Effect of Physiological Demands on Decision-Making in Soccer Referees

By Carlos Mercado (Thesis) submitted to the School of Graduate Studies in partial fulfillment of the requirements for the degree of

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Abstract

Decision-making ability is critical to sport officials' performances. However, current training methods that simulate the task of soccer referees ignore physiological factors that may affect decision-making. The primary objective of this research was to investigate the influence of physiological demands on decision-making accuracy among non-professional soccer referees. Skilled soccer referees (N = 10; male = 9, female = 1) were tested on a decision-making simulator. Participants ran on a treadmill for 30 minutes at varying speeds, while watching 30 different video clips; one each minute. The videos presented the referees with a foul or no foul situation, and participants called their match decisions out loud. Simultaneously, the experimenter recorded participants' heart rate and rating of perceived exertion. Two one-way repeated measures Friedman's tests were performed to assess decision accuracy in relation to running speed and block during the experiment. Consequently, there was no significant difference in decision accuracy for participants based on the speed at which they were running: $\chi^2(2) = 5.013$ and $p = .286$. Similarly, no significant difference was shown for the effect of blocks on referees' accuracy in decision-making: $\chi^2(2) = 1.500$ and $p = .472$. Finally, two Pearson's correlation tests were completed. There was no significant relationship between the referees' average heart rate and their accuracy: $r = .078$, $p = .689$. Similarly, there was no relationship between referees' decision accuracy and the rating of perceived exertion: $r = -.078$, $p = .686$. While the findings were not significant, it is imperative to continue this research. Specifically, studies that place referees in their natural environment (enhancing ecological validity) might offer more insights into the relationship between physical load and decision-making.

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Contents

1.0 Introduction

Soccer is arguably the most popular sport in the world. According to Badinger (2020), soccer is practiced by more than 250 million people in over 200 countries. It is practiced mainly in Europe, Asia, and Central America, with a considerable increase in its popularity in North America (the USA and Canada) in the last 20 years. It is no wonder that sport scientists have an extensive research repertoire related to the sport. Incidentally, the greatest amount of research is focused on players and coaches, leaving aside other relevant actors in the performance of this sport, such as referees.

Soccer referees play a primary role in which their main function is to be "the person who controls the actual play of a competition by using the rules and laws of the sport to make judgments on rule infringement, performance, time and score" (MacMahon et al., 2014). Referees favour the harmonious development of a soccer game by applying the rules and fair play to ensure the integrity of the players, coaches, and even fans. Consequently, this opens up a great possibility of developing research related to these actors.

However, in the last 20 years, despite the increased interest of sport scientists in generating research related to soccer referees, this attention has been primarily focused on studying and quantifying their performance as a merely physical entity and examining elements such as age, distance travelled, and heart rate (Weston et al., 2011). Other studies have been based exclusively on the analysis and observation of components of cognitive origin such as decision-making and the judging process (Dosseville & Laborde, 2015). Often overlooked are how physiological demands during the performance of soccer referees in a match are possibly linked to accurate decision-making.

Furthermore, the small percentage of research related to the effect of physiological demands on decision-making focuses mainly on athlete populations from sports other than soccer, such as volleyball, basketball, and individual sports (e.g., weightlifting and track and field) (Coyne et al., 2021). In addition, the emerging investigation of this phenomenon in soccer is mostly directed at professional soccer officials, as a consequence of the available monetary resources and general interest towards this population, leaving aside millions of practitioners of this sport who officiate for recreational purposes only.

As a solution to this lack of research in the field, it is relevant that the institutions or organizations dedicated to disseminating the practice of soccer, such as the federations of the countries and even FIFA (Fédération Internationale de Football Association) itself, promote financial incentives for the development of research on referees. And thus, to be able to obtain more information applicable to the improvement of the performance of the referees as fundamental actors in the development of a game, not only at a professional level, but also at an amateur level. The objective of this thesis was to study amateur soccer referees to determine if physiological demands influence decision-making and accuracy. Results might enable strategies and guidelines for improving the performance of soccer referees. As a result of the implications of COVID-19, only 10 participants could be evaluated in this study. However, the results might enable strategies and guidelines to improve the performance of soccer referees.

This thesis was designed using the chapter-style approach. Chapter 2, "Literature Review", provides relevant research findings about soccer referees' decision-making, physical fitness, and physiological demands that impact decision-making to provide a contextual framework for the research question. Additionally, the purpose describes how the research was developed, establishing the objectives and the research problem. In Chapter 3, "Method,"

participants, study design, and statistical procedures are presented. This section includes the details of the sampling method used, participant demographics, the procedure and materials to collect data, as well as how the data were processed and analyzed in this research, including data preparation, software used, and statistical methods. Subsequently, Chapter 4, "Results", reports the findings of the study with specific sub-sections for each type of statistical test. Lastly, Chapter 5, "Discussion", summarizes, interprets, and discusses the findings and implications for officiating research.

2.0 Literature Review

Regular sport participation facilitates good health, which is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 2020). According to Eime et al. (2013), there is substantive evidence demonstrating that youth and adult sport participation yields physical, psychological, and social health benefits. Bailey et al. (2021) outlined many of these benefits including reduced risk of obesity and chronic diseases (i.e., physical benefits), elevated self-esteem with reduced stress (i.e., psychological benefits), and learning to respect authority and teamwork (i.e., social benefits). It was further suggested that many of these benefits are not as easily acquired in physical activity or leisure settings—a sentiment shared by the American College of Sports Medicine, which suggested that participation in team sports rather than individual activities is associated with better health outcomes (Liguori, 2020). Bailey et al. (2021) demonstrated that lifelong sport participation results in physical and mental health benefits that contribute to healthy aging. While many researchers have identified youth sport participation as a key contributor to lifelong physical activity (e.g., Kjønniksen et al. 2009), it is important to note that youth sport participation also predicts adult sport participation (Tammelin et al., 2002). In fact, a nearly three-decade longitudinal study highlighted that youth sport participation leads to healthy adult behaviours (Palomäki et al., 2018). Thus, sport has tangible mental and physical benefits that contribute to healthy aging (Côté & Hancock, 2014).

With so many potential benefits gleaned from sport participation, it is not surprising that sport scientists have dedicated considerable efforts to understand the environment. Logically, most research studies use athletes as participants, as they are the main actors within sport. This has enhanced our understanding of many principles of athletic performance such as goal-setting,

imagery, and arousal regulation (Weinberg & Gould, 2019). Likewise, several researchers have studied sport coaches, which has yielded valuable insights into leadership styles (Goleman, 2005), leadership behaviours (Smoll & Smith, 1989), and coach-athlete relationships (Weinberg & Gould, 2019). A third important actor in the sport environment is the sport official, who receive little attention from sport scientists—at least compared to athletes and coaches. Since sport officials play a vital role in sport, they warrant further investigation.

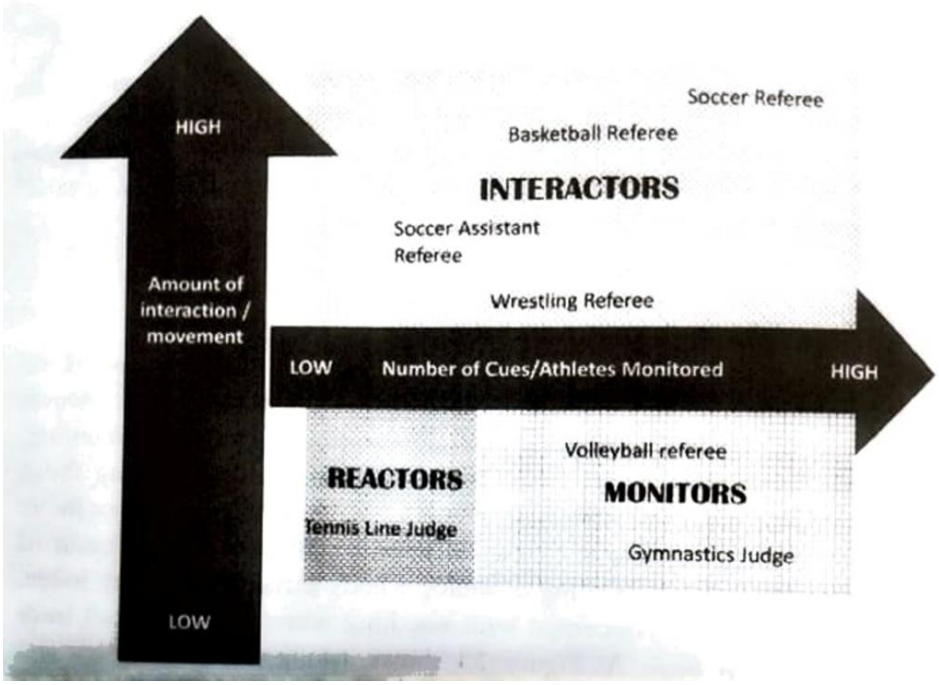
Sport officials is a collective term to group referees (e.g., soccer referees), umpires (e.g., tennis chair umpires), judges (e.g., gymnastics judges), and officials (e.g., swimming timers) (Hancock et al., 2021). Collectively, sport officials are tasked with applying their specific sport rules, maintaining competitive fairness, and reducing the risk of injury for athletes (Dosseville & Laborde, 2015; Helsen & Bultynck, 2004). While these broad roles of a sport official are applicable across sport officiating contexts, the environment in which they operate and the way in which they achieve these objectives differs greatly based on the sport.

