The Effects of a 90-Minute Soccer Match on Aerobic and Anaerobic Capacity, and Repeated Sprint Ability

By

Frank V. Becerril

A Thesis Submitted to

Sonoma State University

In partial fulfillment of the requirements

For the degree of

MASTERS OF ARTS

In

Kinesiology

____

Dr. Bülent Sökmen, Chair

____

Dr. Steven Winter

____

Dr. Lauren Morimoto

____

Date

By Frank V. Becerril

Authorization for Reproduction of Master's Thesis

I grant permission for the print or digital reproduction of this thesis in its entirety, without further authorization from me, on the condition that the person or agency requesting reproduction absorb the cost and provide proper acknowledgement of authorship.

Date: __________________

Signature

Street Address

City, State, Zip

The Effects of a 90-Minute Soccer Match on Aerobic and Anaerobic Capacity and Repeated Sprint Ability
Thesis by

Frank V. Becerril

Abstract

INTRODUCTION: Soccer is the most popular sport in the world. Players have different skills for their positions; they must be able to maintain their physical performance at satisfactory levels to compete at elite levels. Although a large amount of data has been published regarding physical characteristics of soccer players, the literature sheds little light on the physiological demands and performance decrements that occur with participation in a soccer match. To address this gap, this study investigated how fatigue development affects the aerobic and anaerobic performance variables before and after a 90-minute soccer match.

METHODOLOGY: Fifteen experienced male collegiate and elite club-level soccer players were recruited from Sonoma State University, Santa Rosa Junior College, and Sonoma County Sol, (mean $\pm$ SD) age 23.0 $\pm$ 2.56 years, height 175.7 $\pm$ 4.75 (cm), weight 71.8 $\pm$ 6.51 (kg), BMI of 23.3 $\pm$ 1.82 (cm/kg). The study tested physiological stress before and after a 90-min soccer match, in aerobic capacity using a beep test, sprint performance using repeated sprint ability, and long anaerobic capacity using a 400-meter sprint test. Following performance testing, results were evaluated with repeated measures of ANOVA, and PRE and POST dependent variables were compared to see if there were any significant differences among trials.

RESULTS: The results indicated that there were significant differences between PRE and POST beep tests ($P<0.05$). RSA had significant differences between PRE and POST ($P<0.05$). There were significant differences between PRE and POST 400-meter sprint tests ($P<0.05$).

CONCLUSION: Results showed the reduction of aerobic and anaerobic performance after a full 90-minute soccer match. The test results assist coaches in evaluating the physiological status of soccer players in order to provide the most effective training methods, diet and tactics to enhance performance.

Acknowledgements

I would like to show gratitude to the following people for their assistance during the completion of my thesis project. My committee members Dr. Lauren Morimoto and Dr. Steven Winter, and my chair Dr. Bulent Sokmen. Thank you for all your hard work, assistance, and commitment to help me accomplish my thesis project.

Also, I want to thank my parents, Gaudencio G. Becerril and Sofia S. Villalva for being patient with me in pursuing my future career and academic accomplishments, and my sisters Thalia N. Becerril, Samantha V. Becerril, brother-in-law Jose A. Castro, and my wife Ingrid A. Becerril for all their love and support.

I want to thank Sonoma State Men's Soccer Head Coach Marcus Ziemer and Assistant Coach Ben Langwith for letting us use their practice goals. Also, Gina Voight for her assistance whenever there was an issue getting accepted into a class to complete my units. As well as Dr. Peter M. Stonebraker for his help and feedback.

To all my participants who donated their time and work to be subjects for my study. I want to thank my friends Thomas J. Young, Erick Delgado Solorio, Maria O. Sanchez, Raymond L. Bazurto, and Joe Masserant who kept encouraging me to never give up.

