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Effects of High-Carbohydrate Versus Mixed-Macronutrient Meals on Soccer Physiology and Performance

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EFFECTS OF HIGH-CARBOHYDRATE VERSUS MIXED-MACRONUTRIENT MEALS ON SOCCER PHYSIOLOGY AND PERFORMANCE

by

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ABSTRACT

EFFECTS OF HIGH-CARBOHYDRATE VERSUS MIXED-MACRONUTRIENT MEALS ON SOCCER PHYSIOLOGY AND PERFORMANCE

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The purpose of the study was to measure the effects of an acute pre-competition high-carbohydrate (HCHO) meal versus a mixed-macronutrient (MM) meal on physiology, perceptual responses, and performance in 15 division I female collegiate soccer players. Being there are conjectural advantages to pre-exercise meals higher in fiber, fat, and protein, this study was conducted to evaluate the physiological and perceptual effects of pre-competition MM meals. This study used a randomized, investigator-blinded, crossover design involving two dietary interventions – HCHO and MM meals – that were consumed four hours prior to two separate intra-squad soccer scrimmages. Assessments included running metrics via global positioning system (GPS) tracking devices (total distance covered [TDC], high-speed running [HSR], sprint count, and explosive count), heart rate (HR) (average percent of max HR and time spent above 90% of max HR), ratings of perceived exertion (RPE), ratings of fatigue (ROF), gastrointestinal symptoms, and perceptions of satiety, hunger, and fullness. Descriptive statistics are presented as means and standard deviations (SDs) for normally distributed data and medians interquartile ranges (IQRs) for non-normal data. The GPS data were normally distributed, so paired samples t-tests were used to evaluate whether differences existed between the HCHO and MM conditions. Differences in HR, RPE, ROF, and gastrointestinal symptom data between conditions were evaluated with the Wilcoxon signed-rank test due to their non-normal distribution. Data from the hunger, satiety, and fullness scales demonstrated normality and were compared between the two

conditions using within-subjects repeated measures ANOVAs involving time (pre-meal, pre-scrimmage, half-time, and end-scrimmage), condition (HCHO vs. MM), and time x condition analysis. Period effects were examined by comparing variables between the two scrimmages regardless of treatment assignment. Significance was set at the $p < 0.05$ level. No statistically significant differences were found between the two meals with respect to GPS, HR, RPE, ROF, and gut symptom data. Significant main time effects were found for hunger, fullness, and satiety, though there were no significant condition main effects or time x condition interactions. With regard to period effects, TDC (8.0 vs. 7.5 km, $p = 0.006$), HSR (694 vs. 525 m, $p = 0.002$), and average percent of max HR (median: 89% vs. 88%, $p = 0.038$) were higher, while pre-scrimmage ROF was lower (median: 0 vs. 3, $p = 0.032$), for the second scrimmage than the first scrimmage, which suggests that players were slightly more fatigued going into the first scrimmage. The direction of the period differences in TDC and HSR were consistent regardless of which meal the participants were assigned pre-scrimmage. In total, these findings provide evidence that a meal with moderate amounts of protein, fat, and fiber consumed four hours prior to a 70-minute simulated soccer competition does not lead to more gastrointestinal symptoms and can be equally as ergogenic for performance and perceptual responses as a meal high in carbohydrate.

This thesis is dedicated to my wife.

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CHAPTER I

INTRODUCTION

Problem Description

Beginning in the first half of the 20th century, scientific investigations revealed the importance of dietary carbohydrate (CHO) for sustaining exercise capacity (Christensen & Hansen, 1939). By 1967, research revealed higher pre-exercise CHO accessibility to be a major factor in successful athletic performance by displaying increases in time to exhaustion when compared to lower CHO accessibility (Bergstrom et al., 1967). Because of these studies, and countless others showing similar effects, dietary CHO recommendations have been issued for various active populations. The U.S. Institute of Medicine recommends a daily amount of 130 g of CHO for sedentary adult men and women, with supplementary CHO necessary to match the needs of physical activity (Institute of Medicine, 2005). Meaning, the athlete's current training load dictates the CHO intake needed on a given day.

The most recent American College of Sports Medicine (ACSM) position stand on nutrition and athletic performance recommends that for very hard exercise, lasting an hour or more (e.g., soccer), 8-12 g/kg of body mass per day of CHO should be consumed (Thomas et al., 2016). Further, the timing, type, and amount of CHO ingestion in relation to training and competition should be manipulated in such a way to promote superior athletic performance and intestinal absorption, while reducing gastrointestinal disturbances and suiting the practical needs of the individual. The ACSM recommends consuming 1-4 g/kg of body mass of CHO 1-4 hours before athletic competition (Thomas et al., 2016). The ACSM also advises that food choices high in protein, fat, and fiber are to be avoided 1-4 hours before athletic events to reduce gastrointestinal side effects, which may in turn decrease athletic performance.

Much of the literature showing benefits of pre-exercise CHO ingestion has used control treatments that provide no energy (e.g., water, placebos) (Gleeson et al., 1986; Sherman et al., 1989; Sherman et al., 1991). Somewhat surprisingly, much less research has investigated the effects of iso-caloric pre-exercise meals with varying macronutrient contents. This indicates an absence of knowledge as to whether using mixed macronutrient (MM) meals – moderate amounts of CHO, with moderate levels of protein, fat, and fiber – impairs, improves, or has no effect on athletic performance.

From a conjectural point of view, fiber and protein have been shown to increase satiety, leaving individuals feeling satisfied longer as compared to a HCHO meal low in fiber and protein (Padden-Jones et al., 2008; Slavin & Green, 2007). Resultantly, an athlete theoretically may experience increased perceptions of hunger if foods high in fiber and protein are profoundly restricted 2-4 hours prior to competition. Restriction of protein frequently throughout an athletic season could lead to sub-optimal muscle protein growth, as every 4-5 hours an athlete should ingest 20-40 grams of protein (Phillips et al., 2016). A small number of studies in athletes have even demonstrated that endurance exercise capacity is increased when high-fiber foods are included in the pre-exercise meal (Kirwan et al., 1998; Thomas et al., 1991; Wu et al., 2006). In the long term, fiber restriction in the athlete may, in theory, lead to negative impacts on the cardiovascular and gastrointestinal systems (Anderson et al., 2009).

The ACSM guidelines recommending athletes restrict protein, fat, and fiber in pre-competition meals warrants additional investigation, as the quality of evidence that's currently available is low. Misinterpretations and lack of context on evidence from research have created a viewpoint on pre-competition nutrition that may not be mechanistically sound for long-term use in the athlete. Being there are some potential conjectural advantages to pre-exercise meals higher in fiber, fat, and protein, this research study was conducted to evaluate the physiological and perceptual effects of pre-competition MM meals.

Statement of Purpose

The purpose of the study was to measure the effects of acute pre-competition HCHO meals versus MM meals on physiology, perceptual responses, and performance in division I female collegiate soccer players.

Significance of Study

The significance of the study was to make available useful information as to whether female soccer players have enhanced physiological and perceptual responses to HCHO or MM meals, demonstrating a potential need for a change in current pre-competition feeding guidelines.

Research Hypothesis

1. In comparison to a HCHO meal, a MM meal (with moderate amounts of CHO, protein, fat, and fiber) eaten four hours before competition will result in minimal gastrointestinal distress while maintaining performance.
2. In comparison to a HCHO meal, a MM meal eaten four hours before competition will increase satiety and reduce hunger as compared to a HCHO meal.

Variables

Independent Variables

The independent variables in the present study were dietary interventions – MM or HCHO meal – given to each soccer player four hours preceding intra-squad soccer scrimmages.

Dependent Variables

The dependent variables were measured before, during, and after simulated soccer matches and included heart rate (HR), distance run (km), ratings of perceived exertion (RPE), ratings of fatigue (ROF), gastrointestinal symptoms, and ratings of hunger, fullness, and satiety.

Limitations

Subjects were not supervised during consumption of pre-game meals. It is acknowledged that subjects may not have eaten or finished the meal designated to them. Each subject was required to keep a dietary record of food and drink consumed before the pre-game meals. It is unknown if dietary records were documented correctly or honestly. Dietary intake over the days leading up to the soccer games was not controlled, though, to some degree, this problem was mitigated by the crossover nature of the experiment. Furthermore, physiological measurements including muscle biopsies and substrate oxidation were not possible given that this study was conducted in the field; thus, specific inferences about the effects of the diets on CHO metabolism are not be possible.

Delimitations

The study encompassed subjects 18 years or older playing on a division I women's soccer team. Subjects with an injury precluding participation in soccer practice were not involved in the present study.

Operational Definitions

- High Carbohydrate Meal (HCHO): A meal consisting mainly of carbohydrates with low concentrations of fiber, protein, and fat.
- Mixed-macronutrient meal (MM): A meal consisting of moderate amounts of carbohydrate, fiber, protein, and fat.
- Ratings of Perceived Exertion (RPE): a perceptual method of measuring exercise intensity in which the athlete rates their effort on a scale of 6-20. The scale begins with "no feeling of exertion" (6) and ends with "very, very hard" (20). The scaling of 6-20 gives the athlete a relatively easy way to estimate HR by multiplying each score by 10 (i.e. score of 14 is equivalent to a HR of 140 beats per min [bpm]).
- Gastrointestinal Symptoms: A relative measure of how an athlete is feeling within their gut (i.e. no discomfort, moderate discomfort, unbearable discomfort).