To better categorize sport officials, Plessner and MacMahon (2013) created three classifications of sport officials based on the number of interactions they had with athletes, their proximity to athletes, the number of athletes in the competitive environment, and the number of cues they monitored (see Figure 1). The first category, *interactors*, are sport officials who attend to several cues during an athletic performance and have a high level of interaction with athletes as they are typically in the field of play. Interactors include basketball, soccer, and ice hockey referees among others. The second category, *monitors*, are sport officials who attend to several cues during an athletic performance and assess the quality of a performance, but have limited, if any, interaction with athletes. Examples of monitors include gymnastics, diving, and figure skating judges. Lastly, there are *reactors*, who have few responsibilities (in terms of number, not

magnitude) and limited interaction with athletes. Example of reactors are volleyball and tennis line judges whose role is to decide if a hit ball is in or out of bounds. While the environments for these sport officials might differ, the ability to make quick, accurate decisions is paramount to their success.

Figure 1

Categories of Sports Officials



Note. From Plessner and MacMahon (2013).

The unique environment of interactors deserves further discussion. There are several challenges for sport officials during a match. Interactors must be in good physical shape (Leicht, 2008), make quick decisions (MacMahon et al., 2007), have extensive knowledge of the rules (Mascarenhas et al., 2005), communicate with athletes and coaches (MacMahon & Plessner, 2007) and cope with tremendous pressure and scrutiny (Neville et al., 2016). Clearly, sport officiating is complicated, especially so for interactors. In professional sports like soccer and

rugby, for instance, interactors cover 10 to 12 kilometers per match, with running speeds predominantly below 13 km/h (Weston et al., 2011). Adding to the distances covered, interactors must also master positioning, as they are in a dynamic environment with athletes and high-quality decision-making depends on being in the correct place at the correct time. Therefore, it is important not only to outline the skills that sport officials hold (as has been done with previous research), but also to detail the specific characteristics that interactors must attain to achieve good performance, especially given the psychophysiological components of elite interactors.

As noted, one specific interactor is the soccer referee. Soccer performance involves a myriad of factors such as technical/biomechanical, tactical, mental, and physiological areas. Thus, the sport needs highly qualified referees. Soccer referees have high movement and decision-making demands due to the area covered with only one main official on the pitch. Research has demonstrated that, in an average match, professional soccer referees cover an average total distance of 10.5 kilometers with speeds predominately below 13 km/h, while making up to 200 observable decisions (Birk Preissler et al., 2021). Based on this, it is imperative to understand soccer referees' decision-making, physical demands, and relationship between them. These topics will be developed in greater detail in the following sections.

2.1 Decision-Making in Soccer Referees

Decision-making is a central factor in soccer referees' performance. Referees are responsible for regulating the game from an impartial point of view, making decisions in fractions of a second and enforcing the rules (Samuel et al., 2019). During a professional soccer game, a referee can make more than 200 decisions, averaging between 104 and 162 (Birk Preissler et al., 2021; Helsen & Bultynck, 2004). This helps matches to be carried out in a safe environment where fair play prevails and thus preserves the integrity of the players, coaches, and

even fans. However, to talk about the elements that make up correct decision-making is to fall into a discussion within a very broad spectrum of elements that can interact in a referee when making a decision or several decisions during the match. Therefore, decision-making is based on a normative judgment that requires the person not only to be consistent but also "well-calibrated", meaning decisions are based on the context of the competition (e.g., score differential; Tversky, 2004).

Considering this complexity that makes up the decision-making process, it is not at all new that during a soccer game, the referees are the centre of observation in terms of the number of errors that they could commit. Consequently, much of the research in the field of soccer refereeing has focused on decision-making as a primary component of referee performance (MacMahon et al., 2014). However, despite the increased interest in studying decision-making in the performance of referees, this phenomenon is still being studied through its underlying mechanisms, as well as certain factors that can influence it (Samuel et al., 2021). Instead, decision-making must be understood from a much more complex and comprehensive point of view. And so, the scientific community seeks to have more precise frames of reference, such as models that include the many factors that make up decision-making in a soccer referee (e.g., physical and cognitive factors), explaining the implications that these have on the performance of the referees. The following is relevant in order to have greater clarity on how these various factors interact in decision-making and thus be able to generate new proposals in the form of referee training that enhance their performance to maintain control and ensure the integrity of the game (Russell et al., 2018).

2.1.1 Decision-Making Models

There is a great number of factors that interact when a referee makes a decision during a match. Since several of these factors can affect the decision-making process, it seems reasonable that no single study design can account for all of them (Samuel et al., 2020). Most authors would agree that the lack of perfection in referee decision-making is largely due to the extremely physically and psychologically demanding nature of the game (Mascarenhas et al., 2005), in addition to the fact that mistakes are always made, which is part of game development.

Although there are no systematic forms of training for referees in decision-making, there are some characteristics that seem constant enough to be able to consider new study alternatives in decision-making for the creation of more optimal training protocols. For this reason, determining what the specific characteristics are that underpin correct decision-making during a call of an infraction in a soccer game has triggered the interest of various research informing models that facilitate organizing and our understanding of the factors that affect decision-making. Therefore, achieving detailed evaluations and understanding of the decision-making process would improve the quality of referees' performance and establishing better models for their training.

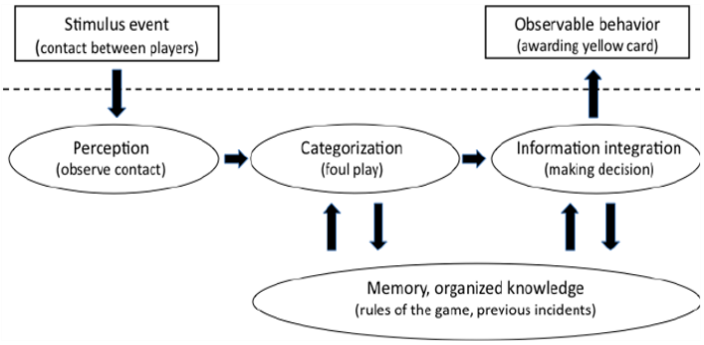
One of the most cited models to understand the phenomenon of decision-making in sport is the Social Information Processing Model (Plessner & Haar, 2006). This model is useful since it differentiates the subtasks of information processing: perception, categorization, memory, and information integration (see Figure 2). The authors of this model argue that many referees' decision-making situations are similar to typical social judgment situations, hence they can be analyzed within a social cognition framework (Plessner & Haar, 2006).

On the other hand, Samuel et al. (2021) simplifies decision-making through the Integrated Conceptual Framework of decision-making in soccer refereeing, seeking to focus more on the task of arbitration instead of the elements that make up the decision-making process. Their proposal is based on the dominant skills such as (1) where to run, (2) where to gaze, (3) what to anticipate, (4) what to call and (5) keep or change the decision that was made. These skills respond to variables like experience, stress, positioning, knowledge and law criteria, and efficacy that are commonly found during the development of a soccer game and that the referee, through appropriate training, can fine-tune to gradually reduce the possibility of an error during decision-making. According to this framework, response selection in dynamic sport contexts refers to adaptive behaviour based on the official's ability to solve problems. The information processing perspective suggests that motor behaviours in complex sport situations consist of encoding relevant environmental cues through the use of attentional strategies and information processing involving a task, while also making multiple successive decisions (sequential) within a match (Samuel et al., 2021).

These models serve as a guide to understand that there are many internal and external factors that influence decision- making. Despite the fact that many of these models were developed primarily for athletes and officials of other sports, both can serve as a basis for developing new, more concise models that explain both internal and external factors in soccer refereeing. Therefore, based on these models, it can be understood how there is a wide range of internal (stress levels, nervous adaptation, etc.) and external factors (where to run, positioning, etc.) which make the possibility that soccer referees will be biased in their decision-making throughout the match.

Figure 2

Social Information Processing Model



Note. An illustration of input-output relations among the concepts of a referee performing the sequential decision-making process in a tackle situation. From Plessner and Haar (2006).

Table 1

An integrated conceptual framework of decision-making in soccer refereeing. Factors associated with soccer refereeing decision-making

Decisions	Operational Mechanism	Influencing Factors
1. Where to run?	a. Diagonal system b. Anticipating the action's location	a. Experience b. Prior knowledge of teams' playing style c. Present match style d. Referee's fitness
2. Where to gaze?	a. Detecting essential stimuli in the visual field (effective attentional focus) b. An efficient fixation/duration ratio	a. Location on the field b. Contextual information
3. What to anticipate?	Upload optional decisions to LTWM (e.g., foul, handling, out of play)	a. Stress b. Fatigue c. Extreme weather conditions (referee's hydration status) d. Previous match events
Event / Infringement	Identification and active processing of events	a. Positioning b. Abstraction of view c. Attentional focus d. Options in LTWM
4. What to call?	a. Attempting to match action with law criteria b. Produce most suitable decision	a. Knowledge of law criteria b. Information from assistants and players c. Game management – context d. Referee's mental state
5. Keep or change the decision?	a. Players' dissent b. Assistants' information (including VAR) c. Self-talk	a. Refficacy b. Self-control
Executing Decision	a. Signaling b. Application of protocols	a. Knowledge of protocols b. Attention selection

Note: From Samuel et al. (2021)

2.1.2 Decision Bias

Despite the new advances in research related to decision-making in soccer arbitration and even the new models that have emerged such as those mentioned above, there will always be the possibility of a bias when making a judgment and making a decision.