Table of Contents

List of Abbreviations

VO_2max:	Maximal Oxygen Uptake
MST:	Multi Shuttle Test
RSA:	Repeated Sprint Ability
ATP:	Adenosine Triphosphate
M.S:	Meters per Second
PCr:	Creatine Phosphate

List of Figures

List of Tables

Chapter I: Introduction

“Soccer is the most popular sport in the world, played by men and women, children and adults with different levels of expertise” (Strauss et al., 2012). Soccer features eleven versus eleven players competing against each other in a sport, involving both anaerobic and aerobic capacity. As Strauss et al. (2012) notes, “Soccer players must possess moderate to high aerobic and anaerobic power, have good agility, joint flexibility and muscular development, and be capable of generating high torques during fast movements.” A player’s physiological features determines their success in soccer due to the strength and speed required to gain an extra edge to be successful at the end of a match. It is important to comprehend the physiological status of soccer players in order to provide effective training methods and tactics to enhance peak performance. “Anthropometric and physiological differences exist among players who play in different positions, with more significant differences among goalkeepers and the forwards” (Strauss et al., 2012). Soccer players must have specific training depending on each player’s position on the field. This cultivates abilities and traits needed to improve overall performance. “On average, during a top-level soccer game, players engage in physical activities of high intensity every 60 seconds and perform a sprint run every 4 minutes” (Andrzejewski et al., 2015). The amount of a player’s sprinting depends on the player’s position on the field. Soccer players usually perform three to forty sprints according to Di Silva et al. (2008). “When a player participates in multiple positions during training session or soccer games, he improves different aspects of his game that are based on anthropometric or fitness characteristics" (Gioldasis et al., 2014). A central defender with a low VO_2max can increase it by interacting and playing as a forward during a game or practice match where high levels of sprinting and aerobic capacity are needed, especially wingers. Mohamed et al. (2014) reported that "According to the American College of Sports Medicine (1998), fitness training conducted systematically at least twice per week with high intensity can increase the power of the leg muscles." They came to the conclusion that plyometric training can enhance physical characteristics among soccer players. High intensity power training can increase performance where physical abilities among player positions are needed to be successful within soccer.

"Performance in soccer is a consequence of psychological/social factors, technical and tactical skills as well as physiological capabilities of an individual" (Bangsbo et al., 2008). Soccer training is beneficial to improve individual physiological skills in each position on the field. Players need to maximize muscle strength, power, and endurance to their highest level in order to perform with power and precision within top levels of the sport. "Optimal aerobic fitness is a prerequisite for elite soccer players and has benefits such as increased work intensity during a game; prevention of a second-half reduction in performance; doubling the number of sprints completed; and allowing players to cover a greater distance" (Strauss et al., 2012). Wide defenders and forward wingers need to adapt and enhance their aerobic capacity to contribute to success in winning possession of the ball, kicking, running, jumping, sprinting, and tackling, while maintaining aerobic capacity for a full 90-minutes match.

The main goal in this study was to assess the physiological demands for success in soccer by investigating how fatigue development affects the aerobic and anaerobic performance variables of college and club level soccer players before and after a full 90-minute soccer match.

Hypothesis

1. "The 20-m Beep Test or Multi Shuttle Test (MST) is an excellent performance indicator of aerobic fitness, which requires many changes of direction" (Chatterjee et al., 2009). Competing in a soccer game might significantly reduce aerobic performance, due to accumulated blood lactate at the end of match, depletion in muscle glycogen content, and central fatigue. "Physiological demands involved during this soccer-specific endurance test are similar to those taxed during a soccer-match" (Castagna, 2006).
2. We hypothesized that competing in a soccer game might significantly reduce repeated sprint ability, since depletion of PCr stores and muscle glycogen does not allow for a maximal effort in single and repeated sprints (Bangsbo, 2006).
3. Competing in a soccer match would significantly reduce 400-meter sprint performance due to accumulated blood lactate levels and depleted glycogen (Bangsbo et al., 2006).

Assumptions

We assumed subjects would employ full effort in all preliminary testing, pre-testing, and post-testing protocols. They would perform to the best of their abilities during the full 90-minute soccer match regardless of health and psychological state of mind.

Limitations

Limitations to the study would include variance of subjects' fasting and hydration conditions before the match, although we have asked them to replicate their meal plan and quantity of drinks from the first visit on the second day of data collection. We asked them to refrain for 24 hours from using drugs of any sort, as well as from heavy exercise.

The change in day-to-day weather conditions might influence the athletic performance, but our data was collected during summer time in Northern California, at the same time of the day and with temperature differences that were not obvious. Some players may have been unable to finish the test protocol due to injuries or health. We used only highly trained college and elite club level male subjects in order to eliminate confounding variables that might arise with different experience levels.

