EXPLORING SOCCER REFEREES' ENERGY EXPENDITURE, DIETARY INTAKE, AND RESTING METABOLIC RATE

By

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Bachelor of Science in Dietetics

Kansas State University

Manhattan, Kansas

2016

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2018

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ACKNOWLEDGEMENTS

To my parents, thank you for the endless support. Thank you for supporting my ambitions, for pushing me to follow my dreams, and for demonstrating what hard work looks like. You have given me everything; love, guidance, education, and endless opportunities. I hope I make you proud.

Name: ERIKA SCHILLER

Date of Degree: MAY, 2018

Title of Study: EXPLORING SOCCER REFEREES' ENERGY EXPENDITURE, DIETARY INTAKE, AND RESTING METABOLIC RATE

Major Field: NUTRITIONAL SCIENCES

Abstract:

Background & Aims: Professional soccer referees must keep up with the physical demands of a soccer match while staying cognitively focused on the game. To sustain high muscle and brain function, a well-rounded and adequate diet is necessary. The main purpose of this study was to determine if male professional soccer referees are fueling their bodies to sustain energy throughout a soccer match and reaching daily-recommended energy needs. The other purposes were to determine how a new metabolic device, Breezing®, compares to commonly used metabolic equations as well as to measure the adequacy of the referees' macronutrient intake and to determine the average distance covered in a match by a center referee.

Methods: Ten professional soccer referees (ages 27-50) from the Professional Referee Organization (PRO) completed 3-day dietary records. Match-day and average energy intake was compared to match energy expenditure, obtained from GPS watches. Average 3-day and match-day energy intakes were compared to recommended energy needs, calculated using Breezing® and three metabolic equations. These methods to determine estimated energy needs were analyzed to evaluate how the values compared between equations. Average macronutrient intakes were compared to recommended values for this population. Lastly, the average distance covered and energy expended per match by the center soccer referee was recorded.

Results: Match day energy intake and average energy intake did not significantly differ from match energy expenditure ($p = 0.459$, $p = 0.936$, respectively). Estimated total energy expenditure was significantly higher than average reported energy intake ($p <0.001$). Breezing® results were most closely related to the Mifflin-St. Jeor ($p=0.286$) and Harris-Benedict ($p=0.045$) equations. Carbohydrate intake was significantly lower than the recommendation ($p < 0.001$), while protein and fat intakes were adequate. The average distance travelled and average energy expended was 9.77 ± 0.91 km (6.07 ± 0.57 miles) and $1,680 \pm 341$ kcal, respectively.

Discussion: Professional soccer referee's reported energy and carbohydrate intake did not cover the costs of the high demands of refereeing. The Breezing® device, along with the Harris-Benedict and Mifflin St. Jeor equations show similar results in estimating resting metabolic rate in this population. Future studies on professional soccer referees should implement nutrition education to increase energy and carbohydrate consumption, maintain fat and protein intake, and reinforce correct reporting on dietary records.

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INTRODUCTION

Professional soccer referees have the strenuous responsibility to stay cognitively attentive in a soccer match while also physically keeping up with the pace of the game. It has been reported that during soccer matches, referees and midfielder players have similar totals in three different areas: distance covered, time spent in high-speed running, and time spent in sprinting (Reñón & Collado, 2015; Weston, Drust, & Gregson, 2011). Along with endurance to keep up with the pace of the match, perceptual-cognitive studies have tallied that male professional soccer referees make 137 observable decisions per match (Helsen & Bultynck, 2004). Therefore, mental attentiveness is crucial as they have the responsibility to make quick and accurate calls to keep the game safe, under control, and fair.

To maintain the muscle and brain function necessary for refereeing a full soccer match, soccer referees need adequate energy. Achieving energy balance is recommended for optimal athletic performance, whereas long-term positive or negative energy balance may result in negative health implications (Thomas, Erdman, & Burke, 2016). Energy balance is defined as total energy expenditure (TEE) equal to total energy intake (Thomas et al., 2016). Basal metabolic rate (BMR) makes up 60-70% of TEE (Psota & Chen, 2013). Resting metabolic rate (RMR) can be calculated if basal conditions are not available and can be estimated using multiple equations, including the Harris Benedict (Harris & Benedict, 1918), Mifflin St. Jeor (Mifflin et al., 1990), and Cunningham (Cunningham, 1980) equations. Along with the equations, the Breezing® technology can be used to measure metabolic rate. The Breezing® device is easy to use, Bluetooth compatible, and conveniently fits in a bag or purse (“Breezing Metabolism”, 2017). The Breezing® device is thought to take the place of the metabolic cart of Douglas bag method in a non-lab situation due to its mobility. After finding RMR using the equations or the Breezing® device, an activity factor can be applied or physical activity energy expenditure can be added to the value, which results in an estimated total energy expenditure (TEE). When the TEE value is compared to reported estimated energy intake, it can be determined if energy balance is achieved for maintaining optimum performance.

Soccer refereeing is a multi-movement sport with quick changes in speed and direction, while also requiring on-the-spot decision-making. To sustain energy for muscle groups and brain function an adequate intake of all three energy-containing macronutrients is crucial. Carbohydrates, fats, and proteins in daily food choices take on different metabolic paths in the body to resupply the fuel needed for athletic performance as well as normal bodily function (Eberle, 2014). Analyses of overall energy intake, as well as macronutrients within the diet, are both vital in measuring the quality of a soccer referee’s diet.

The purpose of this study was to determine if male professional soccer referees are properly fueling their bodies to sustain energy throughout a soccer match and meeting daily-recommended energy needs. The secondary purpose of this study was to compare the accuracy of the new Breezing® technology to commonly used equations for predicting energy expenditure, the Harris Benedict, Mifflin-St. Jeor, and Cunningham equations. The third purpose of this study was to compare the amount of recorded macronutrient intake to the recommended energy intake for athletes. The final purpose of this study was to determine the total distance referees cover and energy expended in one soccer match.

Research Questions

1. Is there a difference between referees' energy expenditure during a match and their energy consumed during an average soccer match day?
2. Is there a difference between referees' energy expenditure during a match and their 3-day average estimated energy intake?
3. Is there a difference between 3-day average estimated energy intake and daily-recommended energy intake with the use of a physical activity factor?
4. Is there a difference between the resting metabolic rate from Breezing® and the calculated rate using the Harris-Benedict, Mifflin-St. Jeor, and Cunningham equations with and without an activity factor?
5. Are the referees consuming an adequate amount of carbohydrates, proteins, and fats?
6. What is the average distance traveled and energy expended by the center referee in one professional soccer match?

Definitions of Terms

Basal Metabolic Rate - the minimal amount of energy expended for homeostatic processes. Measured before any engagement in physical activity and after a 10 to 12 hour fast (Hasson, Howe, Jones, & Freedson, 2011; Psota & Chen, 2013)

Resting Metabolic Rate – energy expenditure when BMR measurement conditions are not met (Kang, 2008)

Resting Energy Expenditure - the amount of energy expended by a person at rest. Used interchangeably with BMR and RMR ("Resting energy expenditure protocol," 2012)

Energy – ability to produce change and is measured by the amount of work performed during a given change (Kang, 2008)

Energy Expenditure – results from cellular oxidation of stored energy (Kang, 2008). Made up of basal metabolic rate, thermal effect of food, and physical activity.

Activity Factor – applied to the basal or resting metabolic rate to account for the energy exertion associated with injury and/or physical activity (Long, Schaffel, Geiger, Schiller, & Blakemore, 1979; Rodriguez, DiMarco, & Langley, 2009; Thomas et al., 2016)

Direct Calorimetry - measures the amount of heat produced during metabolism with the use of a unique chamber (Kang, 2008)

Indirect Calorimetry - measures metabolic rate via oxygen consumption and carbon dioxide produced, which corresponds to cellular respiration (Oshima et al., 2016)

VO2 – oxygen consumption (Oshima et al., 2016)

VCO2- carbon dioxide production (Oshima et al., 2016)

Respiratory Quotient - ratio of VCO2 produced and the VO2 consumed. Complete oxidation of the carbohydrates, lipids, or proteins requires different amounts of oxygen and produces ranging amounts of carbon dioxide due to the compositions of the nutrients (Compher, Frankenfield, Keim, & Roth-Yousey, 2006)

Breezing® - the resting metabolic rate measurement technique that uses a portable, easy to carry battery operated metabolism tracker that syncs with any smartphone and measures oxygen consumption rate (VO2) and CO2 production rate (VCO2) using a pre-calibrated built-in flow sensor ("Breezing Metabolism," 2017)

3-Day Dietary Recall - assesses daily caloric consumption in order to make adjustments to caloric intake for weight gain, loss, or maintenance (Taylor, 2012)

Abbreviations

Resting Metabolic Rate (RMR)

Basal Metabolic Rate (BMR)

Resting Energy Expenditure (REE)

Oxygen Consumption (VO2)

Carbon Dioxide Production (VCO2)

Professional Referee Organization (PRO)

Lean Body Mass (LBM)

Respiratory Quotient (RQ)

Adenosine Triphosphate (ATP)

CHAPTER II

REVIEW OF LITERATURE

Soccer Referees

Football or American soccer is defined by Merriam-Webster as a game played on a field between two teams of 11 players each with the object to propel a round ball into the opponent's goal. Soccer is actively played by 270 million people, making it one of the most popular sports in the world (Mazaheri, Halabchi, Barghi, & Mansournia, 2016). Ninety minutes of actively chasing a round ball makes this sport a significant challenge of athletic ability, aerobic capacity, and muscular strength for all individuals on the field, including the referees.

All professional soccer referees are trained through the United States Soccer Federation (USSF) or the Canadian Soccer Association (CSA). Competitive soccer matches must be regulated by a head/center referee, two assistant referees, and a side-line official (Castagna, Abt, & D'ottavio, 2007). They have very specific duties such as enforcing the Laws of the Game, controlling the match, acting as the timekeeper, and supervising the start of play ("Laws of the Game 2016/17," 2016). There are expectations of the referees in how they call plays, where they position themselves during the game, what message their body language portrays, and how they follow whistle rules ("Laws of the Game 2016/17," 2016).

The Professional Soccer Referee Organization (PRO) has a group of trained and certified full-time male soccer referees that want to become the best in the world. In order to do this they are part of PRO. This means they are a team, but a team unlike other sports teams. This is a group of referees from Canada, the United States and Mexico who meet every other week from the end of January to the end of October in person. These meetings are called training camps. Training camps are in one specific location (example: Cooper Center in Dallas, TX) and last from Wednesday through Friday afternoon. Camps consist of working on physical aspects of the game, understanding how to react to stressful situations, sports nutrition education and physical therapy sessions. So this "team" of referees meets 2 times/month for 2.5days during the season and then they referee matches outside of those times. When they are not at camp or refereeing matches they are at their respective homes in Canada, the US or Mexico.

