughout a match.

Trewin, Meylan, Varley, Cronin, Ling, 2018

Effect of Match Factors on the Running Performance of Elite Female Soccer Players

This study aimed to observe the effects of environmental conditions and match outcomes on match performance in professional female soccer players. Forty-five professional female soccer players were equipped with Catapult's Minimax S4 global positioning system units to cumulate total distance and speed data. Results found that total distance covered and low-speed running were lower in games played at altitude. Additionally, low-speed running was lower in warm temperatures in comparison to cold or mild temperatures. Running performance overall was lower during higher temperatures, especially temperatures over 21 °C. Running performance was lower when a match was played at an altitude greater than 500 meters, but more accelerations were performed.

Environmental Conditions

Chaen, Onitsuka, Hasegawa, 2019

Wearing a Cooling Vest During Half-Time Improves Intermittent Exercise in the Heat

The aim of this study was to observe the effect of a torso and neck-cooling vest during halftime on intermittent exercise on a bicycle ergometer that mimicked athletic competition. Eight volunteer male soccer players performed two sessions of intermittent exercise for two sets of 30 minutes each, with 15-minute halftime in-between. The protocol consisted of a 5-second maximal power-weighted pedaling bout (bodyweight x 0.075 kp) every minute, followed by 25 seconds of unweighted pedaling at 80 revolutions per minute and 30 seconds of rest in a 33 °C, 55% relative humidity climate. One session included a cooling vest worn at halftime for 15 minutes, while the other session served as the control, with no cooling garment at halftime. Mean, and peak power output, temperature, rating of perceived exertion, thermal comfort, and thermal sensation were collected during the two sessions. The cooling vest showed a significant improvement in mean power output during the 2nd half compared to the control. Thermal sensation, thermal comfort, and rating of perceived exertion were all significantly lower during the second half of the session with the cooling vest. Heart rate was significantly lower during halftime and higher during the last 5 seconds of maximal pedaling with the cooling vest. These results showed that a cooling vest could significantly improve performance when worn at halftime.

Chmura, Konefał, Andrzejewski, Kosowski, Rokita, Chmura, 2017

Physical activity profile of 2014 FIFA World Cup Players, with regard to different ranges of air temperature and relative humidity

The purpose of this study was to assess the physical activity changes in professional male soccer players playing in the 2014 FIFA World Cup concerning environmental conditions. Thirty-two national teams and 340 players were observed in this tournament to look at total distances covered in low, moderate, and high intensities, the number of sprints, and peak running speed. Official FIFA match data were extracted and analyzed from the Castrol Performance Index system. The highest average distanced covered in temperatures below 22 °C and relative humidity below 60%. The shortest distance covered was in the same ambient temperature but with relative humidity above 60%. When comparing low and moderate temperatures but different humidity, a significantly greater number of sprints were recorded when the humidity fell below 60%. There was no significant difference in peak running speed across all temperature combinations. The results found that 22 °C and relative humidity under 60% was the best environmental conditions to perform comfortably.

Chtourou, Souissi, 2012

The effect of training at a specific time of day: a review

The aim of this review article was to assess and explain the effect of time of day on the performance of both short and long-duration events. This article found several studies pointing towards mornings being the lowest point for performance and late afternoons being the highest point for performance. Although late afternoons are better for performance, they may also maximize daily variations of neuromuscular performance. Resistance training is dependent on several factors, including duration and frequency, thus needing more research to conclude its benefit at different times of the day. The consensus is that training time should coincide with competition time, whenever possible. Resistance training should be practiced in the morning hours to reduce any effect that time has on physical performance.

Coker, Wells, Gepner, 2020

Effect of Heat Stress on Measures of Running Performance and Heart Rate Responses During a Competitive Season in Male Soccer Players

This study aimed to analyze collegiate male soccer players and the differences in running performance and heart rate responses in different heat stress conditions. Data from 15 male NCAA Division I soccer players was collected for 12 matches of one competitive season. Players wore a Zephyr Model BH3 bioharness with a GPS unit and heart rate monitor to track total distance covered six-velocity thresholds and heart rate data. Environmental conditions, such as wet-bulb globe temperature(WBGT) and humidity, were documented at the competition site. Results found that walking distance was significantly greater in high heat stress conditions when compared to low heat stress conditions. Low-intensity running distance had a significantly larger distance in moderate heat stress conditions in comparison to low heat stress conditions. Results found a significant effect in total distance covered in all environmental conditions. The high-intensity running distance being maintained throughout rising heat stress conditions can be potentially explained by adopting a pacing strategy by the players. It was concluded that running performance is significantly affected by rising heat stress conditions.

Edwards, Noakes, 2009

Dehydration: cause of fatigue or sign of pacing in elite soccer?