Definition of Terms

Anaerobic glycolysis: The alteration of glucose to lactate when limited amounts of oxygen are available. It is only used to produce energy during short, intense exercise, providing energy for a period ranging from 10 seconds to 2 minutes.

Aerobic glycolysis: Utilizes carbohydrates, fats, proteins with sufficient oxygen to re-synthesize ATP. Used for moderate to prolonged activity lasting more than 2 minutes.

VO2max: "VO2max is defined as the maximum amount of oxygen that the body consumes per minute during endurance exercise". Before a player can perform to their max abilities and skills they must improve their oxygen uptake.

Repeated Sprint Ability [RSA]: During RSA, energy is initially supplied by anaerobic metabolism (i.e., ATP-PC and glycolysis), which is gradually reduced during subsequent sprints as the participation of aerobic metabolism increases (Galy, 2015). High intensity exercise stresses the anaerobic energy system. Every short burst of high intensity exercise depletes the stores of creatine phosphate and utilizes anaerobic glycolysis in which lactic acid is produced.

400 m sprint test: This common event in track and field competition measures an athlete's ability to run quickly over a distance of 400 meters.

Chapter II: Review of Literature

Power, Change of Speed and Direction

“Power is the ability to produce as much force as possible in the shortest possible time” (Castagna et al., 2006). It is important to understand the ability to use muscle power during a soccer game because it can enhance one’s ability to play at the elite and professional level. “During a soccer match, lower body power is important for executing different activities such as stopping and changing running speed and direction (Wisloff et al., 1998). Soccer is a sport that requires muscle power to be able to accelerate or change direction at competitive levels. A player must be able to adapt to certain actions and perform different mechanical movements. “Furthermore, as soccer performance is characterized by several actions, such as sprinting, jumping, changes in direction, and tackling, muscular strength and power has also been shown to be important characteristics for soccer players” (Castagna et al., 2006). Soccer players need to adapt to high endurance training to improve aerobic and anaerobic fitness. “Complex training is the result of a combination of strength and plyometric exercises in the same session” (Cavaco et al., 2014). It is important for coaches to prepare specific training methods to physically enhance their players’ abilities by performing specific protocols involving speed, agility, strength and power. Coaches should recognize the benefits of explicit training to develop physical characteristics according to soccer position on the field. “More powerful players were able to sprint more times without loss of performance and they were faster in all sprint measures” (Lopez et al., 2014).

This study revealed how repeated sprint protocols can enhance lower limb power output where soccer players can perform more sprints during a match. “The power output of the lower limbs as the product of strength and velocity has been associated with soccer players´ sprint performance” (Lope-Segovia et al., 2011). In this latter study it was concluded that U-21 soccer athletes could create proper strength and power training to increase aerobic capacity. With proper training, a player such as a forward or fullback can increase their ability to enhance their capability of changing speed and direction. They adapt to high intensity demands to recover faster and sprint more times with power.

Sprint Ability

“Several match analysis studies in a variety of team sports have shown that improved sprint performance and ability to repeat efforts at high intensity are associated with playing at higher competitive levels” (Strauss et al., 2012). Speed is an important attribute that will enhance an attacker’s sprinting ability during a soccer game. “The ability to perform repeated sprints with minimal recovery between sprint bouts, termed repeated sprint ability [RSA], is an important capacity for team sports athletes” (Strauss et al., 2012). They will have a better chance of winning and taking possession of the ball by enhancing their sprint ability. “Speed ability among elite soccer players is very important and may be related to the capacity to avoid obstacles at high speed, which is an important quality in soccer games" (Strauss et al., 2012). Velocity is important to increase a forward's chance of scoring a goal or for a defender to take the ball from the opposing players. "It is well documented that high-intensity interval training improves the aerobic fitness of elite and sub-elite soccer players" (Macpherson et al., 2015). This study showed that sprint interval training can increase a player's high-intensity intermittent-running performance and VO_2max.