Physical Demands

Football or American soccer referees are a very unique population in that they have both physical and cognitive demands, making their energy supply crucial for optimum performance. An analysis done on thirty-five soccer referees from the Spanish National soccer division concluded that refereeing consists of cycles of short, high-intensity bursts of activity, such as sprints, followed by jogging and higher paced running (Reñón & Collado, 2015). A study which used video analysis technology, identified 6 locomotor activities (standing still, walking, jogging, backwards running, running, and sprinting) and measured energy expenditure and the intensity of physical activity in professional referees working the Parana Championships (Da Silva, Fernandes, & Fernandez, 2008). During the games, they changed motion activity every 4-6 seconds making up 1,268 different activities in 90 minutes. During a match, the referees spent 52% of the time walking, 19% spent jogging, and 15% spent standing (Da Silva et al., 2008).

Another study using video analysis technology that included 18 referees during 236 matches of the English Football Association Premier League concluded that there were very small differences between the total distance covered, high-speed running, and sprinting between players and referees (Weston et al., 2011). Referees cover a total of about 5.7 to 6.84 miles in one match, which is considered to be very similar to the midfielder's position (Da Silva et al., 2008; Reñón & Collado, 2015).

Energy Intake and Availability

For referees to meet their unique physical and cognitive demands, the consumption of adequate fuel from all energy sources is necessary. Energy for the body, measured in calories (kcal), is obtained from energy-containing macronutrients that include, carbohydrates, fats, and protein. Dietary energy requirements differ between individuals depending on their total energy expenditure, made up of basal metabolic rate, the thermic effect of food, and physical activity. In athletes, the appropriate energy intake is crucial as it supports optimal performance, and influences body composition (Thomas et al., 2016). Macronutrients in daily food choices take on different metabolic paths in the body to resupply the fuel needed to continue normal function (Eberle, 2014). For referees, all macronutrients are essential as they must utilize all energy sources to fuel their multitude of movements.

Carbohydrates (CHO), which provide 4 kcal of energy per gram, are converted to glucose to be used as immediate energy or stored in the liver or muscles as glycogen (Daries, 2012). During exercise, muscle glycogen is converted back to glucose, which the muscle fibers use as fuel. Liver glycogen stores are also converted back to glucose; however, the glucose is released directly into the bloodstream to maintain blood glucose levels to fuel other cells in the body, particularly the brain and the nervous system (Eberle, 2014). The brain alone accounts for 20-25% of adult basal metabolic expenditure (Hardy, Brand-Miller, Brown, Thomas, & Copeland, 2015). A daily recommendation is at least 150 g/day for adequate glucose to sustain brain function (Hardy et al., 2015).

Glycogen stores in the body only contain enough energy to fuel 90-120 minutes of continuous exercise or about 1,800-2,000 kcal worth of energy expenditure (Rodriguez et al., 2009). The depletion of these stores is associated with reduced work rates, impaired skill, and can also starve the brain of glucose leading to impaired brain function. Therefore, it is critical to consume adequate carbohydrates and refuel during endurance exercise lasting longer than 60 minutes (Rodriguez et al., 2009; Thomas et al., 2016). The intake of carbohydrates is recommended to make up 45-65% of the diet, however, for athletes this percentage may be 55-65% to compensate for strenuous exercise (Taylor, 2012; Thomas et al., 2016). The Academy of Nutrition and Dietetics recommends 6-10 g/kg of body weight/day for individuals participating in 1-3 hours of exercise per day. With previous studies showing low carbohydrate intake by referees (Reñón & Collado, 2015; Souglis et al., 2013), a minimum recommended level of 6 g/kg/day will be used for the professional soccer referees in this study as a starting point for gradual increase in carbohydrate intake (Thomas et al., 2016).

Carbohydrates are the energy source during anaerobic exercise as they have the ability to produce energy without oxygen. However, in events lasting longer than 2 to 3 minutes, the body shifts to oxidative pathways, which utilize carbohydrates, fats, and some proteins as energy (Rodriguez et al., 2009). Fat is the most concentrated source of energy at 9 kcal per gram and a recommended amount being 20-35% of the diet coming from fat sources (Taylor, 2012). After the consumption and digestion of fat from the diet, it is stored as triglycerides or triacylglycerols in adipose tissue (under the skin, muscle tissue, and in between organs), as essential fat and only a small amount circulating as free fatty acids in the blood (Rosenbloom, 2000).

In prolonged (90-120 min) and anaerobic exercise, such as a 90-minute soccer game, in response to depleting glycogen stores, hormones, epinephrine and glucagon, are released that stimulate lipolysis, which hydrolyzes the breakdown of stored triglycerides into fatty acids and glycerol that are then used as energy for the exercising muscles (Kang, 2008). Studies have shown that the body taps into intramuscular triacylglycerol (IMTG) stores, especially during prolonged moderate-intensity exercise (Spriet & Gibala, 2004). In endurance cyclists, it was found that a carbohydrate-rich, low-fat diet, caused IMTG stores to decrease farther than those on a regular diet containing higher fat (van Loon et al., 2003). For the professional male soccer referees, a recommended diet consisting of 20% fat should maintain the IMTG stores for lipolysis as an energy source if glycogen stores are depleted.

Proteins, which provide 4 kcal of energy per gram, are made up of amino acids linked together forming complex structures that make up proteins (Rosenbloom, 2000). Protein builds and maintains tissues and becomes a crucial energy source during intense exercise when the carbohydrate and fat energy sources are not substantial enough to support the activity (Daries, 2012). The body must then break down amino acids found in skeletal muscle protein into utilizable components of energy (Daries, 2012). Post exercise, adequate protein intake is essential as muscle protein synthesis is up regulated for 24 hours causing an increase in dietary protein sensitivity during this period of (Thomas et al., 2016).

The basic recommendation for protein intake is 12 to 15% of the total diet, but there has been discussion about whether the recommended levels for athletes should be higher. The Institute of Medicine, which develops the Recommended Dietary Allowance (RDA), established a level of 0.8 g protein/kg of body weight/day for adults of all ages (Thalacker-Mercer, Fleet, Craig, Carnell, & Campbell, 2007; Thomas et al., 2016; Trumbo, Schlicker, Yates, & Poos, 2002). However, there are multiple mechanisms that occur in athletes such as damage to muscles and gains in muscle mass that cause an increased need for daily dietary protein (Thomas et al., 2016). Endurance athletes should be receiving 1.2 g/kg of body weight/day, while resistance exercise has been found to increase the requirement even more to 1.6 to 1.7 g/kg per day (Lessen & Kavanagh, 2015; Thomas et al., 2016). Considering the length of a 90-minute soccer match and the running demands, 1.2 g/kg per day of protein is the recommended amount for the referees in this study.

Energy Balance and Fatigue

Through assessment of the perceptual-cognitive demands of top-class referees in the Euro 2000 Championships, it was observed that referees in those games made about 137 observable decisions, 44.4 of which were made without the help of the assistant referees (Helsen & Bultynck, 2004). The even distribution of the calls throughout the entire game shows that referees must stay on their feet from start to finish despite any distractions, fatigue, or stress they may be experiencing. They must work through noise and disturbances from the crowds, aggressive behavior from players and coaches, while also being able to make mistakes and move on from them (Johansen & Haugen, 2013).

To best perform, the referees should aim to be in energy balance, which occurs when energy intake (EI) is equal to energy expenditure. In other words, when energy intake is equal to total energy expenditure (TEE), energy balance is achieved (Thomas et al., 2016). When energy expenditure exceeds kcals consumed, the body enters a negative energy balance. For example, if an athlete consumes 2,000 kcals, but burns 2,200 kcals in a day, he or she is in a 200 kcal deficit. For athletes, being in a negative energy balance can have very negative health implications and effects on performance, such as decreased endurance, impaired judgment, decreased coordination, and decreased muscle strength (Thomas et al., 2016).

Insufficient energy intake has been identified in professional soccer referees along with soccer players. Using a 3-day dietary record and 24-hour recall, male professional soccer referees (age 18-50) were found to be consuming 33% less energy than the recommended calorie intake for high activity levels and 11% less than the recommendation for light activity (Reñón & Collado, 2015). In studies focusing on soccer players, it was discovered that a group of professional Japanese soccer players (age 22 ± 1.9) were consuming only enough to meet 88% of their total energy expenditure (Ebine et al., 2002). A group of younger professional male soccer players in the United Kingdom (age 17 ± 0.01 years) were also found to be at an average daily energy deficit of 788 ±174 kcal, a conclusion based on dietary recalls and physical activity tracking (Russell & Pennock, 2011).

Studies conducted to evaluate the extent of physical activity demands of the referees have also identified trends in lower activity in the second half of a match due to possible fatigue or dehydration, which may be attributed to insufficient energy intake (Reñón & Collado, 2015).

High intensity activities were performed 4-18% of match time, but with a significant reduction in the second half, especially in backwards running (Da Silva et al., 2008). Not only was there a decrease in backwards running (467.3 ± 33.1 m to 385.3±27.5 m), but also a decrease in jogging (1,353.6 ± 355.3 m to 1,224.0 ± 347 m) from the first half to the second half. An analysis of activity on elite-level Italian soccer referees discovered a 4.1% decrease in distance covered during the second half. Similarly, an analysis of work rate of English Premier League referees found a similar decrease of 5.5% in distance covered during the second half of the game (Castagna et al., 2007; Catterall, Reilly, Atkinson, & Coldwells, 1993).

With the decrease in fast paced movement and increased fatigue, referees may also have difficulties keeping up with the players, which has been seen in the increased distance referees are from infringements in the second half (Da Silva et al., 2008). Also, 25% of injuries to referees occur in the last 15-20 minutes of the match (Reñón & Collado, 2015). A study conducted using 74 referees from the Iranian Premier Football League focused on the incidence rate and patterns of acute injuries obtained during the 2009-2010 season and found muscular and tendon injuries as the most common type, most occurring in the lower leg (Kordi, Chitsaz, Rostami, Mostafavi, & Ghadimi, 2013). A decrease in covered distance between the first and second half along with reported injuries in the last 15-20 minutes are signs of muscular fatigue that may be explained by a lack of appropriate energy levels to support the physical demands of a lengthy soccer match (Castagna et al., 2007; Catterall et al., 1993; Reñón & Collado, 2015).