CHAPTER II

LITERATURE REVIEW

The Demands of Soccer

Team sports such as soccer require athletes to perform recurring efforts of high-intensity exercise interspersed with lower-intensity exercise. For instance, soccer players may sprint to beat a defender, gain possession, dribble, pass, then walk or jog back into position. Rarely will these sprints last longer than 3-4 seconds and are often followed by several seconds of recovery before athletes are required to perform yet another soccer move (Spencer et al., 2005). Over the course of a season, high volumes of training that include sprints may drain muscle glycogen and result in excess fatigue if proper recovery protocols are not followed. Power output coinciding with a reduction in work rate during training and competition hinders on-field performance (Williams & Rollo, 2015). A specific situation when this becomes increasingly important to performance is during the conference tournaments that follow the conclusion of the regular season; specifically, players compete every other day with minimal recovery time, which underscores the importance of consuming adequate dietary energy and carbohydrate.

Technology as a Means of Measuring the Demands of Women's Soccer

The status and prominence of women's soccer has increased in recent years, as most elite players are employed on a professional basis. In 2011, 29 million females were noted to participate in soccer activities, an increase of 34% from 2000 (Fahmy, 2011). Since 1993, over 2,000 scientific articles have been published on women's soccer (Datson et al., 2014). Compared to previous years, elite level players engage in higher training and competitions stresses, leading to elevated injury risk and increased physical and mental demand during competition. Recent technological advances allow scientific staff to support players in a way superior to even a decade past. The use of global positioning systems (GPS) to evaluate external loads and on-field player performance is becoming commonplace, especially in the male premiership league (Di Salvo et al., 2009). Despite advancements with this technology in elite male players, much less research has employed this technology in the study of elite female players (Vescovi, 2012).

In 1993, there had been no published research on the activity profile of female soccer players (Davis & Brewer, 1993). More recently, using larger sample sizes, GPS was used in female national team players to measure distance covered (Andersson et al., 2010; Gabbett & Mulvey, 2008; Krustrup et al., 2008). Players covered, on average, 10 km during match-play. Total distance covered (TDC) provides the athlete with an estimation of the physical demands of match-play, but high-speed running (HSR) is regarded as a superior metric to reflect the physiological demands of gameplay (Bradley et al., 2009; Di Salvo et al., 2009; Di Salvo et al., 2010). In a previous review by Davis and Brewer (1993), average sprinting distance was the only reference to high-speed activity. Since that time, studies have shown that female national team players cover an average distance of 1.53-1.68 km at speeds greater than 18 km/h (Andersson et al., 2010; Krustrup et al., 2008). In another analysis, elite female players performed 5.1 sprinting bouts and 31.2 high-intensity efforts per game (Gabbett et al., 2013). Events such as these are deemed important indicators of in-game performance, yet diminutive attention has been generated in the literature on female soccer players.

Changes in HSR between each 45-minute half have also been used to evaluate match fatigue. As expected, Mohr et al. (2003) found that players experience fatigue towards the end of games. Interestingly, TDC was shown to be almost identical for each 45-minute half, though severe decreases in HSR and sprinting occurred (Mohr et al., 2004), and in other research, decrements of up to 30 and 34% from the first to the final 15-minutes of each half have been found (Krustrup et al., 2005). The 5-minute period directly following the peak 5-minute period of HSR during a game is also commonly analyzed to indicate levels of fatigue (Mohr et al., 2008). Outcomes such as these show the inability of some players to maintain HSR for the full duration of a match. As tactile methods are key during a soccer match, some of the evidence listed above may not directly assess fatigue. Other assessments such as repeated sprints, counter movement jumps, Yo Yo Intermittent Endurance test level 2, and peak torque knee flexion and extension have been used to give players, coaches, and staff a clearer indication of post-match fatigue (Andersson et al., 2008; Krustrup et al., 2010).

In contrast to the external measures of load quantified through GPS systems, HR is used as an internal measure of the demands of match play (Helgerud et al., 2001). As exercise intensity increases, sympathetic drive and HR increase to meet the physiological requirements imposed on the cardiovascular system. These HR adjustments allow the body to dynamically adjust to the energetic requirements of a given activity. As result, HR data provide an indication of the physiological load experienced by an athlete. However, because other factors such as sleep, stress, and training status are known to impact HR, the utility of HR monitors as a means to track training and competition loads is limited (Lambert & Borresen, 2010). That said, evaluating HR during match play, especially in conjunction with other measures such as GPS and subjective perceptions, can be useful for tracking the demands of soccer.

Early on, much of the HR data in female soccer players was collected and analyzed after small-sided games, but more recently, a few studies have tracked HR during competitive match-play. The average HR noted for domestic female players has been estimated at 86-88% of HR_{peak}

with slightly lower values observed for international female players (82 ± 3% of HRpeak) (Andersson et al., 2010; Krustup et al., 2005). Although athletes' work rates may decline in the second half of matches, HR values are similar between both halves and any 15-minute period of match-play (Krustrup et. al, 2010), which re-enforces the notion that the entirety of match play is severely taxing on the aerobic system.

As technology advances, it is imperative to appropriately select and analyze data in a way that is useful for the player, coach, staff, and general body of knowledge. Given that GPS and HR trackers each have their advantages and disadvantages, a multi-pronged approach should be utilized when evaluating external and internal loads in players of any sport, not only soccer. Understanding the movements and the physical demands of the specific sport being studied is critical when looking to apply evidence-based findings into practical applications.

Roles of CHO in the Body

Dietary CHOs contain carbon, hydrogen, and oxygen in a 1 to 2 to 1 ratio, with the carbon atoms linking together in rings or chains. Importantly, CHOs are a main source of energy utilized by all cells in the human body (Patton & Thibodeau, 2016). CHO fuels the brain and central nervous system while systematically providing energy for mechanical work of varying durations and intensities. During a soccer game, CHO serves as the primary fuel source during repeated bouts of high-intense soccer moves, and the catabolism of blood glucose and muscle glycogen powers the biological work necessary for sustained efforts over the course of a 90-minute game (McCardle et al., 2015). Finally, there is evidence that CHO can enhance long duration and high-intensity intermittent exercise, while exhaustion of CHO stores results in reduced work rates and mental ability and increased perceptions of effort (Thomas et al., 2016).

Because of this, CHOs are thought to possess a number of special features that are important for optimizing sport performance and training adaptations. Notably, the size of CHO stores in the body can be manipulated on a day-to-day basis through exercise and dietary habits (Thomas et al., 2016).

Beyond serving as an energy substrate during exercise, CHO also plays an integral role in cell production and protein synthesis as structural constituents for DNA and RNA (Patton & Thibodeau, 2016). Additionally, CHOs are cell membrane components that act as identification tags in the immune system, provide extracellular matrix support, and play a role in composition of plant fibers the promote digestive health (Patton & Thibodeau, 2016). Tissue protein can be preserved by intaking the appropriate amounts of CHO, as depletion of glycogen stores causes the breakdown of protein for the purposes of synthesizing glucose from amino acids. This places strain on body protein levels, especially that of muscle protein (McCardle et al., 2015).

A continuous source of CHO is required for the nervous system to properly function under normal conditions. Glucose supplies fuel for metabolism of nerve tissue and represents the only source of energy for red blood cells (McCardle et al., 2015). Throughout rest and exercise, the breakdown of glycogen to glucose in the liver maintains blood glucose within a normal range (e.g., 70-100 mg/dL). When engaged in prolonged, intense exercise (especially without consuming exogenous CHO), hypoglycemia can develop as the liver's ability to release glucose into the blood fails to match the rate of glucose uptake by the skeletal muscle. A hypoglycemic athlete will show symptoms of dizziness, mental confusion, weakness, and hunger, which can ultimately impair performance (McCardle et al., 2015).

Female Representation in Sports Science and Carbohydrate Research

For many years, research has assumed that the male and female bodies work essentially the same way during exercise. Even though female participation in sport has increased by 600% at the college level since 1972, this cohort has continued to be underrepresented in exercise research (Kaestner & Xu, 2010). This itself has created a large gap in the literature on female performance and physiology. One review, including 1,382 exercise science studies, found that women made up 39% of total participants (Costello et al., 2014). Among top journals in the field, the average percentage of female participants per article was 35%, 35%, and 37% in the *British Journal of Sports Medicine*, *American Journal of Sports Medicine*, and *Medicine and Science in Sports and Exercise*, respectively. But, only 4-13% of the articles solely enrolled females, a negligible amount considering the number of female athletes competing currently. The largest gap seems to be in sports performance, or the ability to enhance performance and recovery. In a follow-up evaluation on sports performance and gender, only 3% of the participants were female (Brookshire, 2016).

The lack of female representation in exercise science extends to the literature on CHO and performance. Various interventions and control treatments have been employed when researching CHO and its effects on exercise performance, whether it be pre-, during-, or post-exercise. Largely, these studies have been male-dominated, rendering much of the evidence suggestive for women. For example, in a review of running studies published by Wilson (2016), eight of 11 eleven studies comparing CHO beverages to artificially sweetened placebos involved men only. Specific to soccer research, a 2014 systematic review of nutritional interventions for improving soccer skill performance found that none of the eight studies that examined the effects of CHO included women (Russell & Kingsley, 2014). While not specifically dealing with CHO, a recent review of studies supplementing caffeine to alter soccer performance revealed that only 33 out of 274 participants were female (Mielgo-Ayuso et al., 2019).