The goal of this review article was to evaluate the existing research on dehydration and its influence on soccer performance. Fluid loss is minimal in match-play under almost all environmental conditions. Therefore, it is suggested that dehydration is not an abnormal outcome and that there is no single factor that causes fatigue at high playing levels of soccer. Instead, dehydration is simply a symptom of fatigue that could negatively affect decision-making moments and physical performance.

Girard, Brocherie, Bishop, 2015

Sprint performance under heat stress: A review

The aim of this review article was to compile literature observing the effect of heat stress on running performance and discuss strategies adopted by athletes to reduce the negative effects of high ambient temperatures on sprinting performance. Short-term heat exposure increases muscle temperature and can benefit power output in the short term, but it negatively influences cardiovascular and metabolic processes when core temperature rises too high and heat exposure is too long. Repeated sprint performance can begin to see decrements in worsened heat stress conditions. Intermittent sprint performance decrements can only be seen when exercise in hotter conditions creates hyperthermia in an individual.

Konefał, Chmura, Zacharko, Baranowski, Andrzejewski, Błażejczyk, Chmura, 2020

The influence of thermal stress on the physical and technical activities of soccer players: lessons from the 2018 FIFA World Cup in Russia

The aim of this study was to analyze the changes in physical performance due to thermal stress in training sessions and competitive matches of the 2018 FIFA World Cup. There were 945 observations for the 340 soccer players representing 32 national teams in the World Cup. The Universal Thermal Climate Index was used to categorize the matches and training sessions into no thermal stress (NTS) or thermal stress (TS). Match data was retrieved from the STATS motion analysis system that FIFA made available on their official website. Match statistics, as well as total distance, covered, and sprints performed, were recorded. This study observed that teams exposed to NTS before their matches were higher overall positions than those exposed to TS. Comfortable environmental conditions during training sessions were shown to increase the average distance covered in the following match. The winner of this tournament covered significantly higher distances than all other teams participating. The shortest total distance and the lowest number of sprints occurred in matches played under TS. Teams exposed to NTS during training sessions and then playing in TS conditions were shown to have a significantly larger number of sprints than teams exposed to TS in training sessions and matches.

Mohr, Nybo, Grantham, Racinais, 2012

Physiological Responses and Physical Performance during Football in the Heat

The aim of this study was to analyze the effect of hot ambient temperatures on physical performance in experimental soccer matches. Seventeen professional male soccer players were observed in two soccer matches in temperate conditions (21 °C) and hot conditions (43 °C). Players wore Polar Team system 2 heart rate monitors to record heart rate and physical performance in the form of total distance covered, high intensity running, and sprinting from the Amisco Pro match analysis system installed on the game field. The average heart rate was comparable in both match conditions, while total distance and high-intensity running declined in hot conditions in comparison to temperate conditions. In addition, peak sprint speed was higher in hot conditions than it was in temperate conditions.

Mohr, Mujika, Santisteban, Randers, Bischoff, Solano, Hewitt, Zubillaga, Peltola, Krustrup, 2010

Examination of fatigue development in elite soccer in a hot environment: a multi-experimental approach

The purpose of this study was to examine the causes of fatigue that come from professional male soccer players playing in a hot environment. Twenty male professional soccer players played a non-competitive soccer match after the last game of their competitive season at an ambient temperature above 30 °C. Players wore GPSport SPI Elite heart rate monitors to record heart rate in 5-second intervals. The Amisco Pro match analysis system was used to record player movements and sort data into total distance covered and time spent in 7 different speed thresholds. The thresholds were grouped as follows: standing, walking, jogging, low-speed running, moderate-speed running, high-speed running, and sprinting. There were no significant differences observed in mean or peak heart rate between halves. The total distance covered was the highest during the first 15 minutes of the game. The lowest total distance covered was observed during the last 15 minutes of the game. High-intensity running distance was significantly greater in the first 15 minutes of the match in comparison to the rest of the duration of the match. Sprinting distance was significantly greater in the first 15 minutes of the match in comparison to the last 15 minutes of both halves. These findings observe fatigue towards the end of halves and the entire match through a decrement in the distance covered.

Özgünen, Kurdak, Maughan, Xeren, Korkmaz, Yazici, Ersöz, Shirreffs, Binnet, Dvorak, 2010

Effect of hot environmental conditions on physical activity patterns and temperature response of football players

The aim of this study was to assess the changes in physical performance during soccer matches played in varying environmental conditions. Nine male soccer players played two soccer matches in moderate heat (MH) and high heat (HH). Average MH conditions were measured at 34 °C and 38% relative humidity, while average HH conditions were 39 °C and 61% relative humidity. Forerunner 305 heart rate monitors from Garmin were used to record heart rate. Percent of total distance covered walking was significantly higher in the HH match when compared to the MH match. The percentage of total distance covered in low-moderate running was significantly lower in HH match when compared to MH match. Although not significant, the mean distance covered while jogging, low-moderate running, and high-speed running were greater during the MH match. Conversely, the mean sprinting distance was greater during the HH match. The average heart rate in the first half of both matches was greater than in the second half.