The foregoing can be explained by understanding that a decision-making bias is nothing more than mental shortcuts that can facilitate problem-solving and probability judgments (Tversky, 2004). These strategies are generalizations or rules of thumb that reduce cognitive load and can be effective for making snap judgments; however, they often result in inaccurate conclusions that can be considered errors in decision-making. Thus, by understanding this phenomenon as part of the nature of the human being, better alternatives adapted to the context of interest can be created. In this case, to the context of soccer arbitration.

Likewise, ample scientific evidence indicates that decision-making in sports performance (in referees, athletes and coaches) is just as likely to have cognitive biases as other social judgments (Plessner & Haar, 2006). Therefore, developing accurate performance evaluations can help improve the quality of decision-making in soccer referees. Additionally, the application of a social cognition approach provides information on the processes that underlie biases in judgments about sports performance and, therefore, some indications on how to prevent them. The above-mentioned will help to have constant scrutiny in the review and development of more solid models for the training of decision-making in referees.

2.1.3 Decision-Making Accuracy

Soccer requires that the referees make perceptive decisions, sometimes under great pressure and with great uncertainty. However, there is still a need to understand in greater depth what elements play a specific role in accurate decision-making in soccer referees. One of the

most recent studies, carried out by Samuel et al. (2019), found that there are factors associated with decision-making accuracy such as physical fitness, fatigue, self-control strength, contextual information, and decision-making performance. However, due to the wide range of elements that interact in the performance of an arbiter at the time of making a call, it is important to emphasize that there is currently no framework that can fully account for a process as complex as the decision-making accuracy and the exact factors that should be considered for its improvement.

Nevertheless, there are models such as the aforementioned Integrated Conceptual Framework (Samuel et al., 2021) and the Social Information Processing Model (Plessner & Haar 2006), which can guide new research with stronger theoretical and empirical frameworks for training to improve decision-making accuracy in soccer referees. As well, this could lead to the development of sophisticated simulators, which can be of great importance for researchers who wish to examine the underlying factors of the decision-making process; for example, the relationships between physical fitness, fatigue, self-control strength, contextual information, and decision-making performance (Samuel et al., 2019). This paves the way to the need for the proposal of effective models for the psychophysiological training of the referees for greater precision in decision-making during a match.

Additionally, some studies such as Helsen et al. (2004), Catteeuw et al. (2010), Mallo et al. (2012) and Samuels et al. (2019) have brought interesting results in relation to decision-making accuracy. Some of these studies have examined the effect of positioning on the correct decision-making of first-class referees and assistant referees during international matches. In one such study, carried out at the 2009 FIFA Confederations Cup, 380 incidents of foul play and 165 offside situations were examined (Mallo et al., 2012). It was found that the lowest percentage of error in signaling incidents was 14% in the central area of the field, where the collaboration of

the assistant referee is limited, and is achieved by signaling incidents from a distance of 11-15 m, while this percentage reaches its maximum (23%) in the last 15 minutes of the match (Mallo et al., 2012). The error rate of the assistant referees was 13%. The distance of the assistant referee from the offside line had no impact on the quality of the off-side decision, whereas the risk of making incorrect decisions was reduced when the assistant referee viewed offside situations from an angle between 46 and 60°. Additionally, incorrect offside decisions were found to occur twice as often in the second half of games as in the first.

On the other hand, de Oliveira et al. (2011) evaluated the fouls made by professional Brazilian soccer referees to determine the possible relationship between the referees' distance to a foul and the accuracy of the sanction. Three-hundred-twenty-one fouls from various soccer matches supervised by the Sao Paulo State Soccer Federation were included. The authors found no significant association between the referees' distance to a foul and the accuracy of the penalty. However, there was a significant increase in the number of correct calls in the last 15 minutes of the second half compared to the number of correct calls in the first 30 minutes of the same half. Similarly, a study by Riiser et al. (2019) sought to assess whether running speed is related to the accuracy in referees. They also investigated the relationships between movement, position, decision-making, and time of infringement. An analysis of 347 free kicks and penalties awarded during 15 home matches in the Norwegian top league was conducted. Movement and position were measured by a radio-based positioning system, and two external experts analyzed the video clips. The referees made the correct decision in 98% of the foul situations. There were no associations between correctness and running speed at the time of the infringement or the total distance accumulated during the 30 seconds prior to the infringement. The precision of decision-making was not associated with the position in relation to the infringements or the area

where the infringements occurred. Foul play incidents were more likely to occur in the central area of the field (84%)—where the distance from the infringements was shorter (13.4 m)—than in the lateral areas (21.9 m). This is due to the ability to avoid fatigue by maintaining quality positioning (Castillo et al., 2016).

Consequently, new studies can be conducted to explore factors such as positioning, distance, and speed, among others, in soccer referees in contexts other than professional, such as grassroots, amateur, and semi-professional.

2.2 Physical Fitness

There are several studies that investigate physical fitness among soccer referees, though these studies primarily focus on professional referees who make up a small percentage of the officiating body. The concept of physical fitness in soccer referees can be understood as the ability of their body systems to work efficiently and thus allow them to perform optimally during the match (López et al., 2021). In order to know which metabolic energy system will be required during a referee's performance in a match, it is important to understand the characteristics of soccer as a sport. And so, the referees can develop physical skills in accordance with the real demands of the sport in question.

Soccer is a collective sport of an intermittent nature whose competition demands periods of activity that vary in intensity, duration, and recovery times (Thorpe et al., 2017). As a consequence, the referees, being directly responsible for implementing the rules of the game, must develop a physical fitness level that allows them to adapt to the rhythm of the match, which in turn allows them to reach correct decision-making (Mascarenhas et al., 2005). Physical fitness is comprised of external and internal physical load (Happach, 2017). The external physical load is that which is directly observable. Some indicators for the external load can be the number and

duration of different types of displacements, the speed in distances covered, the number of steps made with certain types of displacements or the number of changes of direction and speed made by the referee. Oppositely, the internal load is defined as the body's response to performing a certain physical activity (Krustrup & Bangsbo, 2001). Its main indicators are heart rate and lactate concentration in the blood and in the muscles involved in physical work (Castillo et al., 2016).

2.2.1 External and Internal Physical Demands

Physical fitness (refers to the ability of your body systems to work together efficiently to allow you to be healthy and perform activities of daily living) plays an important role in the performance of soccer referees. Referees who officiate at a professional level cover distances between 10-14 km during a match (Krustrup & Bangsbo, 2001) with an average distance of 10.2 km and an average heart rate of 161 beats per minute, which was 86% of their individual maximum heart rate (Mallo et al., 2009). However, speed is an even more relevant element than the distance covered in a match (Castagna et al., 2004). It can be considered that a referee with high performance can travel 200m from 25 km/h to 27 km/h (Castillo et al., 2016). In addition, the demands of running at high speeds during a game also require considering acceleration phases, deceleration phases, and sudden changes of direction that apply great stress to the musculoskeletal system, placing a great demand on glycogen stores (Ahmed et al., 2017).

Additionally, various authors agree that the motor actions most used by referees are jogging and walking, but it is also documented that the intensity of the game has a great influence on this aspect (Webb, 2017). The performance profile of referees is directly influenced by the distance covered by the ball in the game. In a study carried out by Weston et al. (2011), 19 referees were analyzed in 254 matches in England during the Premier League. The purpose of

the study was to find the correlation of the physical performance of the referees with that of the players. The authors observed that the physical performance of the referees presents a negative correlation between the first and second half of the games, because when the first half is very intense it tends to decrease in the second half, assuming that an energy-saving behaviour may be adopted by the referees. Castagna et al. (2004) did not find significant differences in the distance covered, nor in the maximum speed between the first and second half of the match. Despite this, the average speed and the time that remained between 90-100% of the maximum heart rate (HRmax) was greater in the first half of the matches. This alternation of intensity between match times was also verified in other studies.

In this sense, heart rate is also another significant factor. Through the comparison of various studies, it can be said that a referee's average heart rate will range between 70% and 85% of their HRmax (220-age). Krustrup and Bangsbo (2001) observed that the highest heart rate value that a referee reaches in a match corresponds to about 97% of their HRmax. This information can be related to other research such as Castillo et al. (2016) and Lopez et al. (2021) who focused on the performance of soccer players. In this sense, it is observed that the players' heart rate during the game varies between 80% and 90% of HRmax; values close to those presented by soccer referees. In addition to the above, it is important to emphasize that other factors are still being reviewed in the impact or relationship between external and internal loads that soccer referees need to develop for good performance. Some of these variables that have also been most studied in the fitness level of referees are age, level of experience, and level of competition.