Along with inadequate overall energy intake, minimal carbohydrates can be detrimental to physical performance. Based on the results of a movement analysis, soccer players on a high carbohydrate diet (8 g/kg) covered a significantly higher distance than the players on a low carbohydrate diet (3 g/kg) in a soccer match (Souglis et al., 2013). Despite this improvement in athletic performance, newer articles have looked at the dietary composition of soccer referees and found reported carbohydrate intake to fall below the recommended amount. A study on 35 professional soccer referees that analyzed dietary intakes, which found inadequate energy intake, also compared the macronutrient compositions to calculated recommendations for referees undertaking light activity and those undertaking high activity. The professional referees were reportedly averaging a much lower amount (279 grams) of carbohydrates against the recommended values for both lightly active (371 grams) and highly active athletes (540 grams) (Reñón & Collado, 2015). Another study conducted on male professional soccer referees from a Portuguese league, based on 7-day dietary records, found inadequate carbohydrate levels that fell below the recommended range of 5-12 g/kg with an average intake of 4.1 g/kg (Teixeira, Goncalves, Meneses & Moreira, 2014).

Along with physical strength, an important aspect of refereeing is decision-making, which requires full attention and brainpower. Low carbohydrate intake and exhaustive exercise can lead to possible hypoglycemia and muscular glycogen depletion, which may result in a decrease in the production of the ATP within the brain leading to disturbances in brain function (Mergenthaler, Lindauer, Dienel, & Meisel, 2013). In a study using male rats, which similar biochemical responses to exercise as humans, discovered that somewhere between 60 and 120 minutes of running, the glucose levels in the brain decreased significantly in the cerebellum, cortex, hippocampus, brainstem, and hypothalamus (Goutianos et al., 2015; Matsui et al., 2011).

Previous studies show achieving energy balance is important for professional soccer referees to avoid issues like fatigue, injuries, and lack of concentration. By measuring energy intake and energy expenditure, comparisons can be made to identify energy imbalances that may lead to complications and the inability to properly perform as a referee.

Reporting Energy Intake

Energy intake can be measured in different ways, which are divided into three general categories; dietary recalls, diet histories or retrospective questionnaires, and diet records. Diet records quantify all food and drinks consumed over a period of time typically ranging from 3-7 days with 3-4 day records being most commonly used on athletes (Hill & Davies, 2001; Magkos & Yannakoulia, 2003). For a 3-day dietary record, an individual must track everything he or she eats and drinks for 3 days. Validity of this method is improved by following clear instructions along with a nutrition professional providing the individual with a clear form and thorough directions. In an analysis of the nutritional intake of thirty-five soccer referees, researchers used a 3-day dietary record including a normal day, a training day, and a match day (Reñón & Collado, 2015). It is imperative to include a match day in an analysis of soccer referees as they have been shown to increase both carbohydrate and energy consumption on match days versus regular training days (Metz, Deleuze, Pereira, & Thivel, 2015).

Despite the convenient and common use of dietary records, there are downsides to relying on self-reported data. It is widely recognized that reported energy intake in dietary surveys underestimates usual energy intake with underreporting ranging from 10-45% due to subjects failing to report foods perceived to be bad or high in fat (Trumbo et al., 2002) . Also, the referees travel from place to place thus eating many meals on the road. Without personally prepping food, it becomes more difficult to record exact portion sizes and ingredients leading to inaccurate recording of energy intake.

Measuring Energy Expenditure

Total energy expenditure (TEE) is made up of basal or resting metabolic rate, thermic effect of food, and physical activity (Taylor, 2012). Basal metabolic rate (BMR), the minimal amount of energy expended for homeostatic processes, makes up the largest component of an individual's daily energy expenditure making up 60-70% (Hasson et al., 2011; Psota & Chen, 2013). BMR is the rate of energy to sustain in order to preserve and maintain vital body functions at rest (Whitney & Rolfes, 2007).

There are two techniques used to measure basal metabolic rate (BMR): direct calorimetry and indirect calorimetry. The method of direct calorimetry measures the amount of heat produced during metabolism with the use of a unique chamber large enough to for an individual to stay in for an extended period of time (Kang, 2008). This process of measurement has been shown to be very accurate, however, it is an expensive, time-consuming, and difficult task to perform with a lengthy time commitment expected of the participant.

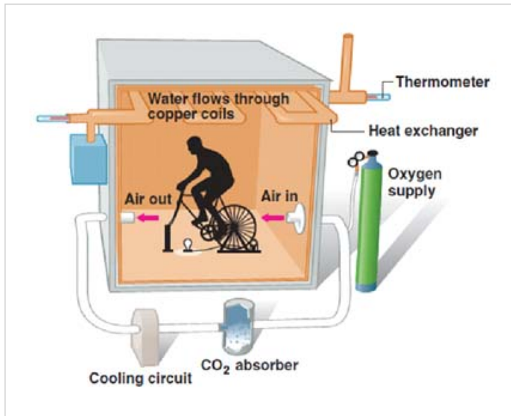

Figure 1. Direct Human Calorimeter
(Katch, 2013)

Indirect calorimetry, which is the more common way to measure BMR, measures oxygen consumption and carbon dioxide production, which corresponds to cellular respiration (Oshima et al., 2016). Indirect calorimetry differs from direct calorimetry in that it determines how much oxygen is required for biological combustion to be completed, rather than measuring the heat that is produced as a result of metabolic processes in the body (Kang, 2008).

Open-circuit spirometry is the most commonly used form of indirect calorimetry and is what is most often seen in clinical or laboratory settings. Some examples include the Douglas Bag, Oxylog, ventilated hood, and whole body calorimeters (Henry, 2005). The Douglas Bag method, considered the "gold standard", is comprised of a leak-proof bag that is connected by tubing to a three-way valve which can be rotated to seal the bag, take in atmospheric air, or admit expired air from the attached respiratory valve (Levine, 2005). To measure metabolic rate, the subject breathes through the mouthpiece and the three-way valve is rotated to allow the expired air in for 10-20 minutes. After collection, the valve is turned to seal the bag and the volume of the expired air in the bag is measured and analyzed to determine oxygen and carbon dioxide concentrations (Levine, 2005). The Douglas bag method is very accurate if the equipment is maintained and is operated by a skilled worker.

An example of a more modern, functional open-circuit spirometry system is the metabolic cart. Since their introduction in the 1970s, automated metabolic gas analysis systems or metabolic carts have become a very popular tool for exercise, cardiovascular, and patient testing (Macfarlane, 2001). In a metabolic cart test, the subject breathes into a mask or mouthpiece that is connected to the cart where the gas analyzers perform the airflow measurements (Haugen, Chan, & Li, 2007). The metabolic cart is more accessible and more easily used than the Douglas Bag method or other earlier mechanisms; however, it is still expensive and requires careful use. If purchased online, the metabolic carts range from $45,000 to $63,000. To help ease this problem, there are energy expenditure predictive equations and recent production of less-expensive, portable handheld metabolic readers, which will help make the technology more accessible to a wider variety of people.

Figure 2. Metabolic Cart ("Vyaire Medical," 2017)

Resting Metabolic Rate

For an energy expenditure measurement to be considered a BMR value, there are certain protocols to follow while performing indirect calorimetry. BMR must be measured in a resting state, so subjects must be comfortable, relaxed, and in a clear state of mind. In a review analyzing indirect calorimetry in a clinical setting, the recommended protocol includes no physical or psychological stress, subject awareness of the apparatus, a neutral temperature environment, and also the subject to be in a fasting state or no oral intake for the previous 10 hours (Oshima et al., 2016)

When any of the conditions for BMR measurements are not met, it is then called resting metabolic rate (RMR), a term that is often used interchangeably with BMR; however, there are clear differences in the measurement protocols between RMR and BMR. RMR does not require an overnight fast, participants could have eaten within the past 4 hours, but RMR is 10 % to 20% higher than BMR due to increased energy expenditure resulting from more recent food intake or physical activity (Haff & Triplett, 2015). It is also important to be familiar with resting energy expenditure (REE), which is defined as the amount of energy expended by a person at rest, but like RMR, it does not require the over-night fast and despite its difference, is often used interchangeably with BMR ("Resting energy expenditure protocol," 2012). With BMR having so many strict requirements, including no psychological stress and no physical activity prior to measurement, making it more difficult to attain, RMR and REE values are more often used.

Breezing® Metabolic Device

Breezing® is a portable, battery-operated device that measures resting metabolic rate or resting energy expenditure. This new 6-ounce device syncs with any smartphone via Bluetooth for easy everyday use by anyone. The device measures oxygen consumption rate (VO2) and CO2 production rate (VCO2) using a pre-calibrated built-in flow sensor to calculate resting energy expenditure (REE) and energy expenditure (EE) using the Weir equation ("Breezing

Metabolism," 2017). The metabolic test takes only two minutes and the synchronized application talks the participant through the procedure.

The Breezing® device comes with all of the essential parts at a price ranging from \$500 to \$650 ("Breezing Metabolism," 2017). The mouthpiece, which connects to the device via the T joint is reusable as long as it is sanitized between uses; however, the sensor cartridges, which detect the oxygen consumed and carbon dioxide produced, are single-use. Other components include the sensor cap that protects the cartridge, a battery charger, a nose clip, alcohol swabs, and information about downloading the Breezing Mobile App ("Breezing Metabolism," 2017).

Xian and colleagues compared the Breezing® technology to the “gold standard” of metabolic testing, the Douglas Bag Method, in twelve healthy adults (Xian, Quach, Bridgeman, Tsow, & Forzani, 2015). The results of the study showed no significant differences in VO2, VCO2, energy expenditure, or respiratory quotient values between the Breezing® and the Douglas Bag method (Xian et al., 2015). The energy expenditure readings from the Breezing® showed less than 10% difference than the Douglas Bag results.

Although Breezing® is a new technology and it’s validity cannot be guaranteed by one study, there are other portable metabolic devices on the market that have shown promising results in accurately measuring resting metabolic rate. Two devices, the BodyGem and the Cosmed Fitmate, have both been compared to the Douglas Bag method without any significant differences reported (Nieman et al., 2006; Nieman, Trone, & Austin, 2003). These previous metabolic devices provide assurance in the portable measuring systems, however, the Breezing® device stands alone in its progressive technology. It syncs with any smartphone via Bluetooth, it fits in a purse or bag, and the easy to follow directions makes it usable by any person (“Breezing Metabolism”, 2017). With the modern, up-and-coming technology associated with the Breezing® device and its ability to withstand the stresses of traveling better than the other handheld devices, it was utilized in this study, rather than the BodyGem and Cosmed Fitmate.

Figure 3. Breezing Phone Application.
("Breezing Metabolism," 2017)

Figure 4. Breezing Test
("Breezing Metabolism" (2017)

Metabolic Equations

Harris Benedict Equation

The Harris Benedict equation was developed to estimate the heat production of an individual (Harris & Benedict, 1918). The researchers collected biometric information from 136 men, 103 women, and 94 new-born infants who participated. Participants were all presumably in good health as the researchers felt they could generalize the results best with this population. After measuring multiple variables, they found significant correlations between stature and heat production while also finding a difference in metabolism between men and women. They found that heat production was more proportionate to stature, weight, and age than it was to body weight and surface (Harris & Benedict, 1918). They developed multiple regression equations for both men and women to predict daily heat production.