Training Load

Halson, 2014

Monitoring training load to understand fatigue in athletes

The purpose of this review article was to report the existing literature on monitoring training load and practical considerations for applying athlete monitoring. There is increasing use of load monitoring by coaches and support staff, and there is no singular tool that is the most accurate and reliable to monitor athlete load. Tools to monitor athlete load include but are not limited to global positioning systems and heart rate monitors, questionnaires and diaries, rating of perceived exertion, power output, and accelerations. In addition, load monitoring can bring down the risk of injury and illustrate an athlete's adaptation to a training program.

Impellizzeri, Marcora, Coutts, 2019

Internal and External Training Load: 15 Years On

The goal of this commentary article was to extend and clarify the definitions of internal and external training load to steer clear from a misinterpretation of the concept. Internal and external load were introduced at the beginning of the 21st century at a presentation discussing the taxonomy of training stimulus. Training load, described as internal or external, is the input variable manipulated to create an intended response to training. The external load can be seen as the physical work done during a training session, such as total distance covered or power output. Internal load involves a mental component to training. It can be seen as the psychophysiological response to the external load. Heart rate and other neuromuscular responses are indicators of internal load. This literature indicates an obstacle in measuring internal load, as there are no established valid indicators of internal load as there are external loads.

Suarrez-Arrones, Torreño, Requena, Sáez de Villarreal, Casamichana, Barbero-Álvarez, Munguía-Izquierdo, 2015

Match-play activity profile in professional soccer players during official games and the relationship between external and internal load

The purpose of this study was to the physical and physiological demands of male soccer players utilizing GPS and heart rate monitors. Thirty professional male soccer players wore SPI Pro X global positioning system and heart rate monitors that collected heart rate, distance, speed, and accelerations in 5-second intervals. Speeds were placed in five categories: walking, low-speed, medium-speed, high-speed, and sprinting. The performance efficiency index (Effindex) was measured by dividing the mean speed in meters per minute by the percentage of maximal heart rate to integrate external load concerning internal load. Defenders covered the lowest total distance. The number of sprints and repeated sprints performed by wide midfielders and strikers were significantly greater than all other groups. A significantly smaller Effindex was observed in center-backs, while wide midfielders displayed a significantly greater Effindex than all other positions except the second striker group.

Torrreño, Munguía-Izquierdo, Coutts, Sáez de Villareal, Asian-Clemente, Suarrez-Arrones, 2016

Relationship Between External and Internal Loads of Professional Soccer Players During Full Matches in Official Games Using Global Positioning Systems and Heart-Rate Technology

The aim of this study was to observe the physical performance and performance efficiency index (Effindex) of professional soccer players. Twenty-six professional male soccer players wore a GPSports SPI Pro X heart rate monitor to capture heart rate, speed, and distance throughout two seasons. Effindex could integrate internal and external load into one single value by dividing velocity in meters per minute by percent of maximal heart rate for each player. The total distance covered in the first half was substantially greater than the second half in all positions. There was a substantial decrease in average heart rate during the second half for fullbacks, second strikers, and strikers compared to the first half. Effindex was substantially reduced in the second half in all playing positions except the striker. Wide midfielders had the substantially highest Effindex and highest total distance covered throughout the entire match. This study confirms a decrease in performance as a match progresses in time.

Physical Performance

Andrzejewski, Chmura, Konefał, Kowalczuk, Chmura, 2017

Match outcome and sprinting activities in match play by elite German soccer players

The purpose of this study was to observe how playing positions and match outcome affect distance-covered sprinting and the number of sprints by German Bundesliga soccer players. Data were recorded and analyzed for 350 soccer players in the German Bundesliga in the 2014-2015 season. An Impire AG motion analysis system recorded all sprints and distances covered in offensive and defensive play in 306 matches. The analysis showed that all defenders covered shorter distances in victorious matches. Forwards and wide midfielders sprinted longer distances in victorious matches over defeats.

Barbero-Álvarez, Bollosa, Nakamura, Andrín, Castagna, 2012

Physical and physiological demands of field and assistant soccer referees during America's Cup

This study aimed to observe the demands of a soccer field and assistant referees both physically and physiologically during America's Cup. The referees wore a global positioning system and heart rate monitor to measure cardiovascular stress and performance efficiency index (Effindex) every 5 and 15 minutes, halves, and the entire match. Field referees covered longer distances for walking and running activities and presented a greater heart rate during match play than assistant referees. Field referees showed a significant drop in accelerations during the second half and a significant drop in Effindex at the end of both halves. Assistant referees only saw a significant drop in Effindex at the end of the second half. This study showed that match play fatigue could be found in both field players and referees.