Finally, it is worth mentioning that Mallo et al. (2009) stated that a referee who performs at the highest level must cover 37% more distance sprinting at an average of 86% or more of

their maximum heart rate during matches than those who referee at a lower level (U17 or less), and that age is not a determining factor if the referees are kept under an adequate protocol of physical training. This indicates that the higher the level where the referee is performing, the greater the physical demand. In summary, whatever the level of competition where a referee performs, the physical demands will always be high and will have a degree of complexity when combined with other factors such as environmental and cognitive factors. To the above, it must be added that the majority of professional-level referees are over 40 years old, which generates the prevailing need to train the physical factor optimally, trying to considerably reduce the natural ageing curve (Castagna et al., 2007).

2.3 Physiological Demands and Decision-Making

It stands to reason that soccer referees' physical performances are linked to their ability to make the correct judgment; decision-making is, therefore, a crucial aspect of refereeing. However, there is currently very little evidence on how these factors interact and how significant their relationship is. Most of the literature emphasizes how distance, speed, and intensity levels can be directly related to the referee's performance when making a decision (López et al., 2021). Today, there is little evidence to clarify what physiological factors may have a greater impact on referees' decision-making. This opens a range of possibilities for new approaches for the study of this phenomenon and thus contributes to the improvement of training systems for soccer referees at various levels.

Mascarenhas et al. (2009) carried out what can be considered the first study that attempted to explain the relationship between decision-making and physiological demands. Five referees aged 31 to 43 from the professional New Zealand Football League were sampled. Referees were monitored for seven regular season games as part of a study design. Monitoring

was done using a GPS system that tracked position, speed, and heart rate in real-time. In the same way, the actions related to the decision-making at the time of making a call by the referees were recorded and edited so that they could be analyzed and vetted by an expert panel of referees. Thereby, it could be determined if the referees' decisions were correct or not. These elements were statistically processed and it was identified that there was a strong relationship between incident difficulty and the correctness of the match referees' decisions ($p < .001$). For the 33 most difficult incidents (i.e., viewed most often by the expert referee's panel) match referees' decisions were only 36% correct compared with 75% correct for the remaining 94 clips. A significant difference was not observed between movement speed, distance travelled, and heart rate at the time of decision-making. There was no difference in the proportion of high intensity running performed, although average heart rates dropped from the first half ($X = 166$ bpm, $SD = 7.4$) to the second half ($X = 160$ bpm, $SD = 9.4$). Thus, physical fitness is an inherent component in the preparation of the referee. It has been shown that good physical fitness in soccer referees enhances their performance regardless of the level or category in which they are officiating.

While no other studies directly examine this in soccer referees, a number of studies have examined the relationship between physical load and decision-making outside the context of soccer. A study by Impellizzeri et al. (2019) highlighted physical exercise as a stressor that induces various psychophysiological responses, which mediate cellular adaptations in many organ systems. Thus, they created a theoretical framework where they established that in order to maximize this adaptive response, coaches and scientists need to control the stress applied to the athlete at the individual level. This can only be accomplished through precise control and manipulation of the training load. As a result, the training load consists of two measurable components: internal and external. As a theoretical framework for developing athlete monitoring

systems, this model can be used to understand the relationship between training and individual adaptive responses. With effective implementation, these systems can help coaches and scientists better control and optimize the performance training process.

Moreover, Bloß et al. (2022) investigated the effect of physical load on the decisions and reasoning of first-class handball referees in a study of handball. Two groups of 73 top-class handball referees from the German Federation of Handball performed two similar experiments. Both experiments consisted of the application of the Yo-Yo test with a decision-making task. When comparing the results of both experiments, the authors concluded that well-trained resistance capacity can support the referees' decision-making; that is, making correct decisions and reasoning. Specifically, higher endurance capacity can lead to less subjectively perceived fatigue, resulting in higher cognitive abilities that may facilitate decision-making by referees.

On the other hand, Belcic et al. (2022) conducted a study whose objectives were to determine the physiological loads of referees during handball matches and whether a higher physiological load during the match had a significant effect on the decision accuracy. Additionally, Rating of Perceived Exertion (RPE) was tested to determine if referees are aware of loads during the match. For this, a sample 32 of handball referees was taken from Croatian Premier handball. This research was divided into two phases. The first stage was carried out in the laboratory with functional abilities and the second stage was the measurement of physiological loads and the quality of refereeing in official matches. The results obtained in the first stage showed that there was no correlation between physiological load (time above the anaerobic threshold zone) and the quality of the referee ($r = 0.25/R^2 = 0.06$), $p = .18$). While in stage 2, the referees' RPE estimates correlated with the physiological demands measured during matches ($r = 0.55$, $p < 0.05$). The authors concluded that referees are exposed to high

physiological loads during handball matches, but there is no correlation with the quality of refereeing measured in time above the anaerobic threshold zone. Therefore, referees must provide scheduled training to increase their level of functional ability; this is based on the results of a battery of tests determined by specific aspects such as the level (professional, amateur, etc.) and the specific physical and cognitive demands made by such tests.

According to previous findings (Belcic et al., 2022; Bloß et al., 2022), it can be inferred that physical load may not affect decisions, but it does affect reasoning (the ability to analyze any match situation and make a call in short period time). On the basis of these results, new approaches can be tested that corroborate the close interconnection between physiological factors and decision-making. To close the knowledge gap in this field, it is important to clarify the relationship between physical demands and decision-making in soccer referees at any level. This study attempts to fill that gap in the influence of physiological demands on decision accuracy and speed among non-professional soccer referees.

2.4 Purpose

In a typical match, professional soccer referees make up to 200 decisions and cover 10.5 km at an intensity of 85% of their maximum heart rate (Birk Preissler et al., 2021; Dosseville & Laborde, 2015). Therefore, the task of being a referee is very demanding and complex. Consequently, in recent years, the sport scientific community has become increasingly interested in studying the factors that determine referees' overall performance in terms of decision-making effectiveness. However, several of these approaches have been dedicated to studying decision-making from an exclusively cognitive level (Catteeuw et al. 2010; Plessner & Haar, 2006). Meanwhile, other studies have focused more on the components of physical and physiological

loads (e.g., speed, distance, intensity, fatigue, etc.) and their influence on the performance of referees (Krustrup & Bangsbo, 2001).

Decision-making and physical (physiological responses) levels have been studied as fundamental components of soccer refereeing. Nevertheless, in most of these studies, these two elements have been evaluated independently and not as a set in the performance of the referee, or they have been explored at the highest ranks of officiating. Thus, the purpose of this study was to investigate the influence of physiological demands on decision accuracy among non-professional soccer referees. This project aimed to: (1) assess decision accuracy in relation to movement speed and movement duration and (2) examine the relationship between decision-making accuracy and physiological variables such as heart rate average and RPE.

3.0 Method

To address the purpose of the study, this research implemented a quantitative research design. The methods discussed below were approved by the Interdisciplinary Committee on Ethics in Human Research at Memorial University of Newfoundland (See Appendix, Document 1; ICEHR Number: 20230211-HK).

3.1 Participants

An a priori power analysis seeking a small effect size revealed that 30 participants were required to detect significant differences based on the study design. Originally, the recruitment process was designed to recruit 30 referees from the Newfoundland & Labrador Soccer Association (NLSA). As such, purposive sampling was used, using media such as posting notices to Twitter and emailing the NLSA for their assistance. However, despite the NLSA sharing the recruiting notice with all eligible referees, there was a very low response rate. Thus, recruitment was broadened to any licensed official operating in a FIFA-recognized country. Specifically, the foregoing enabled the recruitment of many international students at Memorial University of Newfoundland who were soccer referees in their home countries. In this study, I evaluated 10 soccer referees (1 female and 9 male) with an average age of 37 years ($M = 37$, $SD = 7.80$). Referees were licensed by FIFA in category U13 or higher, and officiating at least 20 matches per season.

3.2 Procedure

To examine the relationship between physical load and decision accuracy, participants completed a laboratory experiment. The 30-minute test (a typical length of one half in youth soccer) was carried out on a treadmill. During the test, participants wore a Polar H10 heart rate monitor. Participants began with a five-minute warm-up on the treadmill, which allowed them to

prepare physically and mentally for the test. After the warm-up, there was a one-minute break before starting the test.

The 30-minute test was divided into three 10-minute blocks. Within these 10-minute blocks, the participants walked and ran at five different speeds (two consecutive minutes at each speed), which were provided in random order. Test speeds were based on an average speed being 8 km/h, which was inferred from previous research in field (Happach, 2017). Thus, the speeds for this study were average (8 km/h), well below average (5 km/h), below average (6.5 km/h), above average (9.5 km/h) and well above average (11 km/h). These speeds were chosen based on the speeds that a referee performs during a match (Happach, 2017).

During the task, a 42-inch TV screen was mounted in the front of the treadmill to enable video playback. The participants watched video clips that were obtained from varsity soccer games (men's and women's) in the Atlantic University Sport Conference. One-hundred-thirty-five clips were received from a repository stored in the Memorial University of Newfoundland athletics department, all of which showed a foul-no foul decision. Subsequently, an expert referee assessor affiliated with the NLSA was requested to vet all clips. The assessor assessed all 135 clips, providing scores based on two criteria. First, there was a score for how similar the video clip view was to a referee's actual view, which was scored from 1 "poor" to 5 "excellent". Second, there was a score for the difficulty of the foul-no foul decision, which was scored from 1 "easy" to 3 "difficult". The assessor also rendered a decision for whether each clip was a foul or not a foul. Subsequently, a total of 110 (55 from male games and 55 from female games)received a visual quality rating of 4 or 5, while also receiving a difficulty rating of 2 or 3. Following, 30 video clips (lasting 3-7 seconds) were chosen randomly for the experiment, in order to evaluate

the referees' decision-making accuracy. Thus, 15 clips fell under the foul category and 15 under the non-foul category.