For men, $66.4730 + 13.7516w + 5.0033s - 6.7550a$

For women, $655.0955 + 9.5634w + 1.8496s - 4.6756a$

Where h represents the total heat production per 24 hours, w is weight in kilograms, s is stature in cm, and a is age in years.

In a study on 362 participants ranging between 18 and 60 years old, basal metabolic rate, calculated using the Harris Benedict equation, was compared with Mifflin-St. Jeor, Owen, and World Health Organization equations and a handheld indirect calorimeter (Hasson et al., 2011). Although it was hypothesized that Mifflin-St. Jeor would most accurately predict resting metabolic rate, the Harris-Benedict was the most accurate equation with 57.5% of predicted BMR values being within 10% of the calorimetric measurement. Despite differences between age groups, the Harris-Benedict did the best job at measuring resting metabolic rate at the group level (Hasson et al., 2011). Research conducted on 30 adults concluded that Harris-Benedict was most accurate at the group level when compared to a ventilated indirect calorimetry method and found to be 70% accurate at the individual level (Flack, Siders, Johnson, & Roemmich, 2016).

With the development of multiple new predictive equations, the Harris-Benedict equation is being criticized for not representing the modern population. The equation was developed using a population much different in body size and composition, levels of physical activity, and diet (Mifflin et al., 1990). A more diverse population lives in the United States nowadays with an increase in height, weight, and age. The constant in the equation has shown a ten-fold difference between males and females and a 10-15% overestimation of BMR has been experienced with the use of the Harris-Benedict equation (Henry, 2005). An analysis of basal metabolic rate in patients ranging from underweight to overweight found that the Harris equation was only accurate, in comparison to indirect calorimetry, in 51.8% of patients with a low BMI (16 to 18.5 kg/m^2). The accuracy dropped to an even lower value of 39.3% in the population of patients with a BMI below 16 kg/m^2 (Jésus et al., 2015).

Mifflin St. Jeor Equation

According to Mifflin and colleagues, the Harris-Benedict equation failed to apply to today's modern population, due to difference in body size, physical activity levels, and diet

(Mifflin et al., 1990). The goal of Mifflin and colleagues was to develop a more predictive equation based on a sample of 498 healthy normal weight and obese individuals along with assessing body composition and distribution in predicting energy expenditure (Mifflin et al., 1990). The participants in the Mifflin study consisted of 247 females, ranging from 20 to 76 years and 251 men, ranging from 19 to 78 years old. Forty-five percent of the women (n=112) and fifty-one percent of the men (n=129) were classified as obese (>120% IBW). Relationships between measured REE and weight, height, age, sex, fat-free mass, %IBW, body mass index, and waist-hip ratio were assessed (Mifflin et al., 1990).

The researchers found that weight and height demonstrated high correlation to REE (r = 0.73 and 0.69, respectively) (Mifflin et al., 1990). With this conclusion, they proposed Mifflin-St Jeor equations including height and weight as variables for females and males:

For females, 10 x weight (kg) + 6.25 x height (cm) – 5 x age (y) – 161

For males, 10 x weight (kg) + 6.25 x height (cm) – 5 x age (y) + 5

An evidence analysis performed by the Academy of Nutrition and Dietetics concluded that the Mifflin-St. Jeor equation is the most appropriate for determining metabolic rate in obese and non-obese individuals (Frankenfield, 2013). In a population size of 337 subjects ranging between the ages of 18 to 85, Mifflin-St. Jeor and Livingston equations had the highest accuracy rate among non-obese participants in comparison to an open-circuit calorimeter. In the obese groups, Mifflin-St. Jeor was also found to be the most accurate calculation (Frankenfield, 2013). Frankenfield and colleagues grouped its participants by obesity levels and found that as a whole, in both obese and non-obese people, Mifflin-St. Jeor was more accurate than the Harris-Benedict, Mifflin St. Jeor, and Owen equations (Frankenfield, Rowe, Smith & Cooney, 2003). The consistency of the equation was shown in the group with BMI over 40 with RMR only differing by 10% from the indirect calorimetry value in 25% of the subjects (Frankenfield et al., 2003).

Despite Mifflin's accuracy in a diverse population, a critique of the equation is that there is no variable that distinguishes between obese and non-obese status (Frankenfield et al., 2003). In a study using 90 adult athletes, it was concluded that the Mifflin equation was not applicable to their population (ten Haaf & Weijs, 2014). While Mifflin is more accurate in predicting REE in the obese population, it may lack statistical accuracy in predicting metabolic rate in a more lean and fit population.

Cunningham Equation

Gender, age, and body composition are factors relating to BMR, however, studies have reported that lean body mass (LBM), or fat-free mass, is a better predictor of oxygen consumption than surface area (Cunningham, 1980). To find percent fat-free mass, the amount of fat mass must be determined, which is calculated using percent body fat. Body fat values, in this study, were estimated through skinfold thickness measurements, which approximate body fat by measuring the amount of subcutaneous fat in different locations of the body with the use of a skinfold caliper ("Comparing Body Composition Assessments", 2011). Seven skinfold sites are commonly measured, which include the abdomen, biceps, front thigh, medial calf, subscapular, supraspinale, and triceps (Rodriguez et al., 2009).

Based on 93 female collegiate athletes, it was concluded that an increase in RMR or REE associated with body size results from the increase in fat free mass, rather than any increase in body tissue. The research concluded that RMR or REE could be assessed by fat free mass regardless of increase in body size (Taguchi et al., 2011). Cunningham used his study to estimate lean body mass as a function of gender, age, and body mass (Cunningham, 1980).

The study consisted of 223 healthy adult subjects taken directly from the classic Harris-Benedict study. Age, height, and body mass values were collected for 120 males and 103 females to estimate lean body mass. They found that LBM accounted for 70% of BMR variability making it the most predictive variable (Cunningham, 1980). Cunningham agreed with the suggestion made by Harris and Benedict that active body mass determines BMR. Gender and age influence body composition, but body composition is the principal determinant of BMR. Cunningham developed an equation using LBM as the single predictor of BMR in normal adults, which could replace separate multiple factor equations for males and females.

BMR (cal/day) = 500 + 22 (LBM)

Although it takes extra steps to calculate fat-free mass, the Cunningham equation has been found to be very accurate in an active population (Thompson & Manore, 1996). The resting energy expenditure in athletes is underestimated by other predictive equations due to athletic individuals' high fat free mass. ten Haaf & Weijs calculated the resting metabolic rate of 103 athletes using the Cunningham equation. In comparison to the Mifflin and Owen equations, the Cunningham equation predicted metabolic rate the most accurately, within 10% of indirect calorimetry measurements for 84.9% of the males and 78.4% of the females in the study (ten Haaf & Weijs, 2014). Measurements of the resting metabolic rates of 37 highly trained endurance athletes found the Cunningham equation predicted metabolic rate within 158 kcal for men and 103 kcal for women (Thompson & Manore, 1996). Fat-free mass accounts for the largest variation in basal metabolic rate, which is why the Cunningham equation is most accurate when measuring an intense athletic population with a higher muscle and fat-free mass composition.

Energy Expenditure During Physical Activity

Along with BMR, food intake and exercise both contribute to total energy expenditure (TEE). The thermic effect of food, which accounts for approximately 10% of TEE, is when the body works to break down meals into the appropriate utilizable components for energy and bodily function purposes causing metabolic rate to increase (Binns et al., 2015). Exercise of any sort, such as regular daily activities, normally account for about 20% of total energy expenditure (Binns et al., 2015). If an individual participates in higher physical activity throughout the day, such as running, weight lifting, or organized sports, physical activity will account for more than 20%. Although the thermic effect of food is not accounted for, by adding the energy expended during exercise beyond daily activities to RMR, a closer estimate of TEE can be made.

Fitness Watches

Energy expenditure during exercise can be measured in multiple ways, including activity diaries and motion sensors (pedometers and accelerometers) (Ainslie, Reilly, & Westerterp, 2003). However, a newer way to measure the energy expended is through the use of a fitness watch, which incorporates heart rate measuring technology. An example is the Polar V800, which is worn by the professional soccer referees to monitor activity during soccer games. The Polar watches have Global Positioning System (GPS) technology, which calculates exact positioning, speed and time of the individual wearing the watch through a network of orbiting satellites ("What is GPS?," 2009). The Polar watches also include a built-in heart rate monitor, which measures the number of beats per minute. Through the measurement of heart rate along with personal information such as age, weight, height, and gender, a programmed mathematical formula is then used to calculate calories expended (Bimbaum, 2003). Giles and colleagues (2016) tested the validity of the Polar V800 heart rate monitor's RR intervals, the time between heartbeats, in 20 individuals. In comparison to an echocardiogram, considered the gold standard of heart rate measurements, the Polar watch displayed an error rate of only 0.086% leading to the conclusion that it is a valid tool in heart rate measurements (Giles, Draper, & Neil, 2016).

To study energy expenditure in athletes, the Polar watch technology is ideal as the information from the wristwatch can be uploaded to a Polar Flow web service and mobile application for analysis (Ivan, 2016). In research, the Polar software and heart rate monitors have been used to measure energy expenditure across the season in D1 soccer players as well as male endurance runners' energy intake versus energy expenditure (Drenowatz, Eisenmann, Carlson, Pfeiffer, & Pivarnik, 2012; Reed, De Souza, & Williams, 2013).

Activity Factor

Without equipment, such as a GPS watch, or information to make a true estimate of physical activity energy expenditure, estimated basal or resting metabolic rate values can be multiplied by an activity factor to account for the energy exertion of physical activity. The physical activity factor considers the impact of the duration and intensity of physical activity (Gerrior, Juan, & Peter, 2006).

The physical activity factor is an estimate of activity level ranging from sedentary to very active. For sedentary individuals, participating in typical activities of daily living, the activity factor is 1.0-1.39. Low activity (1.4-1.59) includes typical activities of daily living plus 30-60 minutes of daily moderate activity. The range 1.6-1.89 applies to active individuals participating in an additional 60 minutes of daily moderate exercise. Very active individuals (1.9-2.5) participate in an additional 60 minutes of vigorous exercise or 120 minutes of moderate exercise (Rodriguez et al., 2009).

The approximation of the average energy needs of an athlete is done with an activity factor ranging between 1.8-2.3, but it is estimated based on the individual athletes' expected participation in physical activities (Rodriguez et al., 2009; Thomas et al., 2016). For example, in a study conducted on men participating in 3 or more hours of aerobic activity per week, the researchers used an activity level of 1.7 (Koehler et al., 2016). In another study, which analyzed the energy intake and expenditure of male rugby players used an activity factor of 1.86 to account for the 7 hours of training they participated in per week (Tooley, Bitcon, Briggs, West, & Russell, 2015). Without complete records of physical activity, it was difficult to make exact estimations of exercise, however, by using previous studies (Koehler et al., 2016; Tooley et al., 2015) and Rodriguez and colleagues' (Rodriguez et al., 2009) criteria for athletes' activities, we concluded that 1.6 is a good activity factor estimate for professional soccer referees.