Bradely, Sheldon, Wooster, Olsen, Boanas, Krustrup, 2009

High-intensity running in English FA Premier League soccer matches

The purpose of this study was to determine the activity profiles of several English FA Premier League soccer players and investigate high-intensity running during the matches of these soccer players. Twenty-eight matches were analyzed in the 2005-2006 season with a computerized tracking system. Results showed a 20% drop in high-intensity running distance in the last 15 minutes of a game in comparison to the first 15 minutes for all defenders and midfielders. Results showed a similar drop in the distance for high-intensity running with and without the ball between the first and last 15 minutes of each half. Attackers and central defenders saw the greatest drop in high-intensity running following their most intense 5-minute period. The findings of this study show a decline in running performance towards the end of each half played in a soccer match.

St Clair Gibson, Lambert, Rauch, Tucker, Baden, Foster, Noakes, 2006

The role of informational processing between the brain and peripheral physiological systems in pacing and perception of effort

The goal of this review article was to examine how the brain can initiate and maintain a pacing strategy that allows an athlete to avoid physiological system failure while also completing the exercise bout in the shortest amount of time. Another aim was to examine how that mechanism could create awareness of the pacing strategy's perceived effort. This article suggested that the brain uses an internal clock to create awareness of the distance that still needs to be covered or the duration left in an event. There will be constant adjustments to power output exhibited by an individual throughout an event.

Varley, Aughey, 2012

Acceleration Profiles in Elite Australian Soccer

The purpose of this study was to analyze the movement profiles of professional male soccer players. Out of the 29 professional male soccer players that partook in this study, only 17 had their data recorded through GPSports SPI Pro's global positioning system and heart rate monitor. The average number of players analyzed per match, due to the inclusion criteria of having played the entire game, was 8. In order to be analyzed, speed was categorized into four thresholds: walk, jog, high-velocity run, and sprint. Wide defenders achieved the largest number of maximal accelerations, the highest number of sprints, and low-velocity accelerations. Central defenders and midfielders completed the lowest number of sprints. Aside from wide midfielders performing fewer sprints, maximal accelerations, high-intensity efforts, and high-velocity running, there were no differences in the number of efforts in the second half across all other positions.

CHAPTER THREE: METHODOLOGY

Experimental Approach to the Problem

NCAA Division I female soccer athletes was 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 TeamPro GPS sensors (Polar Electro, Co, Kempele, Finland) to monitor external load defined as the physical work done in relation to a training plan (Impellizzeri et al., 2019). Dependent variables that examined external load included distances and speeds covered during the competitive season and average and maximal heart rates. At the end of the season, heat stress conditions were extracted from the Weather Underground's website, using the University of Central Florida's WeatherSTEM system for home matches. For away matches, heat stress conditions were extracted from the nearest weather station to the university at that moment. Wet-bulb globe temperature (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, jogging, low-speed running, high-speed running, and sprinting.

Participants

Athletic performance data from 8 Division I female soccer players were examined. The competitive season took place in the summer and fall months from August to November of 2019. Athletes that played over 30 minutes or more per match were included in this analysis. 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 in 75% of the matches, creating a final sample of data from 8 players. The average minutes played by the eight players in the analysis was 83.26 ± 11.25 minutes. The sample included defenders (n = 4), midfielders (n = 3), and forwards (n = 1). All participants were cleared to participate in physical activity by the University of Central Florida's Sports Medicine staff before collecting data. A retrospective examination of the data was approved by the University of Central Florida Institutional Review Board for Human Subjects with approval #2673.

Procedures

Participants' data were collected for all 21 matches played in the 2019 season but were only analyzed for 9 of the matches due to the inclusion criteria of having played over 30 minutes in 75% of the total matches for the competitive season. All 8 participants were equipped with Polar Pro sensors and a chest strap to attach the sensor. 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. 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 TeamPro's online database once connected to the internet. Substitutions and playing time were calculated in real-time by an investigator 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).

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 relative total distance (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 (Varley & Aughey, 2013) or 168 meters per minute. Speed zones were separated into 5 categories: walking ($WALK_{REL}$ 0.83 – 1.94 m/s), jogging (JOG_{REL} 1.94- 3.05 m/s), low-speed running (LSR_{REL}3.06-4.16 m/s), high-speed running (HSR_{REL}4.17- 5.27 m/s), and sprinting ($SPRINT_{REL}$ 5.28+ m/s).