Training, exercise adaptations, and dietary intake recommendations for sport performance and recovery are primarily constructed on research with male participants, then extrapolated poorly to females. The ability to perform better should not be limited to one gender, age, or sport; rather, research should be guided towards specific goals within populations as there is no one size fits all principle for every athlete. As athletes become more diverse, recommendations for sport performance should be constructed on evidence-based research conducted in the population of interest.

Combating Poor Dietary Intake

Low energy availability, defined as energy intake minus exercise energy expenditure, is common among female athletes and can pose significant health risks (Mountjoy et al., 2018). When insufficient energy is consumed, the amount of energy used for cellular maintenance, thermoregulation, growth, and reproduction is reduced. Medical complications of low energy availability affect the gastrointestinal, central nervous, skeletal, cardiovascular, endocrine, reproductive, and renal systems (Becker et al., 1999; Mountjoy et al., 2018). Athletes at the greatest risk for undereating are those who exercise for prolonged periods, restrict intake, and limit types of food they eat (Cobb et al., 2003; Manore, 1999). Additional risk factors for female athletes include early start to sport-specific training and dieting, injury, and rapid increases in training load (Sundgot-Borgen, 2002).

To mitigate these declines in performance and health, female athletes need to adjust dietary intake to counteract energy burned during exercise. One study found that 31% of elite female athletes in thin-build sports have eating disorders, while another found that 25% of elite female endurance athletes had clinical eating disorders (Byrne & McLean, 2002; Sundgot-Borgen & Torstveit, 2004). With this relatively high prevalence of disordered eating, the opportunity to control and correctly feed female athletes before training and games appears essential. If a female athlete adheres to the ACSM recommendation of HCHO intake pre-exercise, it's theoretically possible that other key macronutrients such as fat, protein, and fiber may be under-consumed over time, putting the athlete at risk for low energy availability. When each meal is so vital to an athlete competing at a high level, it's important for future research to compare the effects of HCHO and MM meals on not only performance but overall health in the long-term.

Dietary Intake and Satiety

As reviewed previously, the effects of pre-exercise meals equivalent in energy content have been scantly investigated. Instead, most of the research on pre-exercise CHO intake and performance has used water or non-caloric placebos as comparators (Ormsbee, Bach, & Baur, 2014; Wilson, 2015). Feeding one subset of individuals energy-containing foods, while withholding from another, renders an expected outcome – subjects consuming dietary energy will feel satisfied and perform better on exercise tests.

From a theoretical perspective, there may be some advantages to consuming MM meals when it comes to hunger and satiety. Protein, when compared to an isocaloric meal of CHO or fat, is considered to be more satiating (Astrup, 2005; Westerterp-Plantenga et al., 1999; Yancy et al., 2004). This may signify that a modest increase in protein – at the cost of other macronutrients – would improve satiety obtained from a pre-exercise meal. Although transiently CHO is considered satiating, protein seems to provide more of a prolonged satiating effect after a single meal or over a 24-hour period (Blom et al., 2006; Lejeune et al., 2006). Ghrelin, a hormone that promotes food intake due to increased appetite, follows a recurrent pattern, increasing before meals and decreasing shortly after. The post-meal reduction in ghrelin is directly related to the quantity of macronutrients in a given meal – the greatest decreases are observed after protein and CHO ingestion (Wang et al., 2001).

A review of the literature supports the belief that increased dietary fiber intake decreases hunger and aids in satiety (Clark & Slavin, 2013). Foods rich in fiber usually have a high volume and low energy density and help to control energy intake. This bulking and textural properties of fiber help to reduce the energy density of the diet. The indicators for satiety in fiber are produced pre- and post-absorption. Viscous soluble fibers are particularly advantageous as they lengthen the intestinal phase of nutrient absorption and digestion. Meaning, there is an extended duration which the macronutrients interact with the pre- and post-absorptive mechanisms of satiation (Slavin & Green, 2007).

Fiber and Exercise

Foods that have a low glycemic index (GI) tend to be higher in fiber, take longer to digest and therefore affect blood glucose at a slower rate than foods with a higher GI (Thomas et al., 1991). These types of foods potentially become advantageous when consumed in the hours proceeding strenuous athletic performance by allowing a slower release of glucose into the blood (Thomas et al., 1994). A low GI food, such as pasta or legumes, which releases glucose slowly from the gut into the blood, conjecturally provides equivalent advantages as high GI index foods given during exercise (Burke et al., 1998). This would prove to be a valuable and strategic method of pre-exercise fueling for an athlete – such as a soccer player – who does not have the ability to consume significant amounts of CHO during a game (DeMarco et al., 1999). In comparison, foods with a high GI do not provide a slow releasing source of blood glucose to the working muscle (Burke et al., 1998; Thomas et al., 1991).

Some data suggest that including fiber and low-GI foods in pre-exercise meals may boost exercise performance. One such study used pre-exercise meals similar in CHO, fat, and protein content, with varying contents in dietary and soluble fiber before a cycle ergometer test (Kirwan et al., 1998). Significant exercise improvement of 16% was observed after a meal high in dietary and soluble fiber was consumed. Another study investigating the effects of ingesting a low- or high-GI meal 3 hours before endurance running found that a low-GI meal resulted in longer running times (8 min) to exhaustion (Wu & Williams, 2006). Thomas et al. (1991) looked at the differences between four pre-exercise meals – water, glucose, lentils, and potato – on strenuous cycling performance. Endurance times were significantly longer in the lentils pre-exercise meal (117 ± 11 min) when compared to the water (100 ± 11 min), glucose (108 ± 10 min), and potato (100 ± 11 min) pre-exercise meals (Thomas et al., 1991).

Pre-Exercise Diet and Gastrointestinal Disturbances

There is a high instance of gastrointestinal complaints among athletes involved in strenuous long-lasting exercise (Rehrer et al., 1992). These complaints occur, among other reasons, because of the redistribution of blood flow to skeletal muscle and skin during exercise (Qamar & Read, 1987). Symptoms such as stomach and intestinal cramps, nausea, vomiting, and diarrhea are common during exercise. Major risk factors for exercise-induced gastrointestinal tract symptoms are dehydration, female sex, younger age, high-intensity exercise, analgesic use, and vertical impact sports (Wright et al., 2009). Moderate-to-severe gastrointestinal distress can negatively impact performance, and therefore it's prudent for athletes to consider strategies that prevent or mitigate GI disturbances during competition.

Dietary choices are also frequently implicated in the etiology of gastrointestinal distress during exercise. In particular, the ACSM explicitly states that when it comes to pre-event fueling, "Choices high in fat/protein/fiber may need to be avoided to reduce risk of gastrointestinal issues during the event (Thomas et al., 2016)." The rationale for this recommendation is largely based on the fact that these nutrients slow gastric emptying, which is obviously not ideal during exercise, especially when an athlete plans to consume fluid and carbohydrate during the event. However, little-to-no direct evidence actually supports the recommendation to avoid fat, protein, and fiber in pre-exercise meals. While studies do show that fat, fiber, and protein can delay gastric emptying, the effects are most pronounced within 1-2 hours of eating (Frost et al., 2003). Thus, concerns over including these nutrients in pre-exercise meals are possibly overblown for athletes that eat 3-4 hours before competition. However, additional research is needed to confirm or refute these speculations.

Summary

After reviewing the research on the topics presently covered, there is negligible research on female soccer players, and even less that considers how nutritional interventions might play a role in internal and external physical capacities during match-play. Soccer is a physically demanding sport, requiring the athlete to perform repeated high-intensity bouts over the course of a 90-minute game. The markedly high training loads from practice and games drain muscle glycogen leading to fatigue and reduced facility in performance.

Much of the evidence states that female athletes often have poor dietary habits, notionally one of many reasons fatigue ensues. The ACSM states a HCHO meal is superior to a MM meal for performance and preventing digestive issues. Yet, this notion would seem to be inherently flawed for females, as a nutritionally dense meal is being lost merely for the sake of CHO loading. If a MM meal is consumed 3 to 4 hours prior to match-play, this provides ample duration in which food can be digested properly, allowing for overall dietary intake to be rich in a variety of key nutrients the female athlete requires.

While foods high in CHO are intrinsically more rewarding during acute ingestion, protein, fat, and fiber aid in prolonged satiety – a factor that may influence performance during competition. The idea of this project is not to say a pre-game meal high in CHO is intrinsically detrimental to female soccer performance. Rather, it strives to demonstrate that a more modest, nuanced approach to female pre-game dietary intake should be considered, as there are many factors specific to the female athlete that consider attention below the superficial level. A female soccer player may find a MM meal key to providing not only superior performance and satiety on the field, but also off the field as a strategic meal facilitating overall health and recovery during the season.