Purpose of this Study

This study will explore male professional soccer referees' estimated energy by exploring and analyzing their 3-day and match day energy intake. Based on dietary records, metabolic rate equations (i.e. Harris-Benedict, Mifflin St. Jeor, Cunningham), Breezing® technology, and GPS watches (i.e. Polar watch), the recorded total energy intake will be compared to the daily estimated energy expenditure, energy expended during a soccer match and energy expended in a soccer match day. This study will a) determine if energy balance is being achieved to maintain physical and cognitive performance as soccer referees, b) measure how a new Breezing® device compares to commonly used metabolic equations, and c) measure macronutrient intake of soccer referees.

CHAPTER III

METHODOLOGY

Study Design, Participants, and Study Procedures

This study was conducted using a convenience sample of male professional center soccer referees from the Professional Referee Organization (PRO). Prior to the beginning of any data collection, the study protocols were reviewed and approved by the Institutional Review Board at Oklahoma State University (Appendix A). All participants were informed of the study purpose, procedures, and could withdraw from the study at any time. Each referee was assigned a number and no identifiers were linking referees to their personal results. Ten referees between the ages of 27-50 years old completed the metabolic test using the Breezing® technology during a training camp at the Cooper Aerobics Center in Dallas, Texas. The metabolic rates taken using the Breezing® method were done under protocols recommended for metabolic rate readings, including after an overnight fast without any previous physical activity (Appendix B). A Registered Dietitian monitored the quick, 5-minute process and all results were recorded promptly after completion of the Breezing® test. The results of the metabolic test, along with age, body weight, and height of each referee were collected. Body fat percentages of each subject was approximated using the seven skinfold site method, which utilizes a skin caliper instrument to measure the amount of subcutaneous fat in seven different locations of the body

(“Comparing Body Composition Assessments”, 2011). The seven sites include the abdomen, biceps, front thigh, medial calf, subscapular, supraspinale, and triceps (Rodriguez et al., 2009). The measurements in this study were taken three times, with the average body fat value of each body location used in an equation to predict body fat.

The anthropometric measurements of each referee were used in three common resting metabolic rate-predicting equations. The calculations were done using excel spreadsheets to decrease user error. The equations included the following:

Harris Benedict (Harris & Benedict, 1918)

$66.47 + 13.75\ (W) + 5\ (S) – 6.75\ (A)$

W = weight (kg), S = height (cm), A = age

Mifflin St. Jeor (Mifflin et al., 1990)

10 x weight (kg) + 6.25 x height (cm) – 5 x age (y) + 5

Cunningham (Cunningham, 1980)

500 + 22 (LBM)

Lean Body Mass (LBM) = weight – (weight * percent body fat)

During the mid-season, the referees completed a 3-day dietary record that was provided with instructions on how to properly fill out the forms (Appendix C). The referees were required to include one match day, travel day, and training day to show any changes or fluctuation in energy intake. The subjects were asked to include all items, including any fluids and serving sizes. The dietary records were analyzed using SuperTracker and caloric, protein, carbohydrate, and fat intakes were totaled ("SuperTracker: My foods. My fitness. My health.," 2017).

Along with dietary recalls, the amount of kcals burned and distance travelled in one soccer match was extracted from the Polar Flow website, which stores data from the referees’ Polar fitness watches. Using the watch readings, each referee’s average soccer match energy expenditure was compared to their match day caloric intake and their average 3-day caloric intake. The Polar Flow website was also used to determine the average distance traveled by a center referee in one soccer match.

The referees' reported 3-day average estimated energy intake was compared to the average resting metabolic rate readings by the Breezing® device and the three equations mentioned above. The RMR values were multiplied by an activity factor of 1.6 or added to recorded energy expenditure to account for physical activity (Koehler et al., 2016; Rodriguez et al., 2009; Thomas et al., 2016; Tooley et al., 2015). The mean resting metabolic rate from each equation was calculated and compared to the average Breezing® value. These comparisons were done without an activity factor then again with an activity factor of 1.6 applied to all calculated metabolic rate values. The macronutrient intakes were compared to daily-recommended intakes set at 6g/kg/day (55-65%) of carbohydrates (Thomas et al., 2016), 1.2 g/kg/day (12-15%) of protein (Thomas et al., 2016), and 20% of calories coming from fat (Taylor, 2012).

Statistical Analysis

The statistical analysis in this study was performed using Statistical Package for Social Science (SPSS for PC 20.0). The level of significance was set at <0.05. Descriptive statistics, including means and standard deviations were used to describe the sample's characteristics, energy intake and expenditure, energy deficit, macronutrient intake, as well as distance traveled during a match.

A paired t-test was utilized to compare the average reported energy consumed by the subjects on a match day with the average energy expended during one soccer match. This same test was performed again using the referees' 3-day average energy intake compared to energy expended during one soccer match. A within-subject ANOVA was used to compare TEE values using the four resting metabolic rate calculations with the average 3-day and match day caloric intake of the referees. The comparisons between metabolic equations and the results of the Breezing® technology were also compared using a within-subject ANOVA, with and without an activity factor of 1.6. Tukey's post hoc tests for both ANOVAs were run to identify where statistically significant differences were found. Paired t-tests were utilized to compare the referee's reported 3-day average protein, carbohydrate, and fat intake to each macronutrient's daily recommended intake appropriate for the subjects.

CHAPTER IV

FINDINGS

Results

Ten male soccer referees working for the Professional Referee Organization volunteered to participate in this study. The ethnicities of the subjects consisted of six Whites, three Hispanics, and one Moroccan. Mean age of the subjects was 42 ± 6.57 years. Average height was 70.3 ± 2.83 inches (178.56 ± 7.10 cm) and average weight was 181.30 ± 21.65 pounds (82.24 ± 9.8 kg). The average body fat percentage was 15.83 ± 1.86. The average lean body mass was 69.46 ± 9.42 pounds (31.5 ±4.27 kg). Anthropometric characteristic of the subjects are summarized in Table 1.

Table 1: Subject Characteristics

Descriptive Statistics			
N=10	**Min**	**Max**	**Mean ± Std. Deviation**
Age (yr)	27	50	42 ± 6.57
Height (in)	67	76	70.30 ± 2.83
Weight (lbs)	148	221	181.30 ± 21.65
Body Fat Percentage	12.62	18	15.83 ± 1.86
Lean Body Mass (lbs)	55.75	87.80	69.46 ± 9.42

yr = years, in = inches, lbs = pounds

Subjects provided 3-day food records, which included a match day, travel day, and training day. The average kcal consumed per day was 1,693 ± 281 kcal and the average energy consumed by the referees on a match day was 1,855 ± 462 kcal. The subjects wore Polar GPS watches during all soccer matches, which recorded energy expended and distance travelled. The average distance travelled and energy expended during a match was 9.77 ± 0.91 kilometers (km) (6.07 ± 0.57 miles) and 1,680 ± 341 kcal, respectively. The average energy consumption, energy expenditure, and distance travelled by the referees are displayed in Table 2.

Table 2: Energy Intakes, Energy Expenditure, and Distance Traveled

Descriptive Statistics			
N=10	**Min**	**Max**	**Mean ± Std. Deviation**
Avg. energy intake (kcal)	1,414	2,267	1,693 ± 281
Avg. match day energy intake (kcal)	1,094	2,651	1,856 ± 462
Avg. distance traveled (km)	8.98	11.8	9.77 ± 0.91
Soccer match energy expenditure (kcal)	1,183	2,152	1,680 ± 341

To estimate resting metabolic rate, three equations and a portable device, the Breezing® technology, was used. The equations included Harris-Benedict (Harris & Benedict, 1918), Mifflin St. Jeor (Mifflin et al., 1990), and Cunningham (Cunningham, 1980). Table 3 displays the minimum, maximum, and mean of each RMR calculation. These numbers were used to estimate the resting energy needs of the referees.

Table 3: Estimated RMR Values from Breezing® Device and Metabolic

Estimated RMR			
RMR Equations	**Min (kcal)**	**Max (kcal)**	**Mean ± Std. Deviation (kcal)**
HB	1,661	2,089	1,812 ± 137
MSJ	1,612	1,976	1,737 ± 114
CUN	1,726	2,431	2,029 ± 207
Breezing®	1,450	1,970	1,656 ± 193

HB = Harris-Benedict, MSJ = Mifflin-St.Jeor, CUN = Cunningham

To account for the energy expenditure associated with the physical demands of soccer refereeing, an estimated activity factor of 1.6 was applied to all RMR calculations. The minimums, maximums, and means are summarized in Table 4.

Table 4: Estimated RMR Values with Physical Activity Factor

Estimated RMR with AF of 1.6			
RMR Equations	**Min (kcal)**	**Max (kcal)**	**Mean ± Std. Deviation (kcal)**
HB	2,658	3,342	2,899 ± 220
MSJ	2,579	3,162	2,779 ± 183
CUN	2,762	3,890	3,246 ± 332
Breezing®	2,320	3,152	2,650 ± 309

HB = Harris-Benedict, MSJ = Mifflin-St.Jeor, CUN = Cunningham

Table 5 shows the differences between the different methods of estimating energy expenditure (i.e. metabolic equations and the Breezing® technology). Mean differences vary; however, p-values are the same for comparisons made with and without the activity factor. The Cunningham equation estimated a significantly higher value than Breezing® ($p < 0.001$). Harris Benedict was also significant ($p = 0.045$) with an RMR estimation that was 156 kcals and 249 kcal higher than the Breezing device; however, the Mifflin-St. Jeor equation was within 81 and 130 kcal of Breezing®, showing no significant difference ($p = 0.286$). The predictive metabolic equations were also compared to one another. Cunningham showed a significant difference from both Harris-Benedict ($p = 0.006$) and Mifflin St. Jeor ($p < 0.001$) predicting higher energy needs. The difference between Harris-Benedict and Mifflin-St. Jeor was not significant ($p = 0.327$).