Heart Rate

Polar 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 as the season progressed during training sessions by updating the maximum beats per minute value on players' profiles in the Polar TeamPro database. The average percent of maximum heart rate ($\%HR_{AVG}$) was extracted from Polar TeamPro'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 (Barbero-Álvarez et al., 2012). 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. Ambient temperature, humidity, and WBGT were reported at the beginning of each match and extracted from WeatherSTEM. 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). When humidity was at or below 50%, Low-Risk was classified as a WBGT below 24 ºC, Moderate-Risk with a WBGT between 24ºC and 28ºC, and High-Risk had WBGT between 26ºC and 29ºC. When relative humidity was more than 50% but less than 76%, Low-Risk was identified with a WBGT below 20ºC, a Moderate-Risk with a WBGT between 20ºC and 25ºC, and a High-Risk between 26ºC and 29ºC. When relative humidity was above 76%, Low-Risk was identified with a WBGT below 18ºC, Moderate-Risk between 18ºC and 23ºC, and High-Risk between 24ºC and 28ºC (Coker et al., 2020).

Statistical Analysis

Repeated measures ANOVA test was used to compare each dependent variable (TD_{REL}, $WALK_{REL}$, LSR_{REL}, HSR_{REL}, $SPRINT_{REL}$, 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. (Green et al., 2000) 0.01, 0.06, and 0.14 represent small, medium, and large effect sizes, respectively. An alpha of $p < 0.05$ was established a priori. SPSS (version 25, SPSS, Inc., Chicago, IL) was used for all statistical analyses.

CHAPTER FOUR: RESULTS

Heat Stress and Playing Time

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

Heat Stress and Total Distance Covered Relative to Minutes Played

A significant effect ($F=10.938$; $p=0.001$; $\eta^2= 0.610$), as shown in Figure 1, was observed across all heat stress conditions and distance covered relative to minutes played. Low-Risk TD_{REL} was significantly greater ($p=0.011$) than High-Risk TD_{REL}. In addition, Moderate-Risk TD_{REL} was significantly greater($p=0.012$) than High-Risk TD_{REL}.

Walking Distance Relative to Minutes Played Across All Matches Played in Each Heat Stress Condition

Total distance covered relative to minutes played across environmental conditions for each speed threshold can be found in Table 1. A significant effect ($F= 13.878$; $p=0.002$; $\eta^2=0.665$) was seen within walking distance in all matches played. Low-Risk Walking $Distance_{REL}$ was significantly greater ($p=0.005$) than Moderate-Risk Walking $Distance_{REL}$. In addition, Low-Risk Walking $Distance_{REL}$ was significantly greater ($p=0.005$) than High-Risk Walking $Distance_{REL}$.

Jogging Distance Relative to Minutes Played Across All Matches Played in Each Heat Stress Condition

A significant effect ($F= 9.451$; $p=0.003$; $\eta^2=0.574$) was observed in several environmental risk levels with jogging distance. Low-Risk Jogging $Distance_{REL}$ was significantly greater ($p=0.005$) than Moderate-Risk Jogging $Distance_{REL}$. High-Risk Jogging $Distance_{REL}$ was significantly greater ($p=0.005$) than Moderate-Risk Jogging $Distance_{REL}$.

Low Speed Running Distance Relative to Minutes Played Across All Matches Played in Each Heat Stress Condition

A significant effect ($F=7.81$; $p=0.005$; $\eta^2=0.527$) was observed in two risk levels compared to the distance at Low-Speed Running. Low-Risk Low-Speed Running $Distance_{REL}$ was significantly greater ($p=0.001$) greater than Moderate-Risk Low-Speed Running $Distance_{REL}$. Moderate-Risk Low-Speed Running $Distance_{REL}$ was significantly lower than High-Risk Low-Speed Running $Distance_{REL}$.

High Speed Running Distance Relative to Minutes Played Across All Matches Played in Each Heat Stress Condition

A significant effect ($F=6.128$; $p=0.012$; $\eta^2=0.467$) was observed in High-Speed Running Distance and risk levels. Low-Risk High-Speed Running $Distance_{REL}$ was significantly greater ($p=0.035$) than Moderate-Risk High-Speed Running $Distance_{REL}$. Low-Risk High-Speed Running $Distance_{REL}$ was significantly greater ($p=0.029$) than High-Risk High-Speed Running $Distance_{REL}$.