CHAPTER III

METHODOLOGY

Research Design

This study used a randomized, investigator-blinded, crossover design involving two dietary interventions – HCHO and MM meals – that were consumed four hours prior to two separate intra-squad soccer scrimmages. The soccer scrimmages involved two equally matched teams made up of players from a division I women's soccer team. Specifically, the coaching staff divided the players into two equally matched squads of ten players. Prior to the first scrimmage, participants who volunteered for the study were randomly assigned to one of the two meals. Both soccer matches occurred at roughly the same time of day (~3:30 p.m.). The following week, a second scrimmage took place and the participants received the opposite meal. Given the nature of the intervention (i.e., dietary), the players remained unblinded to the treatments but were not explicitly told about the study's hypotheses to minimize any expectation effects. The investigators collecting the data were blinded to treatment assignments until data collection was finished.

Subjects and Recruitment

The sample for this study was comprised of division I women's soccer players who were greater than 18 years of age. Players who had an injury precluding them from participation in soccer practice did not contribute to this study. A flyer was distributed to each player on the soccer team before a scheduled practice or at another time that was convenient for the team. An oral presentation about the study was used to recruit players for participation. Players expressing interest in the study went through an informed consent process approved by ODU's Institutional Review Board after first being permitted by the soccer coaching staff and the institution's athletic director. Once players were enrolled into the study, they were given a background questionnaire on demographics and food allergies, at which time height and weight were collected. All participants were familiarized with any subjective questionnaires used during the data collection process.

Twenty-one soccer players were consented. Two of the participants were goal keepers and were therefore dropped from the analyses. Four additional players were dropped from the analysis due to injuries not allowing them to participate in the scrimmages. Thus, a total of 15 participants remained for the main analyses (Table 1).

Table 1

Subject Characteristics

Age (yr)	Height (cm)	Weight (kg)
19.6 ± 1.3	165.9 ± 9.1	67.5 ± 12.9

Pre-Scrimmage Dietary Procedures

Throughout the spring season, this soccer team periodically uses 70-minute intra-squad scrimmages to mimic match play. Two of these scrimmages were utilized for this study. Prior to the first scrimmage, participants were randomly assigned to consume one of the two meals (HCHO or MM) four hours prior. Food allergies and intolerances were identified through a questionnaire and taken into consideration when the meals were designed for each subject.

For convenience and food safety purposes, the meals consisted of packaged foods that did not need to be cooked (e.g., sports bars, fruit, yogurt, etc.) or that only need to be microwaved. The nutrient composition of the meals is present in **Table 2**. Alternative foods were used for two athletes with food allergies to match macronutrient values and total.

Table 2

Nutrient Content of Meals

High-Carbohydrate Meal	Mixed-Macronutrient Meal
30 g Craisins (100 kcals, 25 g CHO, 2 g fiber, 0 g protein, 0 g fat)	60 g Craisins (200 kcals,50 g CHO, 4 g fiber, 0 g protein, 0 g fat)
12 oz of apple juice (210 kcals, 52 g CHO, 0 g fiber, 0 g protein, 0 g fat)	1 Muscle Milk (160 kcals, 7 g CHO, 4 g fiber, 25 g protein, 4.5 g fat)
1 Chocolate Chip Clif Bar (250 kcals, 45 g CHO, 4 g fiber, 9 g protein, 5 g fat)	1 pack Nutella (80 kcals, 9 g CHO, 1 g fiber, 1 g protein, 5 g fat)
2 Microwavable Kraft Mac and Cheese Cups (440 kcals, 81 g CHO, 0 g fiber, 12 g protein, 7 g fat)	2 oz roasted peanuts (320 kcals, 12 g CHO, 4.5 g fiber, 12 g protein, 28 g fat) 1 Whey Protein Clif Bar (250 kcals, 25 g CHO, 3 g fiber, 14 g protein, 11 g fat
1000 kcals, 203 g CHO, 6 g fiber, 21 g protein, 12 g fat	1010 kcals, 103 g CHO, 16.5 g fiber, 52 g protein, 48.5 g fat

Several strategies were employed to minimize the impact of other nutritional choices on the outcomes. Other than the supplied meals, the participants weren't allowed to eat any other energy-containing foods for three hours before the meal through the end of the scrimmage, and they recorded their food intake on the morning of the first scrimmage using paper records. These food records were returned to the participants before the second scrimmage so that the participants could match their food choices to the previous pre-scrimmage period (other than the supplied meals). The participants were given 16 ounces of water to consume at the meal to ensure they were adequately hydrated for the scrimmage. In addition, the food records were analyzed to examine whether there were any differences between the conditions in pre-meal nutritional intake.

1st Scrimmage Protocol

Participants competed in a 10 on 10 intra-squad scrimmage consisting of two, 35-minute halves that was held on April 4th. The halftime was five minutes. Participants were allowed to drink water as desired, but no energy-containing liquids or foods were permissible at that time. Given that these scrimmages were conducted during the team's official practices, the protocol for each scrimmage was at the discretion of the coaching staff.

2nd Scrimmage Protocol

After completion of the first scrimmage, the same procedures were implemented during a second scrimmage that was held on April 9th. The only difference was that the participants who initially received the HCHO meal received the MM meal, and vice versa for the participants who originally received the MM meal. The participants were also asked to eat the same foods that they consumed prior to the first pre-scrimmage meal.

Outcome Variables

The outcome variables collected at regular intervals before and during the two scrimmages includes the following:

- TDC (i.e., total meters covered), HSR (>14.5 km/h), sprint count (number of sprints >17.1 km/h, sustained for at least 3 seconds), and explosive count (number of accelerations >17.1 km/h, from a standstill) using Titan 1+ GPS trackers (Integrated

Bionics). (Note: the sample size for this outcome was limited to 12 because of equipment availability.)

- Mean HR during the scrimmages as well as time spent above 90% of max HR collected and calculated via Firstbeat monitors (Firstbeat Technologies, Finland).
- RPE on Borg's 6-20 scale (Borg, 1982) at the end of each 35-minute half.
- ROF on a 0-10 scale (Micklewright et al., 2017), collected pre-scrimmage and at the end of each 35-minute half.
- Gastrointestinal symptoms (nausea, fullness, reflux, abdominal cramps, flatulence, and urges to have a bowel movement) a 0-10 scale (0 = no discomfort, 5 = moderate discomfort, 10 = unbearable discomfort) collected before the meal, within 10 minutes of the scrimmage start, and at the end of each 35-minute half. For the analyses, gastrointestinal ratings were summed into upper (nausea, fullness, reflux) and lower (cramps, flatulence, urges to have a bowel movement) categories, with possible scores ranging from 0-30 at each time point.
- Ratings of hunger, fullness, and satiety on validated visual analog scales (Flint et al., 2000) collected before the meal, within 10 minutes of the scrimmage start, and at the end of scrimmage.

Statistical Analysis

Normality of the data was evaluated via the Shapiro-Wilk test and visual inspection of histograms. Descriptive statistics are presented as means and standard deviations (SDs) for normally distributed data and medians interquartile ranges (IQRs) for non-normal data. The GPS data were normally distributed, so paired samples t-tests were used to compare TDC, HSR, sprint count, and explosive count between HCHO and MM meals. Differences in HR data between HCHO and MM conditions were evaluated with the Wilcoxon signed-rank test, as were differences in pre-meal nutrition intake, RPE, ROF, and gastrointestinal ratings. Data from the hunger, satiety, and fullness scales demonstrated normal distributions and were compared using within-subjects repeated measures ANOVAs with Bonferroni post-tests. Sphericity was evaluated with the Mauchly test, and Greenhouse-Geisser statistics were provided if sphericity was violated. To test for period effects (i.e., differences in variables between scrimmages irrespective of treatment assignment), paired samples t-tests and Wilcoxon signed-rank tests were used to evaluate whether data between scrimmage one and scrimmage two were significantly different. The analyses were carried out using SPSS software (version 24), and the significance level was set at $p<0.05$ *a priori*.

CHAPTER IV

RESULTS

Environmental Conditions

At the time of scrimmage one (3:30 PM) on April 4th, Norfolk, Virginia, had a temperature of 60 degrees Fahrenheit, with 51% humidity. Scrimmage two, taking place at the same time and place on April 9th, had a temperature 64 degrees Fahrenheit and 90% humidity.

Nutrition Intake

Nutritional intake was recorded prior to the HCHO and MM meals on the days of the scrimmages, and the median dietary energy consumed before the experimental meals was 267 and 200 kcals for HCHO and MM, respectively. Median values for fat (HCHO, 6 g; MM, 5 g), CHO (HCHO, 31 g; MM, 31 g), protein (HCHO, 11 g; MM, 11 g), and fiber (HCHO, 3 g; MM, 3 g) showed consistency across each condition. When using Wilcoxon signed-rank tests, there were no significant differences between conditions for kcals ($p = 0.593$), fat ($p = 1.000$), CHO ($p = 0.109$), protein ($p = 0.655$), and fiber ($p=0.593$).

GPS

Table 3 presents TDC, HSR, sprint count, and explosive count over the 70-minute intra-squad scrimmage format. The data were normally distributed, so a paired sample t-test was used for the analysis. For average TDC, HSR, sprint count, and explosive count, no significant differences were seen between the two conditions (all $p > 0.05$).