Table 5: Breezing® Device Compared to Metabolic Equations With and Without AF of 1.6

Variation in RMR Estimations				
Equations		Mean Dif. (kcal)	Mean Dif. w/ AF (kcal)	P-value
Breezing	**HB**	-156	-249	0.045
	MSJ	-81	-130	0.286
	CUN	-373	-597	<0.001
HB	**MSJ**	75	119	0.327
	CUN	-217	-347	0.006
MSJ	**CUN**	-291	-466	<0.001

HB = Harris Benedict; MSJ = Mifflin St. Jeor; CUN = Cunningham; AF = activity factor; kcal = calories

Using the 3-day food records and Polar watch data, the average energy consumed per day (1,693 ± 281 kcal) was compared to the average energy expended during one soccer match (1,680 ± 340.74 kcal). A difference of 13 ± 512 kcal between energy expended and consumed was not significant (p = 0.936). Match day energy consumption (1,856 ± 462 kcal) versus soccer match energy expenditure (1,680 ± 341 kcal) was also compared. The difference of 176 ± 719 kcal between energy consumed on a match day and energy expended was not significant (p = 0.459). These relationships, shown in Table 6, were analyzed to identify if the subject's were meeting the energy demands of refereeing a complete soccer match.

Table 6: Estimated Match Energy Expenditure Compared to Reported Energy Intake

Kcals Consumed vs. Soccer Match Energy Expenditure			
		Mean Dif. ± SD. (kcal)	P-value
Average Kcal	**Match EE (kcal)**	13 ± 512	0.936
1,693 ± 281	1,679.80 ± 341		
Match Day Kcal	**Match EE (kcal)**	176 ± 719	0.459
1,856 ± 462	1,680 ± 341		

Significance set at ≤ 0.05; Average Kcal = average 3-day calorie intake, Match Day Kcal = average calories match day calorie intake; EE = energy expenditure; kcal = calories

Table 7 summarizes the relationship between the subjects' average kcal consumption and the estimated RMR value with a 1.6 AF. All equations plus a 1.6 AF predicted significantly higher energy needs than what was reportedly consumed by the subjects resulting in an energy deficit. For example, Harris Benedict predicted an energy expenditure higher than what was reportedly consumed, resulting in an estimated 1,205 kcal deficit ($p < 0.001$).

Table 7: Reported Energy Intake Compared to RMR with Physical Activity Factor

Caloric Intake vs. RMR with AF			
Average Kcals Consumed	**Predicted Energy Needs (kcal)**	**Mean Dif. (kcal)**	**P-value**
1,693 ± 281	**HB** 2,899 ± 220	-1,205	<0.001
	MSJ 2,779 ± 183	-1,086	<0.001
	CUN 3,246 ± 332	-1,553	<0.001
	Breezing® 2,650 ± 309	-956	<0.001

Significance set at ≤ 0.05; Average Kcals Consumed = average 3-day calorie intake;HB = Harris-Benedict; MSJ = Mifflin St. Jeor; CUN = Cunningham

Along with average TEE estimated using an activity factor of 1.6, a more specific estimated soccer match day TEE can also be calculated by adding the energy expended in a soccer match to estimated RMR by utilizing information from the Polar watches. Table 8 displays the minimum, maximum, and average values for estimated match day total energy expenditure using each RMR estimation method.

Table 8: Estimated Match Day Energy Expenditure Using RMR and Polar GPS Watch

TEE Estimation (RMR + EE)			
RMR Equations	**Min (kcal)**	**Max (kcal)**	**Mean ± Std. Deviation (kcal)**
HB	2,886	3,958	3,491 ± 404
MSJ	2,826	3,863	3,417 ± 388
CUN	3.009	4,253	3,708 ± 451
Breezing®	2,643	3,962	3,336 ± 396

EE = match energy expenditure; HB = Harris Benedict; MSJ = Mifflin St. Jeor; CUN = Cunningham

To further measure energy deficit, reported match day energy intake was subtracted from estimated TEE (displayed in table 9) to evaluate how much of the energy expended was fueled by the diet. Table 9 displays the high-energy deficits found with all metabolic calculations, therefore, estimated expenditure exceeded the subjects' match day caloric intake. Based on HB, an average deficit was 1,636 ± 755 kcals and according to MSJ, the average energy deficit was 1,561 ± 746 kcals. There was a wide range of deficits with the smallest being 286 kcals and the largest being 2,773 kcals. Minimum, maximum, and average energy deficits are displayed in Table 9.

Table 9: Estimated Match Day Energy Deficits

Predicted Energy Deficit (TEE-Kcal)			
RMR Equations	**Min (kcal)**	**Max (kcal)**	**Mean ± Std. Deviation (kcal)**
HB	330	2,595	1,636 ± 755
MSJ	286	2,553	1,561 ± 746
CUN	358	2,774	1,853 ± 797
Breezing®	559	2,455	1,480 ± 750

HB = Harris Benedict; MSJ = Mifflin St. Jeor; CUN = Cunningham

Along with energy consumption, the macronutrient composition of the referees' 3-day average dietary intake was also analyzed using SuperTracker. Included in Table 10 are the average intakes and the average recommended intakes for each macronutrient. The minimum and maximum macronutrient intakes and recommendations are also listed.

Table 10: Reported Macronutrient Intakes

Macronutrient Intake						
Macronutrient	**Avg. Intake (g) ± SD**	**Min**	**Max**	**Avg. Rec. Intake (g) ± SD**	**Min**	**Max**
Carbohydrates	180.6 ± 54.6	132.0	279.0	494.5 ± 59.1	403.6	602.7
Fats	55.9 ± 10.7	39.5	75.6	58.9 ± 6.9	51.6	70.0
Protein	106.3 ± 24.8	81.0	160.0	98.9 ± 11.8	80.7	120.6

Avg = average; Rec = recommended; SD = standard deviation

To evaluate the quality of the referees' dietary intake, their average macronutrient intakes were compared to the recommended intakes for this population. Table 11 displays the results, which shows that the referees met the recommended values for fat and protein ($p = 0.427$, $p = 0.438$, respectively), but a significant difference in carbohydrate intake was found ($p < 0.001$).

Table 11: Reported Macronutrient Intake Compared to Recommendations

<table>
<tr><th colspan="4">Macronutrient Intake vs. Macronutrient Recommendations</th></tr>
<tr><th colspan="2"></th><th>Mean Dif. ± SD.</th><th>P-value</th></tr>
<tr><th>Avg. CHO Intake (g)</th><th>Avg. CHO Rec. (g)</th><td rowspan="2">-313.9 ± 90.2</td><td rowspan="2"><0.001</td></tr>
<tr><td>180.6 ± 54.6</td><td>494.5 ± 59.1</td></tr>
<tr><th>Avg. Fat Intake (g)</th><th>Avg. Fat Rec. (g)</th><td rowspan="2">-3 ± 11.4</td><td rowspan="2">0.427</td></tr>
<tr><td>55.9 ± 10.7</td><td>58.9 ± 6.9</td></tr>
<tr><th>Avg. Protein Intake (g)</th><th>Avg. Protein Rec. (g)</th><td rowspan="2">7.4 ± 28.9</td><td rowspan="2">0.438</td></tr>
<tr><td>106.3 ± 24.8</td><td>98.9 ± 11.8</td></tr>
</table>

Significance set at p ≤ 0.05; SD = standard deviation; Avg = average; Rec = recommendation

CHAPTER V

DISCUSSION

In 2014, 3.2 billion viewers tuned in to watch the 4-day long Soccer World Cup tournament ("2014 FIFA World Cup Brazil," 2015). These worldwide viewers were counting on the soccer referees to stay cognitively focused, keep up with the fast pace, and call fair soccer matches. However, previous studies have shown that male referees are not consuming the adequate energy to support the demands associated with the job (Reñón & Collado, 2015). This study's main purpose was to determine if full-time center referees were properly fueling their bodies to sustain energy throughout a soccer match, while also meeting daily-recommended energy needs.

On average, the referees in this study reported consuming about 1,700 kcal per day and increasing their energy consumption on match days to about 1,850 kcal. Both reported energy intake values are low in comparison to energy intakes (normal day = 2,371 kcal, training day = 2,479 kcal, match day = 2,368 kcal) in a study that utilized 3-day dietary records and 24-hour recalls with Spanish professional male soccer referees of similar age, height, and weight (Reñón & Collado, 2015). Using information from their GPS Polar watches, the average distance travelled during one soccer match was found to be just shy of previous studies (5.7-6.84 miles) (Castagna et al., 2007; Reñón & Collado, 2015), but still covered a distance of 9.77 ± 0.91 km (6.071 ± 0.57 miles) . On average, about 1,700 kcal was expended during a soccer match by the center referees in this study, a value higher than found in a previous study on Brazilian referees of similar weight, height, and age (734.7 ± 11.9 kcal) (Da Silva et al., 2008).

Energy Balance

To evaluate whether the subjects were meeting the energy demands of a soccer match, the average soccer match energy expenditure was compared to both reported average 3-day energy consumption and match day energy consumption. The referee's reported energy intake was enough to cover the energy expended during a soccer match, but the mean difference found between average 3-day energy intake and average match energy expenditure was only about 13 kcal, meaning after a soccer match, 13 kcal was the only energy remaining to cover all energy costs of RMR and other daily activities. This low value implies a lack of adequate calories thus potential negative energy balance and risk of decreased endurance, impaired judgment, decreased coordination, and decreased muscle strength (Thomas et al., 2016).

The potential negative energy balance in this population was researched further by incorporating the referee's RMR and energy expended from physical activity to create a closer estimate to total energy expenditure. The estimation of TEE was made by either multiplying RMR values, obtained from the three equations and Breezing® device, by an activity factor of 1.6 or by adding soccer match energy expenditure, collected from the Polar watches, to the RMR values. All values were compared to the referees' reported energy intake to identify whether the referees' diets were meeting or exceeding recommended energy needs. Significant differences across all RMR values confirmed the subjects to be in a negative energy balance and being at risk for physical and cognitive impairments.

Energy deprivation has been recorded in studies on male athletic populations, including professional soccer referees, endurance athletes, and college athletes (Drenowatz et al., 2012; Hinton, Sanford, Davidson, Yakushko, & Beck, 2004; Reñón & Collado, 2015). This occurrence of low dietary intake poses risks for decreases in physical performance, including decreased endurance, increased injury risk, and impaired judgment (Thomas et al., 2016). These impairments have been identified in soccer referees through match analysis, which included replacing jogging with walking in the second half of a match, a higher magnitude of injuries occurring in the last 15 minutes of a match, and fatigue leading to the inability to maintain an adequate distance from calls (Da Silva et al., 2008; Reñón & Collado, 2015). Motion analysis is beyond the scope of this study, but with such high-energy gaps, further research is essential on this specific group of referees to pinpoint any possible physical impairment due to low energy intake.

Imbalances between energy intake and energy expenditure can result in gains or losses of body composition, mainly pertaining to fat, leading to a change in body weight (Thomas et al., 2016). In this current study, the referees were experiencing an energy deficit in reference to their reported energy intake and daily estimated energy expenditure. With such high-energy deficits in the subjects, it might be assumed that the referees would display low body fat percentages. Despite this assumption, based on skin caliper measurements, the subjects' average body fat percentage was 15.83 ±1.86. While this range is lower than the average American male between the ages of 20-59 (26.1-28.7%), it still falls within the recommended range for males between ages 30-50 (15-20 %) and male soccer players (10-18%) (Jeukendrup, 2010; Li, Ford, Zhao, Balluz, & Giles, 2009). With self-reporting posing possible bias, issues in reporting, and other studies identifying underreporting in their subjects, it is likely that the professional referees did not record all food items eaten throughout the day. Therefore, it is hypothesized that the low energy intake as well as the disconnect between energy intake and normal body fat percentage is related to inaccurate 3-day dietary records (Liberato, Bressan, & Hills, 2008).