Sprinting Distance Relative to Minutes Played Across All Matches Played in Each Heat Stress Condition

A significant effect (F=12.009; p=0.001; η^2=0.632) was observed in all heat stress conditions during sprinting (Figure 2). Low-Risk Sprinting Distance$_{REL}$ was significantly greater (p=0.017) than Moderate-Risk Sprinting Distance$_{REL}$ and High-Risk Sprinting Distance$_{REL}$ (p=0.005). In addition, Moderate-Risk Sprinting Distance$_{REL}$ was significantly greater (p=0.035) than High-Risk Sprinting Distance$_{REL}$.

Environmental Conditions and Low-Intensity Running Distance$_{REL}$ During Matches Played

A significant effect (F=10.988; p=0.001; η^2=0.611) was observed between environmental conditions and low intensity running (Table 2). Low-Risk Low-Intensity Running Distance$_{REL}$ was significantly greater (p=0.004) than Moderate-Risk Low-Intensity Running Distance$_{REL}$ and High-Risk Low-Intensity Running Distance$_{REL}$ (p=0.032).

Environmental Conditions and High-Intensity Running Distance$_{REL}$ During Matches Played

A significant effect (F=13.955; p=0.001; η^2=0.647) was found between environmental conditions and high-intensity running (Table 2). Low-Risk High-Intensity Running Distance$_{REL}$ was significantly greater (p=0.005) than Moderate-Risk High-Intensity Running Distance$_{REL}$ and High-Risk High-Intensity Running Distance$_{REL}$ (p=0.003).

Performance Efficiency Index

A significant difference (F= 13.478; p=0.001; η^2=0.658) was observed in Effindex across all environmental condition risk levels (Figure 3). Low-Risk Effindex was significantly greater

($p=0.041$) than Moderate-Risk Effindex and High-Risk Effindex ($p=0.001$). Moderate-Risk Effindex was significantly greater ($p=0.05$) than High-Risk Effindex.

CHAPTER FIVE: 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 (Effindex) during a competitive female soccer season. The results of this study indicate that matches played by female soccer players in environmental conditions categorized as moderate and high-risk are detrimental to running performance in all five-speed thresholds, total distance, and Effindex. While there were significant differences in distance covered (Figure 1, 2, Tables 1 and 2), interestingly, our results also demonstrated that total minutes played among the eight female soccer players analyzed in this study were not significantly different among the three environmental conditions. Thus, this study served to address the insufficient amount of research examining collegiate female soccer players in varying 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 (Chmura et al., 2017; Konefał et al., 2020; Mohr et al., 2012). Chmura and colleagues (2017) examined the players' performance measures of the 32 teams competing in Brazil's 2014 FIFA World Cup at different air temperatures and relative humidity. 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%) (Chmura et al., 2017). Konefał and colleagues (2020) reported that 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 (Konefał et al., 2020). Mohr and colleagues (2012) attempted to examine 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). Total distance, in meters, was found to be 7% shorter in hot environmental conditions compared to normal environmental conditions (Mohr et al., 2012). This current study found similar results in female soccer players.

In agreement with the above studies in men, our data demonstrated that total distance relative to minutes played (TD_{REL}) was significantly higher in Low and Moderate-Risk conditions. The longest TD_{REL} played was seen in environmental conditions of Moderate Risk. Although relative to the opponent played, longer distances do not necessarily coincide with fatigue, as Andrejewski and colleagues (2018) concluded, longer total distances were correlated to successful performance through a victorious match (Andrzejewski et al., 2018). In support, the team analyzed in the current study went undefeated in their three matches played under Moderate-Risk conditions, with two being ties and one being a victory.

In support of the literature mentioned above on male soccer players, a study examining the effects of environmental conditions on NCAA female DI athletes found that High-Risk environmental conditions significantly affected total distance when compared to Low-Risk conditions (Benjamin et al., 2020). As described by Benjamin and colleagues (2020), the environmental conditions were considered High-Risk under the following wet-bulb globe temperature (WBGT) 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 this current study were similar to those of Benjamin et al., 2020, and our results were in agreement 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. This current study had a higher average WBGT for the High-Risk category, and the High-Risk environmental conditions were deemed worse due to hotter temperatures and humidity combinations. The significant difference in distance covered during games played in different environmental conditions in the Benjamin et al. study may have been due to pacing. Benjamin and colleagues suggest that using a pacing strategy during High-Risk environments may allow players to cover similar distances. 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 (Table 1) compared to Moderate-Risk conditions and sometimes High-Risk conditions ($Walk_{REL}$, HSR_{REL}, $Sprint_{REL}$). Contrary to Coker et al., 2020, 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, Coker and colleagues (2020) found that there is a significant impact on running performance in $Walk_{REL}$ and Jog_{REL} when playing soccer in the same Low-Risk environmental conditions as this current study (Coker et al., 2020).