Table 3

External Load Scrimmage Results

	High Carbohydrate	Mixed Macronutrient	t-statistic	p-value
TDC (km)	7.78 ± 0.58	7.67 ± 0.46	0.463	0.652
HSR (m)	636 ± 253	583 ± 169	0.829	0.425
Sprint count	24.7 ± 12.4	21.4 ± 11.9	1.128	0.283
Explosive count	19.9 ± 9.1	18.2 ± 10.5	1.145	0.276

Note. Values are shown as mean ± SD. The same size for the GPS data is 12 due to the availability of monitors. HSR, high-speed running; km, kilometers; m, meters; TDC, total distance covered.

Heart Rate

Presented in Table 4 are median and IQR values for HR, percent of max HR, and time spent above 90% of max HR during the scrimmages. A Wilcoxon-signed rank test was used to analyze for significant differences between the conditions since the data were non-normal. No significant differences were seen when comparing the two conditions (all $p > 0.05$).

Table 4

Internal Load Scrimmage Results

	High Carbohydrate	Mixed Macronutrient	z-statistic	p-value
Average HR (bpm)	180 (171-186)	182 (173-189)	-1.036	0.300
Average % of max HR	87% (85-90%)	90% (84-91%)	-1.068	0.285
> 90% max HR (min)	28 (14-47)	41 (9-55)	-0.284	0.776

Note. Values are shown as median (IQR). HR, heart rate.

RPE and ROF

Table 5 shows the median and IQR values for RPE and ROF at different time points. Normality was not observed in the data, so Wilcoxon-signed rank tests were used to analyze for any significant differences between the conditions. No significant differences in RPE or ROF were found (all $p > 0.05$).

Table 5

Pre-scrimmage, Halftime, and End-scrimmage RPE/ROF Results

	High Carbohydrate	Mixed Macronutrient	z-statistic	p-value
Pre-Scrimmage ROF (0-10)	3 (0-3)	2 (0-3)	-1.149	0.250
Halftime ROF (0-10)	5 (4-6)	5 (4-7)	-0.000	1.000
End-Scrimmage ROF (0-10)	6 (5-8)	7 (6-7)	-0.224	0.823
Halftime RPE (6-20)	14 (13-15)	14 (13-15)	-0.052	0.959
End Scrimmage RPE (6-20)	15 (14-16)	15 (14-16)	-0.209	0.834

Note. Values are shown as median (IQR). ROF, rating of fatigue; RPE, rating of perceived exertion.

Hunger, Satiety, and Fullness

Table 6 presents F-statistics and p-values (Greenhouse-Geisser because of non-sphericity) for time, condition, and time x condition for ratings on the hunger, satiety, and fullness scales. There were no statistically significant condition or time x condition effects, though there were significant main time effects for all three variables.

Table 6

Results (p-values) from Repeated Measures ANOVAs for Hunger, Satiety, and Fullness

	Time	Condition	Time x Condition
Hunger	7.73 (0.003)	0.04 (0.843)	1.45 (0.249)
Satiety	3.54 (0.036)	0.43 (0.522)	1.02 (0.369)
Fullness	7.97 (0.002)	2.97 (0.107)	0.92 (0.412)

F-statistics with p-values shown in parentheses.

The hunger, satiety, and fullness data are shown visually in Figure 1, Figure 2, and Figure 3, respectively. For hunger, ratings were significantly lower pre-scrimmage relative to pre-meal ($p = 0.001$). In addition, hunger was rated lower pre-scrimmage relative to end-scrimmage ($p = 0.03$) and at half-time relative to end-scrimmage ($p = 0.001$). When examining the pairwise comparisons for satiety, ratings were not significantly different when comparing individual time points (all $p > 0.05$). For fullness, ratings were significantly lower pre-meal relative to pre-scrimmage ($p = 0.033$). Also, fullness was rated higher pre-scrimmage relative to halftime ($p = 0.002$) and end-scrimmage ($p = 0.002$).

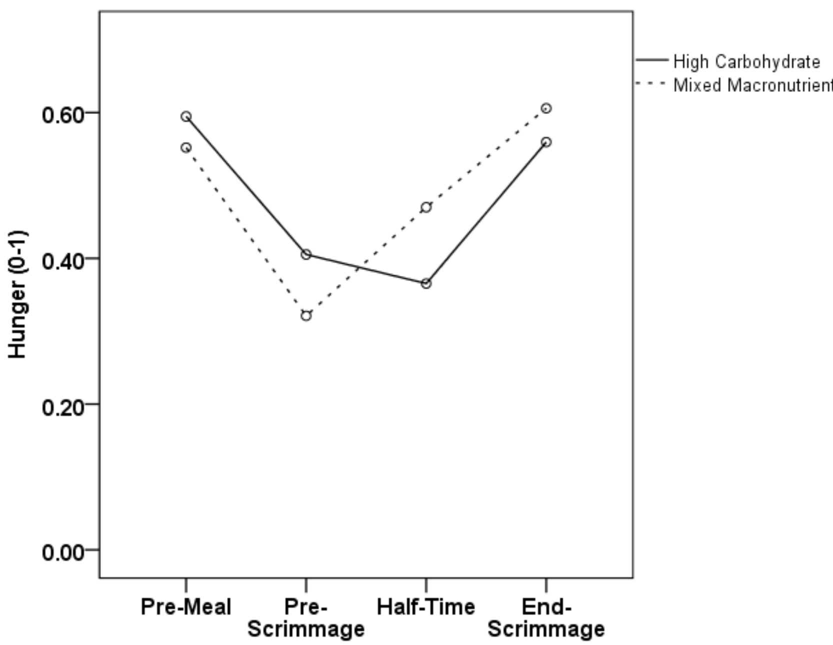

Figure 1. Hunger

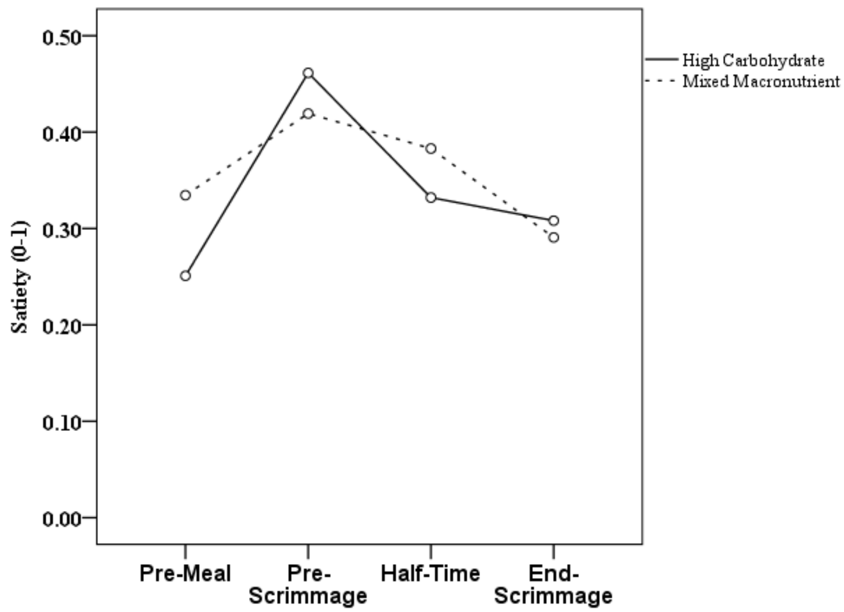

Figure 2. Satiety

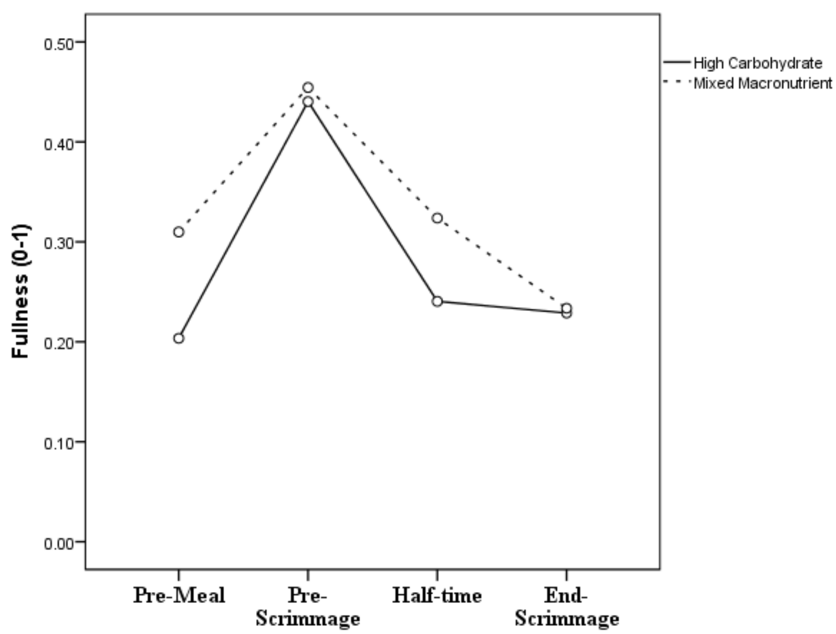

Figure 3. Fullness

Gut Symptoms

Medians and IQRs for upper and lower gut symptoms are displayed in Table 7, along with p-values from each Wilcoxon signed-rank test. No significant differences were observed between the MM and HCHO conditions at any time point.