Along with under-reporting, the 3-day dietary records provided only a brief snapshot of the referees' daily living and traveling schedules. The intake on the specific 3 days used for the study may not be representative of the referee's normal or common everyday intake. Soccer referees are unique in that they travel to and from various match locations. As a result, daily food choices vary as meals are not prepared at home, but are mainly consumed on the road from a multitude of restaurants. Although the referees reported low energy intakes, restaurant food consumption is associated with high-energy intakes, along with greater body fatness, regardless of age, sex, physical activity, education, or alcohol consumption (McCrory, Suen, & Roberts, 2002). So, based on the refereeing lifestyle yet low energy intake and normal body fat measurements, under-reporting on the dietary records should be a consideration before concluding that all referees fell significantly below energy recommendations.

Estimated Metabolic Rate Equations and Breezing® Device

The second purpose of this study was to compare the results of three predicting metabolic equations (Harris-Benedict, Mifflin St. Jeor, Cunningham) to the new tech-savvy Breezing® device. The metabolic equation that showed the most significant difference in estimations from Breezing® device was the Cunningham equation with statistically higher values ($p < 0.001$) (Cunningham, 1980). The Cunningham equation was also significantly higher than the Harris-Benedict ($p = 0.006$) (Harris & Benedict, 1918) and the Mifflin St. Jeor equations ($p < 0.001$) (Mifflin et al., 1990).

The Cunningham equation has shown to be accurate in the athletic population because it takes into account lean body mass and fat-free mass (Cunningham, 1980; ten Haaf & Weijs, 2014). However, many studies that have shown good results when using Cunningham to predict RMR included high endurance athletes, a population with both lower lean body mass and body fat percentage than other strength-trained athletes (Morehen et al., 2016). For example, a study on a population consisting of trained endurance athletes found the Cunningham equation to predict RMR within 158 calories, whereas, in a population of elite rugby players with a higher lean body mass, Cunningham overestimated RMR by 16.5% (Morehen et al., 2016; Thompson & Manore, 1996). The overestimation by the Cunningham equation in this study may be due to a higher lean body mass, but human error in reporting body fat percentage is a consideration as well that may effect the Cunningham value. The use of skin calipers poses the risk for inaccurate skin pinch or body location, which can skewer body fat percentage readings ("Comparing Body Composition Assessments," 2011) that are then used to calculate lean body mass utilized in the Cunningham equation.

The Academy of Nutrition and Dietetics concluded the Mifflin St. Jeor equation to be most appropriate for determining metabolic rate in obese and non-obese individuals (Frankenfield, 2013). In regards to this current study, that conclusion is found to be true. Mifflin St. Jeor was the closest to the Breezing® reading in mean RMR comparisons, with and without an activity factor ($p = 0.286$). The Harris-Benedict equation calculated values just slightly higher than the Breezing® device ($p = 0.045$) and estimated similar values to the Mifflin St. Jeor equation ($p = 0.327$). Utilizing past studies that focused on metabolic equations (Flack et al., 2016; Frankenfield et al., 2003; Hasson et al., 2011) and the close relationship seen between Breezing, the Mifflin St. Jeor, and the Harris-Benedict equations in this study, two conclusions can be made. First, the Mifflin-St. Jeor and the Harris-Benedict equations are better predictors of RMR than the Cunningham equation in the referee population. Second, the equations are easy, simple and predicted values similar to the Breezing® device, therefore, the device is not a necessity for this population when measuring metabolic rate..

Macronutrient Intake

Carbohydrates, proteins, and fats are the necessary energy-containing nutrients to fuel the body. While overall energy intake is important, the quality of the diet is just as critical for referees as their sport requires the use of all energy sources. Therefore, the third purpose of this study was to analyze the referees' 3-day average macronutrient intake. The suggested carbohydrate (CHO) intake in this study was 6 grams/kg of body weight/day, which falls within The Academy of Nutrition and Dietetics recommendation for individuals participating in 1-3 hours of exercise per day (Thomas et al., 2016). The referees' diets were significantly lower than the carbohydrate recommendation with a mean difference of about 315 grams between the recommended and actual average carbohydrate intake ($p<0.001$).

High CHO intake has been shown to improve distances covered by soccer players and increase sprinting and jogging efficiency during a match; however, it is common to see low CHO intake in the athletic populations (Balsom, Wood, Olsson, & Ekblom, 1999; Hinton et al., 2004;

Reñón & Collado, 2015; Souglis et al., 2013; Teixeira et al., 2014). Lower than recommended carbohydrate intake can negatively affect physical performance along with impairing cognitive function. With exhaustive exercise, hypoglycemia and muscular glycogen depletion is possible, which may result in decreased ATP within the muscles and the brain (Mergenthaler et al., 2013). Referees make about 137 observable decisions, switch between 6 different locomotor activities, and cover 5.7-6.84 miles per match (Balsom et al., 1999; Castagna et al., 2007; Da Silva et al., 2008; Helsen & Bultynck, 2004; Reñón & Collado, 2015) showing the requirement for attentive brain and optimal muscle function, therefore, adequate carbohydrate intake.

Despite the low reported carbohydrate intake seen in this study and the associated physical risks of low intake, the distance covered by the referees was very similar to previous motion analysis studies (Castagna et al., 2007; Da Silva et al., 2008). Even the subjects with the lowest carbohydrate intakes (132 g) covered distances, which fell within the distance range in this study and previous studies (Castagna at al., 2007). This low intake of carbohydrates might be explained by failing to report all food items thus under-reporting on the 3-day dietary records.

Although carbohydrate intake was significantly low, fat intake did not show a significant mean difference from the recommended intake, which was set at 20% of caloric intake (Taylor, 2012). With so many different movements in refereeing and the long match time, a diet consisting of adequate fat intake is ideal for this population as it promotes higher intramuscular triacylglycerol stores, and maintains a secondary source of energy when glycogen depletion occurs with long-lasting exercise (Kang, 2008; Spriet & Gibala, 2004).

Like fat intake, the referees consumed an adequate level of protein, recommended to be 1.2 g/kg of body weight/day (Thomas et al., 2016). Protein may only supply 2-8% of the energy needed for a muscle contraction, but for 24-hours post-exercise, muscle protein synthesis is up-regulated causing an increase in protein sensitivity and a critical time for muscle healing and growth (Daries, 2012; Thomas et al., 2016). In previous research, an adequate protein intake, even at hypo energetic levels, can maintain lean body mass and reduce muscle damage in athletes making protein a crucial aspect of the soccer referees' diets (Mettler, Mitchell, & Tipton, 2010).

Based on macronutrient analysis, the subjects reached recommended intakes of fat and protein, but carbohydrate intake was extremely low. However, with under-reporting being a concern, actual intakes of the macronutrients may be much higher than what the subjects recorded on their 3-day dietary records.

Study Strengths

A strength of this study was the use of the Breezing® device as a method to estimate resting metabolic rate. This portable device has been found comparable to the gold standard of metabolic testing, the Douglas Bag method, in regards to accuracy and validity (Xian et al., 2015). Although it cannot be concluded that this method is reliable or valid based on one research study, our study was able to further verify the method and conclude that the Breezing® device is similar to the Harris-Benedict and Mifflin-St. Jeor equations, both commonly used and well-respected methods of determining RMR (Flack et al., 2016; Frankenfield, 2013; Frankenfield et al., 2003; Hasson et al., 2011). Also, this device is lightweight, just 6 ounces, so it can easily be carried around in a bag or purse and used at different locations. In comparison to a large metabolic cart, this device is more accessible and convenient for measuring metabolic rate. Through these conclusions, future studies can more confidently use the Breezing® technology, as well as the Harris-Benedict and Mifflin St. Jeor equations to estimate subjects' energy expenditure and required energy intake.

Another strength of this study was the collection of dietary records from the subjects that included a match day within the 3-day recording period. Past studies on professional soccer referees have identified an increase in caloric intake on match days, so by implementing a match day in this study's analysis, a more complete look at energy intake variability was accomplished (Metz et al., 2015).

Limitations and Future Research

A limitation of this study was the use of self-reported, 3-day dietary records to calculate total energy intake. Low energy and carbohydrate intake reported by the subjects may be due to inaccurate reporting. However, whether the subjects were underreporting or their diets were actually inadequate, nutrition education is necessary to improve recording habits and overall dietary intake. For example, with the use of food records along with nutrition education, an NCAA volleyball team showed improvement in the quality of their diaries from the beginning to end of the season (Valliant, Pittman Emplaincourt, Kieckhaefer Wenzel, & Garner, 2012). Another study conducted on D1 male baseball players showed increases in nutrition knowledge, along with improvements in physical performance with the intervention of Sports Nutrition education (Rossi, Landreth, Beam, Jones, Norton & Cholewa, 2017). For the referees, nutrition education is critical to explain the importance of all energy sources and honest reporting of the three macronutrients. An increase in energy consumption from proper food sources will be a large aspect of education to maintain adequate intake of fat and protein, while increasing carbohydrate intake. Future studies, on referees and other populations, can minimize recording bias and improve overall diet quality by implementing nutrition education and being more attentive in guiding the participants through the recording process.

Another limitation of this study was the lack of motion analysis technology to evaluate how a low amount of daily energy intake may impact the referee's performance in a match. With this study revealing a possible inadequate consumption of calories and carbohydrates within the population of professional soccer referees, by implementing motion analysis; distance covered, along with the jogging to walking ratio and distance from calls can be measured (Castagna et al., 2007; Catterall et al., 1993; Da Silva et al., 2008). By merging together nutrition education, dietary analysis, and motion analysis, a future study can determine how improving the diet (i.e. carbohydrate and energy intake) may impact distance covered and overall physical performance in a soccer match.

A small sample size of only 10 subjects also caused some limitations. To make a generalized conclusion about all professional soccer referees, a higher number of participants should be recruited. Also, many of the studies used as reference for motion analysis of soccer matches were done in other countries due to the popularity of soccer throughout the world (Castagna et al., 2007; Da Silva et al., 2008; Reñón & Collado, 2015; Weston et al., 2011). Future studies should recruit subjects from many different soccer leagues across the globe, as there will be differences in dietary consumption, exercise patterns, and daily living that will make the study more generalizable to the total professional soccer referee population.