During the task, at the 40-second mark of each minute, participants were shown a clip on the TV screen. When the referees were ready to make a decision, they verbalized their answer as "foul" or "no foul", which was recorded by the experimenter. At that time, the experimenter also recorded their heart rate using the heart rate monitor. At the same time, participants were asked for their RPE, which is a subjective measure of how hard a person feels like they are working during physical activity (Impellizzeri et al., 2019). This scale ranges from 6 to 20, being 6-8 "well below average", 9-12 "below average", 13-15 "average", 16-18 "above average" and, 19-20 "well above average" (Castillo et al., 2016). To facilitate the procedure, the scale was taped to the treadmill to facilitate participants' responses.

3.3 Analysis

Measures for analysis included decision accuracy (measured as the percentage of correct decisions), heart rate (in beats per minute), and RPE (on a scale from 6 to 20). The RPE is a way of measuring physical activity intensity level. Although this is subjective, your exertion rating based on a 6 to 20 rating scale may provide a fairly good estimate of your heart rate during physical activity. Through the experience of monitoring how your body feels, it will become easier to know when to adjust your intensity. The RPE scale is mainly used to measure your exercise intensity. The RPE scale runs from 6 to 20. The numbers below relate to phrases used to rate how easy or difficult you find an activity. For example, 6-11 (very light) would be how you feel when sitting in a chair; 12-16 (somewhat hard-hard), and 17-20 (very hard-maximum exertion) is how you feel at the end of an exercise stress test or after a very difficult activity. Thus, a high correlation exists between a person's RPE (multiplied by10) and their actual heart

rate during physical activity; thus, a person's RPE may provide a fairly good estimate of the actual heart rate during activity.

These measurements were recorded manually during the test on a record sheet, which was divided into 6 columns assigned the following values: (1) block, (2) minute, (3) speed, (4) heart rate, (5) decision, and (6) RPE. Meanwhile, the rows were divided into three blocks of 10 minutes, and each block was subdivided into ten rows from 1 to 30 symbolizing the minutes of the test. Every two rows, that is, every two minutes, the randomly chosen speed to which the referee would be subject was assigned. Subsequently, the 30 rows corresponding to the heart rate, decision, and RPE columns were left blank for the manual recording of the data reported from the test. Next, the data collected manually during the experiment were entered into Microsoft Excel. These data sets were uploaded to IBM SPSS (v 27.0) for processing.

Data inspection and descriptive analyzes were conducted first, which included assumptions testing (e.g., normality and sphericity). Friedman tests (the non-parametric equivalent of ANOVA) were performed to assess decision accuracy in relation to speed and block during the experiment. To account for potential violations of sphericity, the Greenhouse–Geisser (GG) correction was used when necessary. The first one-way repeated-measures Friedman test was performed on a sample of 10 soccer referees to test the effect of treadmill speed on decision accuracy. Meanwhile, the second one-way repeated-measures Friedman test was performed to determine if there were differences in decision accuracy due to the time elapsed across the three 10-minute blocks test.

Finally, two Pearson's correlation tests were completed. The first examined the relationship between decision accuracy and average heart rate. A second Pearson's test was conducted in order to examine the relationship between decision accuracy and RPE. Values of

0.2, 0.5, and 0.8 were interpreted as small, moderate, or large effects, respectively (Cohen, 1988).

4.0 Results

4.1 Data Normality

4.1.1 Data Normality for Speed

Since I had a small sample size, determining the distribution of the variable speed (S) was important for choosing an appropriate statistical method. Thus, a Shapiro-Wilk test was performed and showed that the data for three speeds were not normally distributed: S1 (p = .004), S2 (p = .012) and S4 (p = .015). However, data for two speeds were confirmed as normal: S3 (p = .089) and S5 (p = .202). Nevertheless, the Friedman non-parametric test for repeated-measures data was implemented to address these non-normal data.

4.1.2 Data Normality for Blocks

The distributions were significantly non-normal for the variables Blocks (B), B1 (p = 0.02), and B2 (p = 0.01) according to Shapiro-Wilk test. Meanwhile, Shapiro-Wilk test showed the variable B3 (p = 0.58) was normally distributed. Friedman test was conducted to address the non-normal data in block's test.

4.1.3 Data Normality for Heart Rate

The Shapiro-Wilk test was performed and indicated a normal distribution for heart rate (p = 0.586). Based on this outcome, and after a visual examination of the histogram of heart rate and the QQ plot, I decided to use a parametric test. Also, the mean with the standard deviation was used to summarize the variable HR.

4.1.4 Data Normality for Rating of Perceived Exertion

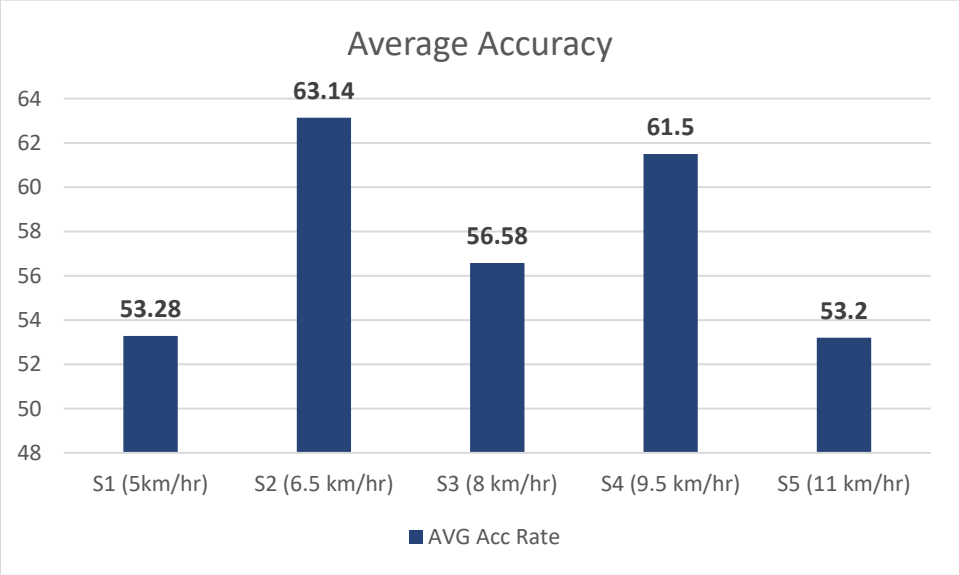
Finally, the Shapiro-Wilk test was run to determine the normality of the distribution of the data of the RPE variable. The results showed that there is a normal distribution with RPE (p = .066).

4.2 Friedman Tests

To determine the effect of treadmill speed on decision accuracy, the first repeated-measures Friedman test was performed. During the experiment, the average accuracy rate for each speed was obtained: S1 = 53.2%, S2 = 63.1%, S3 = 56.5%, S4 = 61.5%, and S5 = 53.2% (see Figure 3). Consequently, there was no significant difference in decision accuracy for participants based on the speed at which they were running: $\chi^2(2) = 5.013$ and $p = .286$.

Figure 3

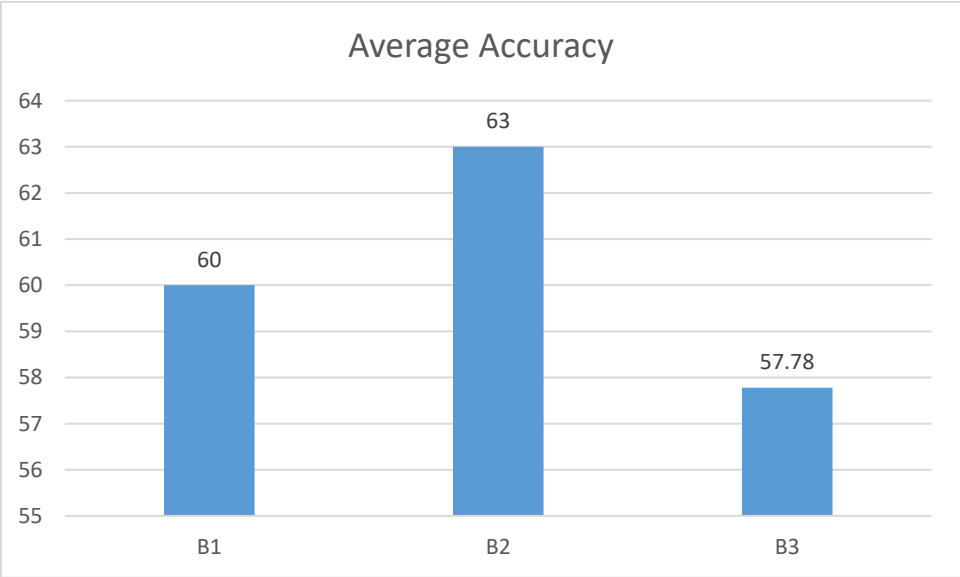
Decision-Accuracy based on Speed



Additionally, a second one-way repeated-measures Friedman test was performed to determine whether there were differences in decision accuracy due to the time elapsed in the test protocol—as indicated by the blocks. The average accuracy rate for the three blocks was: B1 = 60.0%, B2 = 63.0%, and B3 = 57.7% (see Figure 4). As a result, no significant difference was shown for the effect of blocks on referees' accuracy in decision-making: $\chi^2(2) = 1.500$ and $p = .472$.