Muscular Endurance

"Soccer is an intermittent sport in which the aerobic energy system is highly taxed, with mean and peak heart rates of around 85 and 98% of maximal values, respectively" (Bangsbo et al., 2008). Soccer is a sport where high aerobic capacity is needed to perform successfully throughout a full 90-minute match. "Elite level soccer players run about 10 km during a 90-minute match, at an average intensity close to the anaerobic threshold (80-90 % of maximal heart rate)" (Strauss et al., 2012). The aerobic system is a huge contributor to energy being delivered to perform at the highest level within soccer where players in a team can find success at the end of the match. "Midfield players are constantly jogging and perform bursts of speed where they must attain a strong lower body to hold the ball when necessary and make quick decisions" (Wong et al., 2009). Running endurance and aerobic capacity are important factors that will make midfield players successful. "Soccer is intermittent movement activity which contains very short, usually 1 to 5 seconds continuing intervals of endurance with high to maximum intensity, which alternate with intervals of endurance with lower intensity or inaction conducing from 5 to 10 seconds" (Pivovarnicek et al., 2013). Coaches need to train their athletes to be able to perform high intensity demands within a match. "Age-related changes were reported in VO_2max among youth boys, with the value increasing with the age of the boys" (Strauss et al., 2012). In order to develop our youth, we must enhance their physiological traits so they can have a better chance of making it to the collegiate level or higher. "It is also important to consider the variation of VO_2max profiles for soccer players, with differences having been identified in terms of playing position as well as playing style" (Da Silva et al., 2008). In their study, Da Silva et al. concluded that the playing position with the highest VO_2max were the external defenders. Other studies done in European soccer indicated that midfielders require the highest VO_2 max values. "In order to advance in playing level, players must develop their aerobic capacity to tolerate the physiological load at higher levels of play" (Da Silva et al., 2008). Within soccer one is involved in a myriad of physiological processes which act in random sequences during a match. Helgerud et al. (2001) demonstrated that by improving VO_2max by 11%, players covered 20% more distance during a game, held the ball 23% longer and increased the number of sprints they performed in a game on average by 100%" (Hoff et al., 2002). While players are training they will increase VO_2max that will increase their performance rate to succeed in a soccer game. It is important for coaches to understand that each player position will need specific conditioning requirements in order for maximum achievement in soccer.

Player Position and Characteristics:

"The differences in performance are to some extent related to the position in the team or rather players are selected to a position in a team due to certain physical characteristics" (Bangsbo et al., 2008). Coaches should keep in mind that they need to place the proper player for each position on the field depending on their physical characteristics. "It has been found that forwards aged between 14-21 years old are considered as the leanest players with the highest percentage of muscle, defenders present very low quantity of fat and goalkeepers reveal high rates of height, weight, body fat and BMI" (Gil et al., 2007). Forwards usually tend to have the leanest body type where they can beat the defenders and sprint towards the goal. According to Wong et al. (2009), "the midfielders were significantly shorter and lighter than players of other playing positions." Midfield players cover the most distance throughout a match and by having a small body mass and height they will be successful in their player position. "However, another study concluded that defenders were the heaviest and tallest players, while forwards were the lightest and shortest" (Wong et al., 2011). "Taller players tend to have an advantage in playing positions such as goalkeeping, defense and attack" (Neto et al., 2007). "Additionally, defenders were taller than midfielders" (Bangsbo et al., 2000). Wong and colleagues suggest that it is important for coaches and trainers to understand that players need specific characteristics to be successful in accordance with playing position on the field. It takes time and dedication to enhance physical characteristics due to the training that is needed in correlation to performance. “The central defenders revealed low physical capacity, low intensity running and they covered shorter distances than players of other playing positions” (Da Silva et al., 2007). They also spent more time walking and jogging (Mohr et al., 2003). Central defenders need to be strong and ready to burst with strength and anticipation. “Fullbacks performed high physical capacity and VO_2max, while they covered a considerable distance at a high intensity running” (Mohr et al., 2003). Coaches need to value the importance of player characteristics according to position on the field. “During a game, professional soccer players perform about 50 turns, comprising sustained forceful contractions, to maintain balance and control of the ball against defensive pressure” (Castagna et al., 2006). Muscle strength can help the soccer player’s physical and technical performance.