The use of the Polar website to record energy expenditure by the referees in one soccer match posed some limitations. Whether or not the referees wore their watches during warm ups, during half time, or during cool downs affects the total time the watch was recording physical activity and therefore total calories being expended. This limitation may have impacted the range of calorie expenditure across the subjects.

Conclusion

As a professional soccer referee, there are expectations to be physically and cognitively prepared to adequately call a soccer match. This study utilized four metabolic rate estimations and analyzed dietary records to come to the conclusion that referees are not consuming enough energy or carbohydrates on a daily basis to properly fuel the high demands associated with the refereeing soccer matches.

In reference to self- reported 3-day dietary records, estimations of physical activity expenditure, and metabolic rate estimations (Harris-Benedict, Mifflin St. Jeor, Cunningham, Breezing®), the referees were barely consuming enough energy to fuel a soccer match. The referees' recorded energy intakes were also significantly below energy recommendations to compensate for estimated resting metabolic rate and total energy expenditure. Whether the high-energy deficits were due to under-reporting on the dietary records or actually represent a need for increased energy intake, nutrition education is critical to implement knowledge about adequate dietary intake and accurate self-reporting. Utilizing nutrition education will emphasize the benefits of including all food groups in the diet resulting in an appropriate caloric and macronutrient intake necessary for the lifestyle and physical demands of soccer refereeing.

The new Breezing® device and the metabolic rate equations, Harris-Benedict and Mifflin- St. Jeor, displayed similar results when compared to one another. With the Breezing® device showing comparable readings to commonly used and well-studied equations, this study provides assurance in the use of the Breezing® technology for measuring metabolic rate in future studies, as well as promoting the Harris-Benedict and Mifflin-St. Jeor equations as predictors of metabolic rate for this population. Based on these conclusions, the Breezing® device, along with the Harris- Benedict and Mifflinf St. Jeor equations can be used interchangeably for calculating resting metabolic rate as they result in similar RMR values for the referee population.

For soccer referees, a balanced, well-rounded diet means more than a healthy lifestyle. It provides the energy to adequately fuel the mind and body for their physical and cognitive responsibilities on the soccer field. Although the referees in this study reached adequate protein and fat intake, the gaps in their diets put them at risk. Their low energy and carbohydrate intake can increase injury risks, impact the jogging to walking ratio, and decrease the ability to maintain an adequate distance from calls (Da Silva et al., 2008; Reñón & Collado, 2015; Thomas et al., 2016). In conclusion of this study, without an increase in energy and carbohydrate consumption and implementation of nutrition education, soccer referees will continue to put themselves at risk for muscular injuries, fatigue, and cognitive impairments that may hinder their ability to properly, fairly, and efficiently officiate a soccer match.

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APPENDICES

APPENDIX A

Oklahoma State University Institutional Review Board

Date:	Monday, May 01, 2017
IRB Application No	HE1730
Proposal Title:	Professional Soccer Referee's Dietary Intake in Comparison to their Measured Basal Metabolic Rate and Match Day Energy Exertion
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 4/30/2020

Principal Investigator(s):

Erika Schiller	Gena Wollenberg
	1015 E Franklin
Stillwater, OK 74078	Stillwater, OK 74075

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

APPENDIX B

BREEZING® PROTOCOLS

Breezing Protocols for REE and MEE Tracking B

Measuring Resting Metabolism, or Resting Energy Expenditure (REE): Before you start, we recommend you practice breathing through the mouthpiece and T-joint assembly (without attaching it to the Tracker) for at least 2 minutes, while wearing the nose clip.

Note: *Resting measurements can only be taken after you pass the New User training – this is designed to ensure the accuracy of your measurements.*

1. Be comfortably reclined on a bed or chair (your head supported by a cushion)
2. Your environment should be quiet and at a temperature that is comfortable for you.
3. The ideal time to measure is immediately upon waking, with overnight (8-hour) fasting. Wait at least 4 hours if you've eaten a moderate (~500 kCal) meal.
4. Wait at least 4 hours after moderate exercise; at least 12 hours after strenuous exercise.
5. To ensure you are truly in a "resting" state, check your heart rate by feeling your pulse or using a heart monitor.
6. Once you are ready, the App will guide your measurement.

Measuring Momentary Metabolism, or Momentary Energy Expenditure (MEE)

MEE measurements can be conducted before and after a variety of exercises or even after eating. For example, you can track your MEE and Energy Source (Respiratory Quotient, RQ) change with aerobic training, then compare your MEE and RQ change with weight training*.

Note: *Momentary measurements can only be taken after completing two successful Resting Metabolism measurements.*

1. Be seated in a quiet environment that is at a comfortable temperature for you.
2. Place the nose-clip over your nose, and at 1-minute intervals, try breathing through the mouthpiece/T-joint assembly (not yet attached to the Tracker).
3. Once you can breathe easily for 2 minutes straight, then continue following the App to guide your measurement.

To share your experiences and to learn from other Breezing users, please email us at info@breezing.co. We'd love to hear from you!

*For an in-depth study of High Intensity Interval Training (HIIT) intervention and Breezing tracking, please see: http://breezing.co/downloads/Breezing-EPOC-Tracking-Exercise-Afterburn.pdf

www.breezing.com

APPENDIX C

3-DAY FOOD RECORD

Tips on Completing an Accurate Food Record

- **Complete it for 3 days. Your food record should be for 3 days of intake. Include the day and date at the top of each form. The 3 days should be consecutive and should include two weekdays and one weekend day.**

- **Use a separate form. Use a separate sheet for each day of the food record. Multiple sheets are included.**

- **Carry it with you. Document your meals and snacks soon after you eat it. It is surprisingly difficult to recall what you ate days or hours later.**

- **Describe combination foods. If you are eating combination foods, such as pizza with various toppings, make sure to record these ingredients.**

- **Estimate serving size. Estimate serving size to the best of your ability. Use the serving size on the food label if available. If you are uncertain, estimate using familiar objects. For example, you can use "palm of your hand" to estimate the size of a chicken breast or "baseball" to estimate an ice cream serving.**

- **Record time. Record the approximate time each meal or snack is eaten.**

- **Don't forget beverages, including water. Specify how many fluid ounces you drank.**

- **If you were not able to complete the food records, don't worry. Any information that you recorded will be helpful to us.**

- **If there is not enough space provided to record everything you eat please utilize the back of the food record sheet.**

FOOD RECORD- DAY 1

BE THOROUGH

Day & Date__________________

Time of the day	Description of Foods & Beverages	Serving Size	Additional Info

<u>**Workout information**</u>

How long was your training session today? Minutes

Intensity (low, moderate, high) ______________________

FOOD RECORD- DAY 2

BE THOROUGH

Day & Date__________________

Time of the day	Description of Foods & Beverages	Serving Size	Additional Info

Workout information

How long was your training session today? Minutes

Intensity (low, moderate, high) ______________________

FOOD RECORD- DAY 3

BE THOROUGH

Day & Date__________________

Time of the day	Description of Foods & Beverages	Serving Size	Additional Info

Workout information

How long was your training session today? Minutes

Intensity (low, moderate, high) ______________________

APPENDIX D

PARTICIPANT INFORMATION

Project Title: Professional Soccer Referee's Dietary Intake in Comparison to their Measured Basal Metabolic Rate and Match Day Energy Exertion

Investigators:

Erika Schiller, Graduate Student & Gena Wollenberg, PhD, RD, CSSD, LD Department of Nutritional Sciences, Oklahoma State University (OSU)

Purpose:

The purpose of the research study is to analyze the accuracy of the new Breezing® machine in comparison to commonly used equations and to see whether or not professional soccer referees are properly fueling their bodies to effectively perform physical and cognitive demands. This is an understudied population in research, especially in regards to nutrition and energy needs.

What to Expect:

We are asking you to participate because you are employed as part time or full time referee for the Professional Referee Organization (PRO). You must be 18 years of age or older. If you agree to participate in this research, you will be asked to allow access to your Breezing® test results, complete a 3-day dietary recall, and share information obtained from your Polar Fitness watch. The 3-day dietary recall and fitness watch readings will be collected mid-season.

You will be asked to provide information from your Polar watch and fill out the 3-day dietary recalls then return them to Dr. Gena Wollenberg.

Risks:

The risk from participating in this study is minimal.

Benefits:

The benefits of this study include maintaining body weight, improving physical and cognitive performance, and increasing overall health. With the metabolic testing results, analysis of energy expenditure, and calculated caloric intake, you can use the information to confidently make daily healthful choices.

Your Rights and Confidentiality:

Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time.

Confidentiality:

The records of this study will be kept private. Research records will be stored on a flash drive in a locked desk and office and only researchers and individuals responsible for research oversight will have access to the records. Data will be destroyed after the study has been completed or given to PRO with no identifiable markers.

Contacts:

If you have questions about the study, please contact:

- Gena Wollenberg at (405) 744-6954 or at gena.wollenberg@okstate.edu
- Erika Schiller at (913) 702-6920 or at erika.schiller@okstate.edu

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate:

You are voluntarily making a decision whether or not to participate in the research study. Returning your completed survey in the envelope provided indicates your willingness to participate in this research study.

Dear Participant,

Attached to this email, you will find a 3-day dietary recall form. There are instructions on the first page describing how to properly fill it out. If you are not sure how to effectively describe a meal, please attach a picture of it or contact me via email.

Please be sure to include a game day and mark on the food record which day that is. For the game day you choose, please also write at the top of the page how many calories you burned during the game on that specific day. Use the value that is recorded on your Polar fitness watch. I will be using that information in analysis of your caloric intake.

Once you have completed the forms, return them to Dr. Gena Wollenberg. Dr. Wollenberg and myself will be the only ones who view the dietary information you provide. If you have any questions or concerns, please feel free to contact Dr. Wollenberg or me. Thank you very much for your participation!

Sincerely,

Erika Schiller

VITA

Erika Rae Schiller

Candidate for the Degree of

Master of Science

Thesis: EXPLORING SOCCER REFEREES' DIETARY INTAKE, RESTING METABOLIC RATE, AND ENERGY EXPENDITURE

Major Field: Nutritional Sciences

Biographical:

Education:

Completed the requirements for the Master of Science in Nutritional Sciences at Oklahoma State University, Stillwater, Oklahoma in May, 2018.

Completed the requirements for the Bachelor of Science in Dietetics at Kansas State University, Manhattan, Kansas in 2016.

Experience:

Graduate Assistant, Oklahoma State University Athletic Department,
Department of Academics Services for Student Athletes, August 2016-Present
Internship, Washington State University, Department of Sports Nutrition,
August 2017
Sports Nutrition Intern, Kansas State University Athletics
May 2015 – September 2015
Healthy Living Intern, Treasure Valley YMCA, Boise, Idaho
Healthy Living Department, May 2014 - August 2014

Professional Memberships:

Academy of Nutrition and Dietetics, August 2015- Present