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 (Edwards & Noakes, 2009; St Clair Gibson et al., 2006). Edwards and Noakes (2009) point towards players downregulating their efforts in the second half, which influences high-demand responses needed during a match. St Clair Gibson and colleagues (2006) explained that players adopt a pacing strategy, regardless of consciousness towards an endpoint, to complete their physical task

(St Clair Gibson et al., 2006). In support of High-Risk conditions contributing to fatigue, this current study observed declines in TD_{REL} Low-Intensity Running and High-Intensity Running when competing in such environments.

Our results, in conjunction with Chmura and colleagues (2017), studying professional male soccer players, can conclude that an ideal soccer environmental condition for peak running performance is below 22°C and an RH range below 60% (Chmura et al., 2017). In agreement with Andrejewski et al., 2017, the current study demonstrates higher running performance, including low-intensity ($Walk_{REL}$, Jog_{REL}, and LSR_{REL}) and high-intensity (HSR_{REL} and $Sprint_{REL}$) efforts 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 1).

Effindex, a measure of players' work efficiency, detects fatigue and identifies the dose-response of a soccer match (Halson, 2014; Suarez-Arrones et al., 2015). It allows for an integration of external and internal load by examining mean running speed in relation to relative cardiovascular stress (Barbero-Álvarez et al., 2012). A lower Effindex value indicates higher cardiovascular stress (Suarez-Arrones et al., 2015). Effindex proved to be 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 during soccer matches. However, there is literature examining Effindex values in both halves of rugby matches (Suarez-Arrones et al., 2014) and in soccer referees (Barbero-Álvarez et al., 2012). Suarez-Arrones and colleagues (2014) found that Effindex was reduced in the second half, indicating fatigue in the latter half of a rugby match

(Suarez-Arrones et al., 2014). Similar to the previous study, Barbero-Álvarez and colleagues (2012) found that Effindex was sensitive to time, with a reduced value in the last 15 minutes of both halves of a soccer match (Barbero-Álvarez et al., 2012). Although our study did not look into 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 (Bohner et al., 2015; Coker et al., 2020; No & Kwak, 2016). 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 between the two (Datson et al., 2014). Research looking at elite male soccer players found that lower sleep efficacy had a negative effect on the incidence of injuries (Silva et al., 2020). 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 (Bohner et al., 2015). 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 severely differ depending on how much distance was between the site of the match played and the nearest weather station. However, Kuuseoks and colleagues (1997) found no significant difference between on-site weather data and data from regional weather stations but emphasized topography before geographic distance (Kuuseoks et al., 1997). A significant limitation of this study was a lack of consideration for each opponent's rating percentage index (RPI) ranking. Using the RPI may have explained whether a decrease in running performance was due to environmental conditions or an easier opponent. However, no difference was observed between RPI and running performance in all environmental conditions by Coker and colleagues (2020) (Coker et al., 2020). Of the 4 matches analyzed in the High-Risk category, two of them included teams with a higher RPI than the original team. All other teams in this study had a lower RPI than the original team from this current study.

This current study found that lower 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 fatigue and performance due to decreased running performance, as observed within the currently available data. Chaen et al. (2019) recently demonstrated that wearing a cooling vest for 15 minutes at half-time improved intermittent exercise performance in male soccer players (Chaen et al., 2019). 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.

This study indicates that running performance and Effindex are attenuated in response to soccer matches played in Moderate-Risk and High-Risk environmental conditions. For practical considerations, the coaching staff is advised to coincide training time with an upcoming match whenever possible (Chtourou & Souissi, 2012). This allows for time-of-day adaptations to be consistent and adaptations to rising environmental conditions and solar radiation from solar elevation angles (Otani et al., 2017). Usage of cooling devices on the forearm, hand, and neck during half-time or substitutions could assist in thermoregulation and, in turn, a reduction in heat-induced fatigue (Zhang et al., 2014). Dehydration and increased sweat rates are examples of fatigue reactions induced by the heat and have a negative impact on running performance in both men and women (Zhang et al., 2014). Cooling devices may be the solution to dehydration and short-term decrements in performance.

APPENDIX A: FIGURES

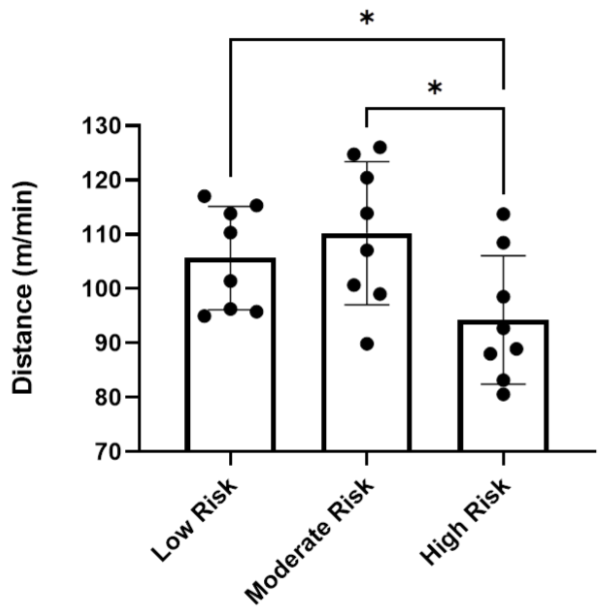

Figure 1. Effect of Environmental Conditions on Total Distance Relative to Minutes Played. *p<0.05