Figure 4

Decision-Accuracy based on Block



4.3 Correlation Tests

To measure the effects of heart rate and RPE on the decision-making accuracy of the referees, the Pearson correlation test was performed. The first Pearson correlation test examined the relationship between decision accuracy and heart rate average. The range of heart rate averages for each of the 10 participants was P1 = 123.1, P2 = 156.0, P3 = 173.0, P4 = 120.6, P5 = 152.9, P6 = 150.9, P8 = 145.0, P9 = 96.9, and P10 = 129.8 Consequently, the test results showed that there is no significant relationship between participants' average heart rate their decision accuracy: $r = .078$, $p = .689$.

In addition, a second Pearson test was conducted in order to examine the correlation between RPE and decision accuracy. The following average RPE scores were calculated for each participant, P1 = 9.3, P2 = 12.3, P3 = 8.9, P4 = 7.1, P5 = 11.9, P6 = 8.6, P7 = 13.5, P8 =

14.3, P9 = 10.7, and P10 = 7.4. Accordingly, Pearson correlation results were r = -.078, p = .686, suggesting that RPE and decision accuracy were not related.

5.0 Discussion

Soccer is a sport played by a large number of professional, amateur, and leisure players, and it has an even larger number of fans, making it the most popular sport in the world (Castillo et al., 2016). Therefore, issues related to soccer lead to a number of controversies such as the incorrect marking of fouls, misplaced penalties that lead to controversial sanctions such as warnings, and even expulsions from the referee towards the players. Consequently, referees play a central role in these controversies, becoming a relevant issue not only from a fan perspective, but also from a scientific point of view.

Within the extant literature, there exist several studies on sport officials' decision-making accuracy, as well as studies on the physical requirements of sport officials (Castillo et al., 2016; Samuel et al., 2019). However, to achieve a deeper understanding of soccer matches and decisions made by officials, it is imperative to study how the accuracy and physical requirements interact. Hence, it is still necessary to conduct more research in these non-professional settings.

Consequently, the objective of this study was to determine whether there was an impact of physiological variables such as running speed, time (block), heart rate, and perceived exertion on the precision of decision-making in non-professional soccer referees. The researcher designed an experimental protocol that consisted of a simulator in such a way that it could be easily reproduced by any researcher, as it uses a regular treadmill, a regular TV screen, and video clips of foul and non-foul situations from varsity soccer matches. This test was designed based on the fact that various studies suggest that using video clips in conjunction with physiological stressors during the execution of the task gives representativeness and closely aligns with the demands of referees' everyday performance context such as movement, speed changes, and the effect of time during the execution of the test (Samuel et al., 2019).

5.1 Speed and Decision-Making

During this research, my aim was to investigate the influence of physiological demands on the accuracy of decision-making. Consequently, some physiological variables considered to have an impact on the decision-making of soccer referees were selected.

Likewise, one of the variables studied in this research was speed and its impact on the referees' performance at the time of a decision. Therefore, participants were subjected to a test at five different speeds in a random manner, testing their decision-making when presented with a sequential video with various foul and non-foul situations. This test showed that there were no differences in decision accuracy based on the speed of the participants. The above is supported by studies that have found speed and accuracy are not related (Mascarenhas, et al., 2009). However, it is important to recognize that absolute velocity can potentially be different in performance impact between referees and soccer players. This is due to the relative speed and its impact on the decision-making of the referees since from the point of view of physics it would evaluate what influence the speeds of the players in relation to the speeds at which can move referees. Therefore, it is a factor to consider in future research.

Additionally, studies related specifically to the decision-making accuracy and external load of the referee (e.g., distance covered as a function of the speeds of the referees) show that the speed at which officials move does not influence decision-making (Castillo et al., 2016; Weston et al., 2011). Other examples in some professional European soccer leagues (England, Spain, Germany, and Italy) indicate that the referees cover approximately a distance of 11-12 km per match, of which almost 1 km is covered at a very high speed (> 19.8 km h) (Weston et al., 2011). These studies also show that referees perform between 20 and 30 sprints at a speed greater than 25.2 km/h (Krustrup & Bangsbo, 2001). In these conditions, results have typically

indicated that these physical demands do not have a negative impact on referees' decision-making (Helsen & Bultynck, 2004). This could indicate that the ability to pick up relevant signals in the environment is not compromised by fast movements. Perhaps, this is because the brain is able to stabilize humans' visual field even when moving quickly. Therefore, it would be relevant to have a more detailed analysis assisted by new technology (e.g., mobile eye tracking glasses) on the impact of external loads such as speed and nervous responses in the visual field.

The above is aligned with other research on soccer referees. One of these studies was carried out by Mascarenhas (2009), where it is mentioned that the lack of perfection in getting it right in decision-making during a match is largely due to the extremely physically and psychologically demanding nature of the game. Thus, it can be inferred that a good physical condition, which is understood as the ability of their body systems to work efficiently, could allow them to make better decisions (Mascarenhas, 2009). However, in that study, no difference was found in the proportion of high intensity running performed and the accuracy of decision-making.

Similarly, Catteeuw et al. (2010) carried out a study in which they investigated the accuracy of offside judgments of assistant referees in the English Premier League. They considered components such as the moment in the match, the position, and movement speed of the assistant referee, attacker, and second-last defender together with the angle of view of the assistant referee, all considered to underlie incorrect decisions. Therefore, they came to interesting conclusions, such as fatigue (e.g., soreness, localized pain, shortness of breath, muscle muscle cramps), movement speed (e.g., changes of acceleration and direction), and angle of vision (e.g., position and distance between the referee and the game situation) not having a detrimental effect on outside decision-making. This is added to similar conclusions such as those

obtained by Castagna and D'Ottavio (2007), who did not find significant differences in the maximum speed between the first and second half of the match.

However, this issue has not only been the subject of discussion in the context of soccer. There are other studies in different sports contexts such as handball, where they have studied this same phenomenon. Examples of this include the studies carried out by Belcic et al. (2022) and Bloß et al. (2022), where they analyzed internal physical loads and anaerobic threshold, which could be linked to the effect of speed on decision-making. These studies showcased that physical load does not affect decision making but might influence other cognitive processes such as reasoning (Belcic et al., 2022).

In conclusion, it appears that soccer referees, at all levels, are able to maintain a level of fitness that allows them to move at various speeds without sacrificing their decision accuracy.

5.2 Blocks and Decision-Making

Another factor of external physical load that was considered in my investigation was the blocks (time). I sought to study if the length of time in the experiment had any relationship with participants' decision accuracy—with the assumption that fatigue might play a role. Therefore, during the 30 minutes of the test, I examined decision-making accuracy as time in the test protocol progressed. The data suggested that there were no differences in the precision of the decision due to the time elapsed in the test blocks. As a result, no significant effect was shown for the effect of blocks on referees' accuracy in decision. This study only included three blocks of 10 minutes, which could still mean decision accuracy is compromised during longer durations.

These results can be contrasted with some research. In a study carried out by Krustrup and Bangsbo (2001), there was no improvement in performance in responses of a physiological nature measured by aerobic threshold, and little evidence of impairment in decision-making

accuracy. This is related to the results of the study conducted by Clemente et al. (2015) with semi-professional referees who underwent a laboratory test on a treadmill for 24 minutes. In their experiment, which was three blocks of 8 minutes with fatigue simulations, there appeared to be no influence on accuracy of foul and offside decisions.

As with speed, the time on the task did not have a direct relationship with the number of correct calls by soccer referees in this study. Using more precise methodologies (e.g., in-game simulations) with amateur referees are needed to shed light on speed, fatigue, and decision accuracy.

5.3 Heart Rate and Decision-Making

Heart rate is one of the most widely used parameters by athletes and referees to quantify physical and physiological loads. Therefore, this variable was considered in the experiment to determine if there was a direct relationship between physiological demands and accuracy in soccer referees. During the 30 minutes when the participants were subjected to different speeds, their heart rate was simultaneously monitored to see if there was any correlation between this variable and accuracy. The data suggested that heart rate, and thus physical demand, is not related to referees' performance in decision-making accuracy.

The above conclusion can be compared with other studies, including naturalistic ones, in which no significant differences were observed between movement speed, distance, and heart rate at the time of decision-making. For instance, there were no differences in the proportion of high intensity running performed, although the average heart rate decreased from the first half to the second half (Mascarenhas et al., 2009).