Table 7

Median and Interquartile Range for Lower and Upper GI Symptoms

	High Carbohydrate	Mixed Macronutrient	z-statistic	p-value
Pre-Meal Upper (0-30)†	5.0 (2.8-6.3)	5.5 (3.3-7.3)	-0.446	0.656
Pre-Meal Lower (0-30)†	2.0 (0.0-4.3)	0.0 (0.0-5.5)	-0.360	0.719
Pre-Scrimmage Upper (0-30)	3.0 (0.0-4.0)	2.0 (1.0-3.0)	-0.874	0.382
Pre-Scrimmage Lower (0-30)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	-0.135	0.893
Halftime Upper (0-30)	3.0 (1.0-3.0)	1.0 (0.0-2.0)	-1.658	0.097
Halftime Lower (0-30)	0.0 (0.0-0.0)	2.0 (0.0-4.0)	-1.719	0.086
End-Scrimmage Upper (0-30)	1.0 (0.0-2.0)	0.0 (0.0-1.0)	-1.853	0.064
End-Scrimmage Lower (0-30)	0.0 (0.0-3.0)	1.0 (0.0-3.0)	-0.762	0.446

Note. Values are shown as median (IQR). †The same size for this time point is 14, as one participant failed to fill out the questionnaire.

Period Effects

Based on paired samples t-tests, TDC during the second scrimmage was greater than the first scrimmage (8.0 vs. 7.5 km, p = 0.006), and participants also did more HSR (694 vs. 525 m, p = 0.002). However, there were no significant period effects for sprint or explosive counts. For HR, participants had a higher average percent of max HR during the second scrimmage than during the first scrimmage (median: 89% vs. 88%, p = 0.038), although there was no significant difference between the scrimmages for time spent above 90% of max HR. The lower TDC and HRs during the first scrimmage may have been due, in part, to the fact that ROF values were higher prior to scrimmage one than scrimmage two (median: 3 vs. 0, p = 0.032), suggesting that participants may have been more fatigued coming into scrimmage one. No significant period effects were observed for ROF at half-time or at end-scrimmage, nor were there any observed period effects for hunger, fullness, satiety, gastrointestinal symptoms, or RPE at any time point.

Although there were significant period effects for GPS data (TDC and HSR), average percent of max HR, and pre-scrimmage ROF, the direction of the effects tended to be consistent regardless of which condition the participants were assigned to first. For example, TDC increased from 7.5 to 8.0 km from scrimmage one to scrimmage two among participants that received HCHO first, while there was an almost identical increase (from 7.4 to 8.0) among participants that received MM first. Likewise, HSR increased from 460 to 598 m from scrimmage one to scrimmage two among those receiving HCHO first, while it increased from 570 to 761 m among participants that received MM first.

CHAPTER V

DISCUSSION

The purpose of this study was to measure the effects of pre-competition HCHO meals versus MM meals on physiology, perceptual responses, and performance in division I female collegiate soccer players. It is common practice to consume a HCHO pre-match meal when playing soccer, and this is believed to be a superior nutritional strategy to enhance match performance because of low gastrointestinal side-effects and the added supply of carbohydrate for high-intensity exercise (Thomas et al., 2016). For this study, on-field performance was measured through GPS tracking and related physiological (HR) and perceptual (RPE, ROF, gastrointestinal symptoms) responses. There were two main hypotheses associated with this study. First, in comparison to a HCHO meal, a MM meal (with moderate amounts of CHO, protein, fat, and fiber) eaten four hours before competition would result in minimal gastrointestinal distress while maintaining performance. Second, in comparison to a HCHO meal, a MM meal eaten four hours before competition would increase satiety and reduce hunger as compared to a HCHO meal. The following sections address each of the dependent variables and whether or not the hypotheses of the study were supported.

GPS

Over recent years, GPS has become a common method of tracking on-field performance in soccer and other outdoor sports (Vescovi, 2012). Still, with minimal research on women's soccer performance, there is scarce data to compare this study's results with, as most of the available evidence comes from studies of males (Brookshire & Otwell, 2015; Russell & Kingsley, 2014). A few different studies published between 2008 and 2010 found that international female soccer players covered an average of 10 km over 90-minute games (Andersson et al., 2010; Gabbett & Mulvey, 2008; Krustrup et al., 2008), equating to 1.1 km every 10 minutes. The players in this study covered roughly 7.7 km in 70 minutes, which also equates to 1.1 km every 10 minutes.

Regarding the effects of the meals on GPS data, there were no significant differences in TDC, HSR, or sprint and explosive counts. For TDC, on average players covered roughly the same amount for each meal (HCHO, 7.78 ± 0.58 m; MM, 7.67 ± 0.46 m). When observing the HSR results, minimal differences were seen between the HCHO (636 ± 253 m) and MM (583 ± 169 m) meals. For sprint and explosive counts, the differences were not statistically significant in this study (Table 3). These results generally support the hypothesis that a meal with moderate amounts of CHO, protein, fat, and fiber eaten four hours before competition will maintain performance. However, it must be acknowledged that a sample size of 12 may not be sufficient for detecting small differences, despite one advantage being each participant served as their own control.

Because soccer is a sport of varying degrees of intensity, lasting for at least 90 minutes, replacing some CHO-rich foods with those higher in fiber and fat may slow gastric emptying and result in a less pronounced rise in blood glucose and insulin levels over the course of a game. As the scrimmage was only 70 minutes in duration, this time period may not have been sufficient to deplete glycogen stores, a possible reasoning for why there were no significant differences in TDC/HSR in this study. In contrast, eating CHO high on the glycemic index will cause a spike in blood glucose, not allowing for a sustained energy source throughout a match causing players to require extra fueling to perform their best. However, another important property of a MM meal is that fat, per gram, delivers double the energy of carbohydrate.

Heart Rate

Evaluation of HR provides an internal measure of stress and strain on the body that can be quantified and measured during and post-competition (Helgerud et al., 2001). When combined with other metrics such as GPS and wellness questionnaires, HR tracking holds a valuable place in a coach's tool belt. When comparing our data to the few studies that have followed HR during competitive match-play, the average heart rate from the present study falls within the estimated range of 86-88% of domestic female players (Andersson et al., 2010; Krustup et al., 2005). In line with GPS results, the HR results from this study showed that exercise intensity was relatively analogous between each of the two meals. As the intensity of the exercise increased during the match, sympathetic drive and HR increased to meet the physiological requirements of the match without elevating the HR further beyond what was expected.

Hunger, Fullness, and Satiety

In comparison to the HCHO meal, the MM meal used in this study contained larger amounts of protein, fiber, and fat and was designed to increase perceptions of satiety and fullness while also reducing hunger. A modest increase in protein, when limiting other macronutrients, has been shown to enhance satiety in some situations (Blom et al., 2006; Lejeune et al., 2006). Mechanistically speaking, the hormone ghrelin, which induces hunger, is decreased after the ingestion of both protein and CHO (Wang et al., 2001), and by adding protein to the pre-scrimmage MM meal, it was hypothesized that greater satiety and less hunger would be observed. This was not the case, as the HCHO diet – lower in protein – seemed to function as well as the MM diet.

Increased dietary fiber intake has also been linked to decreased hunger and increased satiety (Clark & Slavin, 2013). When a food is higher in fiber, especially viscous fiber, it will form a gel-like substance in the stomach that delays gastric emptying. In addition, because of fiber's low energy density, it provides greater bulk for a set amount of energy (Slavin & Green, 2007). Even though this study doubled the amount fiber in MM, no differences in hunger, fullness, or satiety from the questionnaires were observed.

The discussion around dietary fat and satiety is still greatly debated. It has been suggested that certain foods with higher amounts of protein, fiber, and a higher ratio of CHO to fat help to control hunger (Chambers et al., 2015). Since fat is high in energy density, it is theorized that its effect on satiety will be low. Because of this, a grading of satiating effects from macronutrients was given in the order of protein, CHO, and fat (Blundell & Macdiarmid, 1997). In support of this, a study by Westerterp-Plantenga et al. (1999) found that women felt more satiated when their diet was adjusted to contain high protein and CHO as opposed to when their primary source of macronutrient was fat, despite being equal in caloric value. Likewise, some studies have found that pre-meal feedings higher in fat are less satiating than HCHO versions when energy is matched (Cotton et al., 1994; Holt, 1999; Robinson et al., 2005), but at least one study by Rolls et al. (1999), found the opposite to be true. In experiments where people are given free access to eat as they desire, individuals tend to consume a higher amount of energy when foods are higher in fat than when they are higher in CHO (Blundell et al., 1994). For an athlete, choosing some foods naturally that are higher in energy density, such as fats, may lead to increased energy availability but may be a little less satiating.

Despite some theoretical advantages for regulating hunger and satiety, this study did not find lower hunger or enhanced satiety with a MM meal. The extent to which an individual may feel satisfied is very much dependent upon a meal's appearance and sensory profile (Chambers et al., 2015). Post-meal satisfaction in greatly reliant on a balance between the expectation and actual satiety of the food (Chambers et al., 2015). With that said, satiety and fullness can be maximized by finding the ideal combination of macronutrients together with a belief that these foods will bring upon satiety. There may have been no enhancement in satiety or decreased hunger because of low food appraisal coupled with a low drive to consume the meals assigned by each player. Also, all pre-meal foods were non-perishable, a pre-game meal that many of the athletes were not accustomed to. Another factor such as the timing of the meal could have affected the sensations of satiety and fullness for many athletes. Four hours prior to a scrimmage may be inadequate for some athletes as they may consume another snack close to match time, tend to graze throughout the time leading during the match, or sip on a CHO beverage or snack at halftime. Changing an athlete's dietary routine may have given the sensation of hunger rather than fullness.