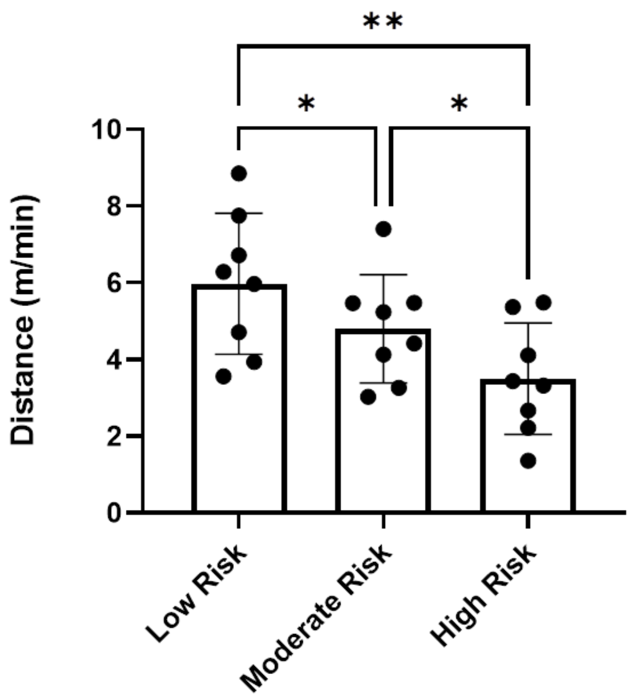

Figure 2. Effect of Environmental Conditions on Sprinting Distance Relative to Minutes Played Across All Matches. **p<0.01 *p<0.05

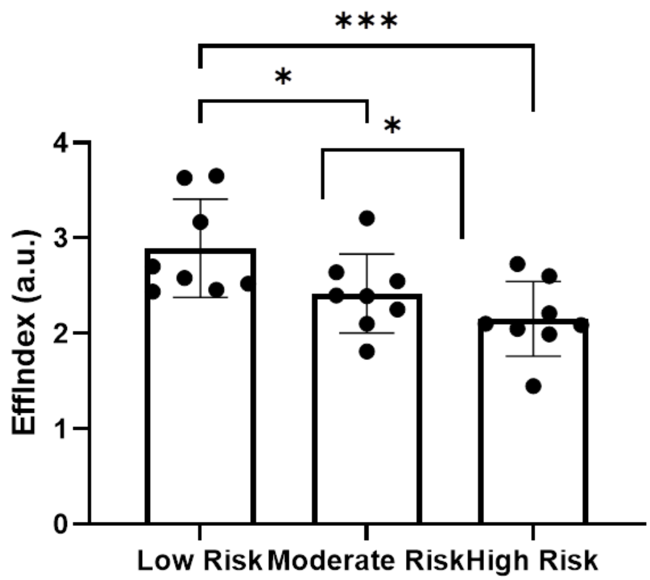

Figure 3. Effect of Environmental Conditions on Performance Efficiency Index Across All Matches
***p<0.001 *p<0.05

APPENDIX B: TABLES

Table 1. Mean ± SD for each environmental condition.

	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

Table 2. Mean ± SD for the effect of environmental conditions on LIR and HIR distance

	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*

APPENDIX C: IRB APPROVAL

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

UNIVERSITY OF CENTRAL FLORIDA

EXEMPTION DETERMINATION

February 22, 2021

Dear Maxine Furtado:

On 2/22/2021, the IRB determined the following submission to be human subjects research that is exempt from regulation:

Type of Review:	Initial Study, Category 4
Title:	Variations of Environmental Conditions on Internal and External Training Load in NCAA Division I Soccer Players: A Sex-Based Comparison
Investigator:	Maxine Furtado
IRB ID:	STUDY00002763
Funding:	None
Grant ID:	None
Documents Reviewed:	• HRP-255-SR update, Category: IRB Protocol;

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made, and there are questions about whether these changes affect the exempt status of the human research, please submit a modification request to the IRB. Guidance on submitting Modifications and Administrative Check-in are detailed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Racine Jacques, Ph.D.
Designated Reviewer

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