Likewise, Krustrup and Bangsbo (2001) observed that the highest value of heart rate that a referee reaches in a match corresponds to about 97% of their HRmax. However, interventions

under this condition are infrequent and even do not affect its accuracy at decision time. This information is complemented by the results of Silva et al., (2019). Therein, Silva mentions that the more experienced referees were better at controlling the heart rate, even maintaining the rhythm between the times of the match without their decisions being negatively affected. Similarly, Aoba et al. (2011) found no significant differences between referees at the international level and the national level of the Japan Football Association in relation to the distance from the points where fouls occurred to the place where the referees were and their heart rates during a match. In conclusion, distance, movement, and heart rate can be used to monitor and control referee performance. However, based on all these indications, it might be that referee experience benefits decision-making and in the administration of physical effort during the game, a fact that requires more studies, since it is necessary to analyze how far away from the game actions the referees were in the moment of decision.

5.4 Rating of Perceived Exertion and Decision-Making

Finally, during the experimental protocol, participants' RPE was considered another indicator of physical load. The data obtained showed that RPE, like the heart rate, was not related to decision-making accuracy. This result again allows us to see that despite the possible fatigue that a referee may have during the match, this does not appear to impact their performance on good decision-making.

The results align with Samuel et al. (2019), who reported that, despite the fact that some soccer referees may show an increase in fatigue through the RPE scale, there were no corresponding negative effects on decision-making. This included decisions such as offside, foul/no foul, and yellow/red card decisions. However, despite these findings, it is important to mention that for future research, it is necessary to differentiate between muscular RPE and

respiratory RPE (Castillo, 2016). The above is in order to analyze the disassociations between muscular RPE and respiratory RPE. Therefore, more data on these variables and their possible relationship with precision in soccer referees. Consequently, I encourage the collection of these measures (muscular RPE and respiratory RPE) in both future practice and research surrounding soccer referees and team-sport match officials.

5.5 Limitations

There are several limitations to this study. First, due to the COVID-19 pandemic, it was impossible for me to start my Master's degree process in person for the fall semester of 2020. As a consequence, the first year was completely online, which made it more challenging to complete the necessary coursework while also building a thesis proposal in my first year. This also delayed my thesis proposal development as I went through the shift from online to face-to-face activities on campus.

Similarly, the ethics submission process was delayed as I had to figure out what protocols were permitted for data collection, given that the university was transitioning back to in-person research. Therefore, due to these delays, the recruitment plan for my November 2021 sample did not happen until July 2022. That compressed my ability for a long recruitment period since, as an international student, I had to return to my home country in August 2022. As a consequence, the sample obtained was too small for what was suggested, as a priori power analysis revealed that 30 participants were required to detect significant differences based on study design, leaving a gap in the scope of this study. Another potential limitation was the design of the test, as the objective was to create the conditions that a soccer referee can encounter when making a call. Due to the use of side cameras, which do not offer the same lines of sight and context that a referee would experience during a game, the experiment lacked some elements of ecological

validity. In addition, the running speeds were constant for two minutes, which differs from the duration of high speeds in a match for a referee, which is less than 10 seconds. Moreover, the experiment was carried out on a treadmill where there were no changes in direction as occurs in normal conditions for soccer referees. Finally, presenting the experiment clips from multiple games meant there was no context, which could influence referees' cognitive processes when making a decision.

5.6 Future Directions

Given that this research was affected by the COVID-19 pandemic during the participant recruitment phase, it is important to consider a larger sample for future research and thus be able to have enough data to detect whether there are significant differences between the variables to be studied. Likewise, with larger samples, it would be possible to do pretesting on fitness levels and see accuracy rates based on fitness levels within such a protocol.

On the other hand, though this research monitored participants' physical load through the recording of different variables of external load (i.e., speed and time) and internal load (i.e., RPE and heart rate), in future research it would be interesting to record other variables such as blood lactate levels, muscular RPE, respiratory RPE, and gaze behaviour (among others) by means of the new technologies existing in the market.

Also, the design of future research should consider ecological validity and thus bring non-professional referees closer to the real conditions in their performance during a match, such as different visual perspectives and distances, change of speed/direction, and external stressors (e.g., weather, temperature, and fans), which can determine variations in their physiological and cognitive responses at the time of making a call and that can be measured by the cutting edge of technology such as heart rate monitor and mobile eye tracking device. Although this is already

done frequently by professional referees, it would be relevant to start implementing it in the amateur and grassroots officiating fields.

5.7 Conclusion

The performance of the referee plays a relevant role in the development of soccer matches at any level. As mentioned, recent studies have shown that a professional referee makes an average of 200 decisions, covering an average of 10-14 km per game at an average heart rate of 161 beats per minute, that is, 86% of their individual maximum heart rate. (Krustrup & Bangsbo, 2001; Mallo et al., 2009). Moreover, in recent decades their role has taken on a role with profound implications in the development and outcome of the games.

However, although referee performance has received increasing attention in recent years, it has largely focused on monitoring external physiological components such as speed, total cover distance, and positioning, as well as internal loads such as levels of glycogen, heart rate, lactate levels among others that soccer referees need to develop for good performance and thus be able to determine better physical preparation methods for referees (Ahmed et al., 2017; Krustrup & Bangsbo 2001; Webb et al., 2016).

Therefore, there is still a great need for studies and information that consider the impact of physiological aspects on the decision-making accuracy of soccer referees. Although more attention has been generated to this problem (e.g., Birk Preissler et al., 2021; MacMahon & Plessner, 2007; Mascarenhas et al., 2009;), this phenomenon has not yet been investigated in detail at a professional level and even less at non-professional levels.

As a result, this research aimed to study amateur soccer referees to determine if physiological demands influence decision-making and accuracy. By means of a laboratory test, the conditions of different speeds were simulated on a treadmill in an interval manner in which

the amateur soccer referees were subjected to a 30-minute test duration divided into three blocks of 10 minutes, where simultaneously, their heart rate, RPE, speed, and precision in decision making were recorded while a series of video clips with foul or no foul situations were displayed once each minute.

It was discovered that the physiological variables considered in the experiment did not seem to have a significant impact on the decision-making precision of amateur referees. However, it is important to note that a larger sample could lead to a different result. This is because none of the experiments previously carried out had a sample of more than 100 participants. Additionally, it is important to underline that FIFA has not made a formal proposal to find gaps or discrepancies between the investigations carried out to date. Furthermore, using a laboratory simulation rendered the experiment devoid of external validity and does not represent what actually occurs during a competitive match in a stadium or crowded venue.

To conclude, it is important to consider the relevance of transferring the purpose of this study to a naturalistic setting. The foregoing will allow elements of relevance in the performance of the soccer referee to be brought closer to a real terrain, such as diagonal displacements, speed changes, player movement, and even external conditions such as temperature, soccer field conditions, and fan pressure, among others.

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7.0 Appendices

Document 1: Ethics Approval Letter

MEMORIAL UNIVERSITY
Interdisciplinary Committee on Ethics in Human Research (ICEHR)

St. John's, NL Canada A1C 5S7
Tel: 709 864-2561
icehr@mun.ca

www.mun.ca/research/ethics/humans/icehr

ICEHR Number:	**20230211-HK**
Approval Period:	June 21, 2022 – June 30, 2023
Funding Source:	
Responsible Faculty:	Dr. David Hancock School of Human Kinetics and Recreation
Title of Project:	*Effect of Physiological Demands on Decision Making in Soccer Referees*

June 21, 2022

Carlos Mercado

School of Human Kinetics and Recreation

Memorial University

Dear Carlos Mercado:

Thank you for your correspondence addressing the issues raised by the Interdisciplinary Committee on Ethics in Human Research (ICEHR) for the above-named research project. ICEHR has re-examined the proposal with the clarifications and revisions submitted, and is satisfied that the concerns raised by the Committee have been adequately addressed. In accordance with the *Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2)*, the project has been granted *full ethics clearance* for **one year**. ICEHR approval applies to the ethical acceptability of the research, as per Article 6.3 of the *TCPS2*. Researchers are responsible for adherence to any other relevant University policies and/or funded or non-funded agreements that may be associated with the project. If funding is

obtained subsequent to ethics approval, you must submit a Funding and/or Partner Change Request to ICEHR so that this ethics clearance can be linked to your award.

The *TCPS2* **requires** that you **strictly adhere to the protocol and documents as last reviewed** by ICEHR. If you need to make additions and/or modifications, you must submit an Amendment Request with a description of these changes, for the Committee's review of potential ethical concerns, before they may be implemented. Submit a Personnel Change Form to add or remove project team members and/or research staff. Also, to inform ICEHR of any unanticipated occurrences, an Adverse Event Report must be submitted with an indication of how the unexpected event may affect the continuation of the project.

The *TCPS2* **requires** that you submit an Annual Update to ICEHR before **June 30, 2023**. If you plan to continue the project, you need to request renewal of your ethics clearance and include a brief summary on the progress of your research. When the project no longer involves contact with human participants, is completed and/or terminated, you are required to provide an annual update with a brief final summary and your file will be closed. All post-approval ICEHR event forms noted above must be submitted by selecting the ***Applications: Post-Review*** link on your Researcher Portal homepage. We wish you success with your research.

Yours sincerely,

James Drover, Ph.D.