With no significant differences in satiety, hunger, and fullness—in conjunction with the fact the performance was similar between conditions—this study provides evidence that a coach should have the opportunity to utilize a wide array of food options for female soccer players in the pre-competition period.

Gut Symptoms

A high incidence of GI symptoms has been observed before, during, and after exercise, such as reflux, fullness, stomach cramps, nausea, and diarrhea (Rehrer et al., 1992; Wright et al., 2009). These symptoms, if severe enough, can decrease performance. Two of the major risk factors for GI symptoms during exercise include being female and participating in high-intensity exercise like soccer (Wright et al., 2009). Regarding nutritional intake, the ACSM states that fat, protein, and fiber should be kept to a minimum in pre-exercise meals to avoid these symptoms (Thomas et al., 2016). Yet, this recommendation is based on theoretical grounds instead of direct data, and assuming an athlete eats several hours before competition, there should be sufficient time for the digestion and absorption of macronutrients to occur, minimizing GI symptoms. Indeed, in the present study there were no significant differences seen in GI symptoms between the two meals despite the fact that the MM meal contained roughly 2.5 times the amount of fiber and protein and 4 times the amount of fat.

Ratings of Fatigue and Perceived Exertion

The ROF and RPE scales are subjective methods that are utilized to better understand how a player may feel at certain time points before, during, or after exercise. Most athletes will experience a wide range fatigue-like symptoms throughout the day, and using a general scale assessing fatigue helps to aid in quantifying variations in performance and to possibly pinpoint where fatigue originates from (Micklewright et al., 2017). Based on these questionnaires, there were no significant differences in ROF and RPE between the two meals in this study, though ratings did increase from pre-to-post match as expected.

Of note, ROF was higher before the first scrimmage than it was before the second scrimmage. The higher ratings of fatigue before the first scrimmage suggest that the players were, on average, in a more heightened state of fatigue, which may have contributed to them completing less TDC and HSR. Unfortunately, this is the reality of conducting research with a competitive soccer team in the midst of their season.

CHAPTER VI

CONCLUSION

The main purpose of the study was to ascertain whether a MM or HCHO meal was superior in performance and perceptual responses during 70-minute intra-squad scrimmages between division I female soccer players. Prior studies show that foods higher in macronutrients such as protein, fats, and fiber slow down gastric emptying, and this has served as the main basis underpinning recommendations to avoid these nutrients in pre-competition meals. However, if meals higher in fat, protein, and fiber are given ample time to be digested, it was believed that GI symptoms would be negated, and performance would be the same as what is observed with a pre-exercise HCHO meal.

Overall, the results of this study suggest a MM meal is equivalent to a HCHO for soccer performance when based on metrics such as TDC, HSR, sprint count, explosive count, and percentage of max HR. In addition, when given the proper time to digest a meal, a MM meal shows no difference in GI symptoms when compared to a HCHO meal. This study provides evidence that if given a proper amount of time before a soccer match, female soccer players can eat a MM and sustain a high level of performance and low GI distress without having to eat a HCHO meal.

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APPENDIX A

BACKGROUND QUESTIONNAIRE

Background Questionnaire

Demographic Information

ID:____________________ Age:__________

Race (check one)

___ White ___ Black or Africa American ___ American Indian or Alaska Native

___ Asian ___ Native Hawaiian or Other Pacific Islander ___ Other

Height: ________

Weight: ________

Please list below any food allergies or intolerances you have.

____

____

____

____

____

____

APPENDIX B

RECRUITMENT FLYER

Participate in a Research Study

ODU
IDEA FUSION
Human Performance Lab

The study will involve:

- Examining how two pre-scrimmage meals affect performance and perceptual responses in soccer players

To be eligible, you should:

- Be aged 18+ years
- Currently playing for the [redacted] soccer team
- No injury precluding participation in soccer practice

Contact person: Jaison Wynne jwynne@odu.edu

APPENDIX C

INFORMED CONSENT DOCUMENT

OLD DOMINION UNIVERSITY

INFORMED CONSENT DOCUMENT
OLD DOMINION UNIVERSITY

PROJECT TITLE: Effects of high-carbohydrate versus mixed-macronutrient meals on soccer physiology and performance

INTRODUCTION
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This form describes what would be asked of you if you participate, as well as the procedures, risks, and benefits involved with participating.

RESEARCHERS
Patrick Wilson, PhD, RD, Responsible Project Investigator, Assistant Professor in the Department of Human Movement Sciences, which is a part of the Darden College of Education and Professional Studies at Old Dominion University.

Jaison Wynne, master's student in the Exercise Science program at Old Dominion University, under the supervision of Dr. Patrick Wilson.

Alex Ehlert, doctoral student in the Applied Kinesiology program at Old Dominion University, under the supervision of Dr. Patrick Wilson.

DESCRIPTION OF RESEARCH STUDY
You have been asked to participate in a study examining how two different pre-scrimmage meals affect performance and perceptual responses in Division I collegiate female soccer players. The study will compare the effects of consuming high-carbohydrate and mixed-macronutrient meals before 70-minute soccer scrimmages. Below is a description of the procedures involved in the study.

For the experiment, you will be randomly assigned (like a coin toss) to consume one of two meals before one of your regularly scheduled practice scrimmages. Specifically, you will eat the meal 4 hours prior to the scrimmage. The meal you eat will either be a high-carbohydrate meal, or a meal that contains relatively equal amounts of carbohydrate, fat, and protein. The investigators will consider any food allergies and intolerances you have when designing the meal. For convenience and food safety purposes, the meal will consist of packaged foods that don't need to be cooked (e.g., sports bars, fruit, yogurt, etc.) or that only need to be microwaved. The meal will contain between 800-1,200 kilocalories. You will also be given 16 ounces of water to consume at the meal to ensure you are adequately hydrated for the scrimmage. You won't be allowed to eat any other calorie-containing foods for 3 hours before the meal through the end of your scrimmage. You will be allowed to consume as much water as you want during the scrimmage but will not be allowed to consume carbohydrate-containing foods or fluids. You will also record your food intake for the day using a paper record.

Data to be collected before and during the scrimmage will include the following:

- Distance run using a global positioning system (GPS) tracker that's worn as a vest
- Heart rate collected via a strap around the abdomen
- Ratings of perceived exertion on a 6-20 scale
- Ratings of fatigue on a 0-10 scale
- Gastrointestinal perceptions (nausea, fullness, reflux, abdominal cramps, flatulence, and urges to have a bowel movement) on a 0-10 scale
- Ratings of hunger, fullness, and satiety

In addition, you will complete a running test after the scrimmage. Specifically, you will have 15 seconds to complete an 80-yard run, followed by a 15-second rest. This will be repeated until you are unable to finish an 80-yard run in 15 seconds or less.

After the first scrimmage, the same exact procedures will be implemented during a second scrimmage at one of your regularly scheduled practices over the subsequent month. The only difference is that if you received the high-carbohydrate meal before the first scrimmage, you will then receive the mixed-meal before the second scrimmage, and vice versa if you originally received the mixed-meal. On the day of the second scrimmage, you will be asked to eat the same foods you consumed before the first pre-scrimmage meal.

If you say YES, then your participation will require about a 1-hour time commitment above and beyond what you would normally do at your soccer practices. Upwards of 22 subjects will be participating in the study.

EXCLUSIONARY CRITERIA
The following are required to be eligible for participation:

- Current [redacted] soccer player
- 18+ years of age

In addition, if any of the following apply you may not be allowed to participate:

- An injury precluding participation in soccer practice

RISKS AND BENEFITS
As with any form of physical exercise, there is a risk of physical injury, and although very unlikely, a chance you could experience a serious event such as sudden cardiac arrest or death. The annual incidence of sudden cardiac death during exercise is 1 per 200,000 to 250,000 healthy young people. Regardless, several steps will be taken to minimize risks associated with the study.

- A CPR trained investigator will be on site in case you experience a serious event.
- An automated external defibrillator (AED) will be available on site in case you experience a sudden cardiac arrest.

If you experience symptoms of chest pain or dizziness after leaving the soccer field, you should call 911 for assistance.

You will be asked to consume two different meals before each scrimmage. There is a chance that you will experience temporary stomach symptoms (fullness, bloating, gas, etc.) from eating these meals.

In addition, there is a small risk that your data may be seen by individuals other than the investigators. To protect against this risk, the investigators are collecting minimal sensitive information and will replace your name on files and forms with alphanumeric ID codes.

And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: There are no direct benefits of participating in this study. The results of this study have the potential to expand society's knowledge related to the effects of different nutrition strategies on performance and perceptual responses before and during a women's collegiate soccer match.

COSTS AND PAYMENTS
The researchers want your decision about participating to be absolutely voluntary. You will receive no payment for your time or to help defray incidental expenses associated with participation (e.g., parking, travel).