Muscular Fatigue

“Fatigue is indicated by a decrease of muscle strength and power which occurs in the course of exercise” (Rahnama et al., 2003). Within a soccer match, a player will constantly perform physical movements such as jogging, walking, and sprinting that will cause muscle exhaustion and the built up of lactic acid. “It has been shown that high-intensity intermittent exercises simulating team sport activities can result in deterioration in central nervous system function” (Welsh et al., 2002). Fatigue level increases in the later stages of a full 90-minute soccer match where muscle glycogen and blood glucose are depleted affecting an athlete's endurance, muscle power, and motor skills. "Neuromuscular fatigue is evident after soccer-match simulations" (Rahnama et al., 2003). Soccer is a sport where muscle fatigue is inevitable due to the involvement of strenuous and prolonged physical activity. "Muscle exhaustion is apparent after bouts of high-intensity intermittent running" (Lattier et al., 2004). Some players will fatigue quicker depending on soccer position than others due to the necessary physical demands throughout a soccer match.

CHAPTER III: METHODOLOGY

Experimental Approach to the Problem:

This study was aimed at determining if soccer players on the field require diverse physiological demands, using collegiate and club men soccer players as subjects. The study also sought to establish the physiological characteristics a player must attain to successfully perform anaerobic and aerobic engagements within a soccer match.

Protocols

Day 1: Fifteen experienced male soccer players (n=15) were recruited for this study. Before the first day of testing, we introduced our presentation on the main goal and intention of the study. The subjects were given informed consent forms; they were notified to sign and turn in the forms to participate. Then, participants were familiarized with the 3 tests that include the beep test, repeated sprint ability test, and 400-meter sprint test.

Day 2: On the second day, the participants performed one trial of PRE and POST soccer match beep test to measure aerobic capacity of the soccer player and fatigue of soccer match on player. Subjects started running back and forth on a 20-meter (m) course and must touch the 20-m line. The initial speed was 8.5 km/h, and got progressively faster (0.5 km/h every minute), in accordance with a pace dictated by a sound signal on an audiotape. Several shuttle runs were made during each stage, and subjects were instructed to keep pace with the signal for as long as possible. When the subject wasn't able to follow the pace, the last stage announced was used to predict maximal oxygen uptake using the equation of Leger et al. (1988) which is Y = 31.025 + 3.238 X - 3.248A + 0.1536AX, where Y= VO_2max (ml/kg/min), X= Maximal shuttle run speed (km/h) and A= Age (yr). The tools used were as follows: four cones, tape measure, stop watch and portable speaker with audio tape.

Day 3: On the third day, subjects performed one trial of PRE and POST soccer match repeated sprint ability test, and the 400-meter sprint test. Participants began the testing with a repeated sprint ability test, followed by 15 minutes of passive recovery, and then subjects performed the 400-meter sprint test.

Each subject took about 3 minutes to complete the test. The test consisted of 6 repetitions of 25m shuttle sprints combined with 25 seconds of proactive recovery. During recovery subjects jogged slowly back to the starting line and waited for the next sprint. Time trials were recorded using photo-cell gates placed 1 m above the ground. Investigators used handheld stopwatches to record recovery time. The subjects started to sprint from 0.5 m behind the starting line after the starter signal. The stance was consistent during the start for each subject. Subjects were encouraged to put forth their maximal effort during each of the 25m shuttle sprints. Data was recorded as follows: (FT) fastest time, (AT) average time, and (TT) total time, (Ideal sprint time) number of sprint X fastest sprint time, and (% dec) percentage decrement score. Tools used: 4 cones, stop watches, whistle, track/field and photo-cell gates.

The aim of the next test was to complete one trial of 400 meters in the quickest possible time on the track. The subjects warmed up and stretched before the test. To start, all participants were line up behind the starting line. The clock started after the signal of ready was given, and they began running. The participants ran the 400-meter route as fast as possible without stopping. The stopwatch was stopped when the subject crossed the 400m finish line. There was an investigator who was responsible for each participant. Tools for this test include: whistle, cones, stop watch and track/field.