Vice-Chair, Interdisciplinary Committee on Ethics in Human Research

JD/bc

cc: Supervisor – Dr. David Hancock, School of Human Kinetics and Recreation

Document 2: Ethics Approval Letter-Amendment

MEMORIAL UNIVERSITY
Interdisciplinary Committee on
Ethics in Human Research (ICEHR)

St. John's, NL Canada
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ICEHR Number:	**20230211-HK**
Approval Period:	June 21, 2022 – June 30, 2023
Funding Source:	
Responsible Faculty:	Dr. David Hancock School of Human Kinetics and Recreation
Title of Project:	*Effect of Physiological Demands on Decision Making in Soccer Referees*
Amendment #:	***01***

July 14, 2022

Carlos Mercado

School of Human Kinetics and Recreation

Memorial University

Dear Carlos Mercado:

The Interdisciplinary Committee on Ethics in Human Research (ICEHR) has reviewed the proposed revisions for the above referenced project, as outlined in your amendment request dated July 11, 2022. We are pleased to give approval to the revised inclusion criteria, as described in your request, provided all other previously approved protocols are followed.

The *TCPS2* **requires** that you **strictly adhere to the protocol and documents as last reviewed** by ICEHR. If you need to make any other additions and/or modifications during the conduct of the research, you must submit an Amendment Request with a description of these changes, for the Committee's review of potential ethical issues, before they may be implemented. Submit a Personnel

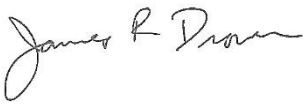
Change Form to add or remove project team members and/or research staff. Also, to inform ICEHR of any unanticipated occurrences, an Adverse Event Report must be submitted with an indication of how the unexpected event may affect the continuation of the project.

Your ethics clearance for this project expires **June 30, 2023**, before which time you must submit an Annual Update to ICEHR, as required by the *TCPS2*. If you plan to continue the project, you need to request renewal of your ethics clearance, and include a brief summary on the progress of your research. When the project no longer requires contact with human participants, is completed and/or terminated, you need to provide an annual update with a brief final summary, and your file will be closed.

All post-approval ICEHR event forms noted above must be submitted by selecting the *Applications: Post Review* link on your Researcher Portal homepage.

The Committee would like to thank you for the update on your proposal and we wish you well with your research.

Yours sincerely,



James Drover, Ph.D.

Vice-Chair, Interdisciplinary Committee on Ethics in Human Research

JD/bc

Document 3: Informed consent form

School of Human Kinetics and Recreation

School of Human Kinetics
Physical Education Building, #2023A, St. John's, NL, Canada, A1C 5S7
Tel: 709 864 8129 Fax: 709 864 3979 www.mun.ca

Informed Consent Form

Title: Effect of Physiological Demands on Decision-Making in Soccer Referees

Researcher: Carlos Mercado (Graduate student, Memorial University, cemercado@mun.ca) Supervisor: David Hancock (School of Human Kinetics & Recreation, Memorial University, dhancock@mun.ca)

You are invited to take part in a research project entitled "Effect of Physiological Demands on Decision-Making in Soccer Referees". To participate, you must be 19 years or older, a current soccer referee in the U13 categories or higher belonging to the Newfoundland and Labrador Football Association or any other league in Canada or the rest of the world, and officiating at least 20 games in a typical season. This study is NOT an employment or organizational requirement.

This document is part of the process of informed consent. It is meant to give you the basic concept of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order for you to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Please read this document carefully and to understand the information presented to you. Please contact me, Carlos Mercado, if you have any questions concerning the study or would like more information before you consent.

It is entirely up to you to decide whether you wish to take part in this research study. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you now or in the future.

Purpose of Study:

The purpose of this experiment is to investigate the influence that physiological demands have on 'non professional soccer referees' decision accuracy.

What you will do in this study:

You will undergo a decision-making task while running on a treadmill. This test will last 30 minutes divided into 3 blocks of 10 minutes. At various times, you will be required to walk/run at different speeds between 5

km/hr to 11 km/hr for two consecutive minutes. During the test, you will view a series of 30 soccer clips on a projected screen, with one clip shown at the 45-second mark of each minute. Upon viewing the clip, you will verbally declare the decision as "foul" or "no foul". At that time, you will also report your rate of perceived exertion on a scale from 6-20. Throughout the test, you will wear a heart rate monitor. At the time of each decision, we will record your current heart rate. At the end of the test, you will take a 3-minute break and then you will perform a 3-minute maximum heart rate test to determine your fitness level.

Length of time:

You will be asked to complete the experiment one time, which should take approximately 60 minutes, which includes an explanation and warm-up.

Withdrawal from the study:

You can choose to withdraw from the protocol at any time for any reason. Simply indicate this to the researcher. Any incomplete experiment protocol will be deleted from the database. After completing the experiment, you can withdraw from the study up until August 31, 2022, when we expect all data collection to be complete.

Possible benefits:

Since little is known about the effect of physiological factors on decision-making in non-professional soccer referees, this study will bring new knowledge to the field, learning about how the intensity during the performance of a soccer referee can significantly reduce their performance when making decisions in a game. As well, this research will be beneficial for participants to learn how physiology affects decision-making, and the NLSA and any league in Canada or the rest of the world will be able to use the results to improve the training it provides to officials in the future.

Possible risks:

Participating in the experiment may cause physical harm due to the physical risk associated with moderate exercise. As you will perform a proper warm-up before the study, there is still a low probability of physical risk. Further, the test protocol has no more risk than when you referee a soccer game**.** However, if you have any situation of physical risk such as a possible injury, you will be attended to. Principal investigator Carlos Mercado is certified in first aid by the Lifesaving Society. This will allow you to have a safe environment during the test.

Confidentiality:

The ethical duty of confidentiality includes safeguarding participants' identities, personal information, and data from unauthorized access, use, or disclosure. Data will be stored on password-protected computers in Dr. Hancock's locked office, and only the research team will have access to them. However, confidentiality cannot be guaranteed in the event of legally-required disclosure.

Anonymity:

Anonymity refers to protecting participants' identifying characteristics, such as name or description of physical appearance. Participation is not anonymous, as the research team will know who you are. However, this experiment and its tests will be carried out entirely in a closed laboratory with one other lab member who will assist the principal investigator in playing the videos and setting the treadmill speeds. This will ensure a private environment for the participants. Additionally, to manage the anonymity of the participants, all the files that contain identifiable information will be stored in password-protected files. When we write our results, they will be presented in aggregate form to avoid identifying you.

Use, Access, Ownership, and Storage of Data:

The resulting electronic files will be password-protected and only stored on the research team members' computers/laptops, which are all password-protected. To reiterate, these data will not be anonymous since they have your identifiable information included. Only the research team will have access to the data. Data will be kept for a minimum of five years, as required by Memorial University's policy on Integrity in Scholarly Research. At that time, all electronic files will be permanently deleted from the research team members' computers and laptops. At that time, all electronic files will be permanently deleted from the research team members' computers and laptops.

Reporting of Results:

We intend to publish the research findings of the study in a scientific journal, and present at an academic conference. Upon completion of the researcher's degree, a copy of the paper and findings will also be publically available at the QE II Library thesis collection: https://www.library.mun.ca/cns/.

Sharing of Results with Participants:

After results are analyzed (approximately December 2022), David Hancock will post a one-page infographic to his Twitter account (@profhancockmun) to share results. You do NOT need a Twitter account to access results.

Questions:

You are welcome to ask questions at any time before, during, or after your participation in this research. If you would like more information about this study, please contact Carlos Mercado (cemercado@mun.ca) or David Hancock (dhancock@mun.ca).

ICEHR Approval Statement:

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Consent:

By signing below, you confirm:

- You are 19 years of age or older
- You are a current referee in the U13 categories or higher in the NLSA or any other recognized league in Canada or the rest of the world, and typically officiate at least 20 matches per season
- You can withdraw from the study at any time; if you've completed the experiment, you can withdraw up to August 31, 2022
- You have read the information about the research.
- You have been advised that you may ask questions about this study and receive answers prior to continuing.
- You are satisfied that any questions you had have been addressed.
- You understand what the study is about and what you will be doing.

By consenting to this research, you do not give up your legal rights and do not release the researchers from their professional responsibilities. Please retain a copy of this consent information for your records.

Signature of Participant	**Date**

Researcher's Signature:

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Principal Investigator	**Date**

Document 4: Study Announcement for Social Media

EFFECT OF PHYSIOLOGICAL DEMANDS ON DECISION-MAKING IN SOCCER REFEREES

- Carlos Mercado (graduate student in Human Kinetics & Recreation at Memorial University) is leading a study with the purpose of investigating the influence that physiological demands have on 'non professional soccer referees' decision accuracy
    - Dr. Hancock (faculty member in Human Kinetics & Recreation at Memorial University) is supervising the study

- You must be **19 years of age or older and a current soccer referee in U13 or higher in the NLSA or any other league in Canada or the rest of the world, and officiate at least 20 matches in a typical season**
- The experiment is voluntary; it is **NOT** an employment or organizational requirement
- The experiment takes ~60 minutes at the Exercise Physiology Lab at the School of Human Kinetics & Recreation
- To participate or get more information, please email Carlos Mercado cemercado@mun.ca or Dr. Hancock dhancock@mun.ca

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as your rights as a participant, you may contact the Chairperson of the ICEHR at icehr.chair@mun.ca or by telephone at 709-864-2861

HUMAN KINETICS & RECREATION

MEMORIAL UNIVERSITY