NEW INFORMATION
If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY
Precautions will be taken to ensure your data remain confidential. Once the data are collected, your name or other identifying information will be removed and replaced with an alphanumeric ID code. All data will be stored according to this alphanumeric ID code in locked cabinets and/or on password-protected computers and secure network servers. A master list linking your name and alphanumeric ID code will be stored in a locked cabinet and/or on a secure computer network. Your name and ID code will only be referenced together in this master list. This list will be destroyed once the data analysis is complete. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY
If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of an injury arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a

result of participation, you may contact Patrick Wilson, PhD, at 757-683-4783 at Old Dominion University, Dr. Tancy Vandecar-Burdin, the current IRB chair at 757-683-3802 at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Patrick Wilson, PhD, RD
Assistant Professor
Human Movement Sciences
Old Dominion University
Phone: 757-683-4783
Email: pbwilson@odu.edu

Jaison Wynne
Graduate Student
Human Movement Sciences
Old Dominion University
Phone: 757-683-6407
Email: jwynn005@odu.edu

Alex Ehlert
Graduate Student
Human Movement Sciences
Old Dominion University
Phone: 919-518-3473
Email: aehle003@odu.edu

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. Tancy Vandecar-Burdin, the current IRB chair, at 757-683-3802, or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Printed Name & Signature	**Date**

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

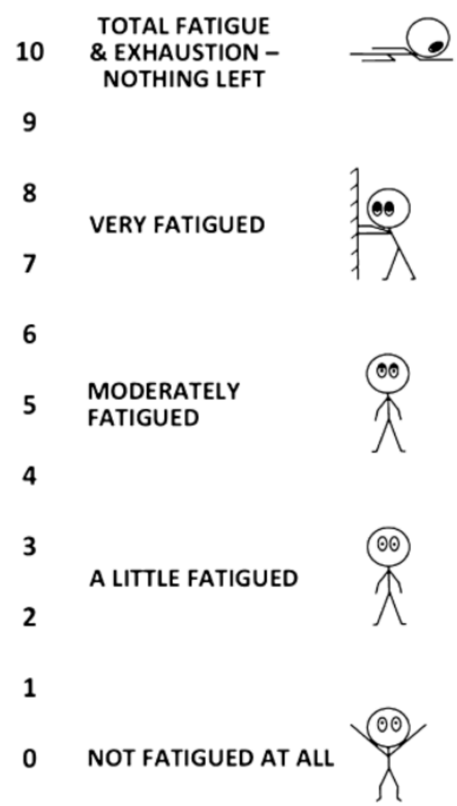
Investigator's Printed Name & Signature	**Date**

APPENDIX D

RATINGS OF FATIGUE SCALE

The rating-of-fatigue (ROF) scale will allow you to rate how fatigued you feel. It is important that you first read the following guidelines:

1. Please familiarize yourself with the scale by looking closely at the ROF scale now. You will notice that the ROF scale consists of 11 numerical points that range from 0 to 10. There are also five descriptors and five diagrams that are intended to help you understand the scale and make you rating.
2. When you are presented with the ROF scale, please carefully inspect the scale before giving a numerical response from 0 to 10. Always try to respond as honestly as possible giving a rating that best reflects how fatigued you feel at the time.
3. Try not to hesitate too much and make sure you only give ONE number as a response. For example, avoid responding by giving two numbers such as 'three or four'.
4. Now please read the following examples of what some of the ROF ratings mean: A response of 0 would indicate that you do not feel at all fatigued. An example of this might be soon after you wake up in the morning after having a good night's sleep. Now try to think of a similar occasion in your past where you have experienced the lowest feelings of fatigue and use this as you reference. A response of 10 would indicate that you feel totally fatigued and exhausted. An example of this might be not being able to stay awake, perhaps late at night but equally could include situations such as sprinting until you can no longer physically continue. Again try to think of a similar example that you've experienced in the past.



APPENDIX E

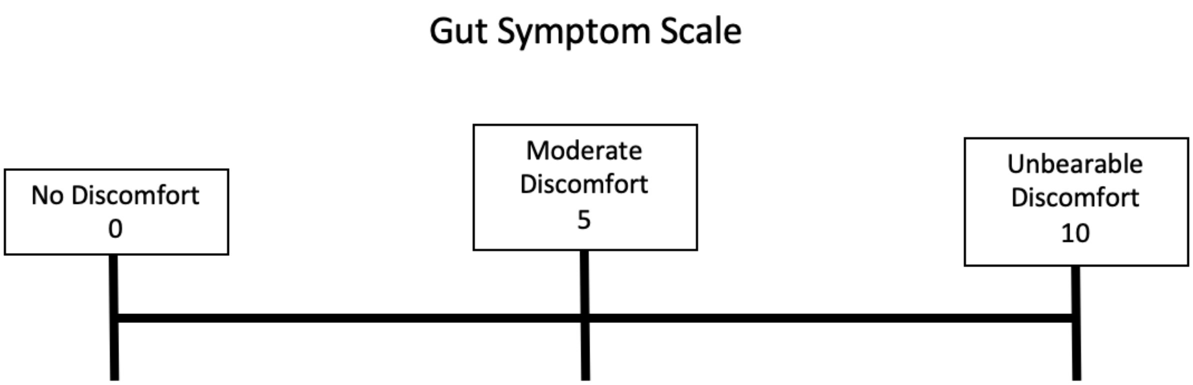
RATINGS OF PERCEIVED EXERTION SCALE

Table 5.2A The original Borg Scale Rating Perception of Effort (RPE)

Rating	Perception of effort
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

APPENDIX F

GUT SYMPTOM SCALE



APPENDIX G

HUNGER, FULLNES, AND SATIETY SCALE

Hunger, Fullness and Satiety Ratings

I am not hungry at all	How hungry do you feel?	I have never been more hungry
I am completely empty	How satisfied do you feel?	I cannot eat another bite
Not at all full	How full do you feel?	Totally full
Nothing at all	How much do you think you can eat?	A lot

APPENDIX H

DIETARY INSTRUCTIONS

Pre-Scrimmage Dietary Instructions

Morning of Scrimmage

- Record any food that was eaten before consuming your pre-scrimmage meal (i.e., breakfast, snacks, coffee that morning) using the food record provided to you.
- Don't eat any calorie-containing foods or beverages for at least 3 hours before your pre-scrimmage meal.

Pre-scrimmage Meal

- Eat all of the food provided, or as much as you can.
- If you cannot finish the entire meal, please record what was not finished and state why.

Post-Meal

- After finishing the pre-scrimmage meal, please refrain from consuming caffeine and any calorie-containing foods and beverages. Water is permitted.
- Please refrain from heavy physical activity.

APPENDIX I

FOOD RECORD

Food Record

Instructions:

- Complete the record as your day progresses. If you wait until the end of the day, your records are more likely to be inaccurate.

- Write down *everything* you eat and drink, no matter how big or small. Try to be as *descriptive* as you can by including brand names of foods and by using the wording that is on the packaging of the food.

- Try to accurately record the amount of food you are eating. If you are portioning food yourself, use measuring cups to help accurately identify how much you are eating.
  - Meat, poultry, fish, and cheese are best described by ounces (3 ounces is = to about a deck of cards)
  - Beverages can best be listed in fluid ounces
  - Vegetables, cut fruit and grains like rice, pasta, cereal, and oatmeal can be described in cups (1 cup is = to about the size of a woman's fist)

- Make sure to also record:
  - Plain water
  - All condiments (1 Tbsp. butter, 2 tsp. ketchup, 2 Tbsp. salad dressing, etc.)
  - Dietary supplements that contain energy
  - The time of day you eat

ID:_______________________________ Date:____________________

Food Record:

Example

Time	Food or Beverage	Amount
7:30 am	Whole wheat bread (Sara Lee)	2 slices (90 calories/slice)
	Peanut butter (Jiff)	2 Tbsp.
	Milk, skim	12 ounces
	Banana, large	1
10:15 am	Nature Valley granola bar	1 (100 calories per package)
	Powerade	16 oz (70 calories)

VITA

Jaison Wynne
180 Haven Drive · Norfolk VA, 23503 · (757) – 310 – 2109 · jwynne@odu.edu

Skills
Graduate Assistant in the Old Dominion University Human Performance Lab with 12 months experience managing all day to day research, testing, and scheduling. Possesses excellent communication and critical thinking skills when administering testing to clients and human subjects.

Core Competencies

- Exceptional critical thinking skills
- Excellent verbal and written communication
- Detailed and organized

Professional Experience
Human Performance Lab
Graduate Assistant – Lab Manager: May 2018 – present day

- Manage all day to day operations of the lab, including research, community and athletic testing, training load evaluation for Old Dominion University Women's Soccer, and lab scheduling.

US ARMY, Fort Benning, GA
Sergeant: January 2012 – January 2016

- Professional Bass Player
- 2 years' experience leading a small jazz ensemble.
- Key performances include playing for four Presidents and various political and military leaders.

Education
Old Dominion University, Norfolk, VA
Candidate for Master of Science in Exercise Science and Wellness

- GPA 3.94
- Expected Graduation Date: August 2019

Bachelor of Science in Exercise Science

- Graduation Date: August 2018
- GPA: 3.83
- Magna Cum Laude