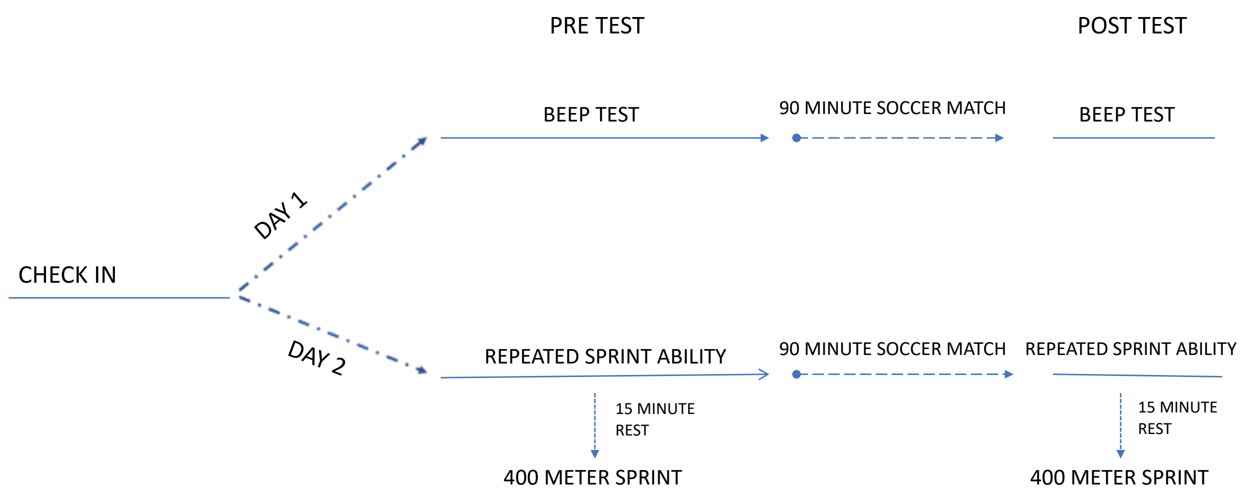

Figure 1. Represents the outline of the study design.

Procedures

We conducted the experimental program during a period of 5 days where the subjects were instructed to have no exercise within 24 hours of testing protocol days. This is characterized by low capacity and high intensity exercise. They visited the laboratory, soccer field, and track for measuring the anthropometric and performance variables at Sonoma State University. There was a warm-up of 10-15 minutes, consisting of stretching and jogging, before the full 90-minute soccer match. The order of test protocol and rest time in between tests was consistent for all subjects. Data was assessed and gathered for baseline testing and for post-testing after a full 90-minute soccer match.

Statistical Analyses

All data were analyzed using the statistical package SPSS 22 (SPSS, Inc., Chicago, IL, USA). Subject characteristics are presented as descriptive statistics for age, height, body mass, body composition, beep test, repeated sprint ability and 400-meter sprint. Measures of central tendency and variations were calculated for all variables, and outliers (2 SD) were identified and analyzed for confounding factors. The effects of the soccer match on VO_2max (beep test), 400-meter sprint performance, and repeated sprint ability Pre- and Post-testing variables were measured with a 2-way repeated-measure analysis of variance with factors group and time (PRE and POST game). In the event of a significant F score, paired t-test was used post hoc to determine pair-wise differences. A t-test was used to see the effect of treatments within groups with the accepted level of statistical significance set at $p < 0.05$. All results are presented as mean ± SD.

Chapter IV: Results

On the morning of check-in, testing took place on the Sonoma State soccer practice fields. Participants were screened for their body composition, height, weight and age. Informed consent was acquired prior to any testing. The participants (n=15 male athletes) with an average age of 23.0 $\pm$ 2.56 years had an average baseline body mass of 71.8 $\pm$ 6.51 (kg), average height of 175.7 $\pm$ 4.75 (cm), and an average BMI of 23.3 $\pm$ 1.82 (cm/kg). They were soccer players from Sonoma State University (Division II NCAA), Santa Rosa Junior College (NJCAA) and Sonoma County Sol (NPSL). They had about 7-10 years of experience and were regularly involved in a fitness routine.

SUBJECT	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)	BMI (kg/m^2)
Averages ± SD	23.0 ± 2.56	175.7 ± 4.75	71.8 ± 6.51	23.2 ± 1.82

TABLE 1. Represents subjects' anthropometric characteristics, represented as ± SD for height, weight, age, and BMI.

Maximal Oxygen Consumption (VO_2max)

For VO_2max measurement, the beep test was used. We noticed a statistically significant ($P<0.05$) decline on player's VO_2max after a 90-minute soccer match. Players attained an average VO_2max of 45.647 ml/kg/min before the match. After the soccer match players received a VO_2max average of 42.593 ml/kg/min. At the end of 90-min soccer match, absolute VO_2max reduced by 2.7% and percent VO_2max reduced to 6.28%.

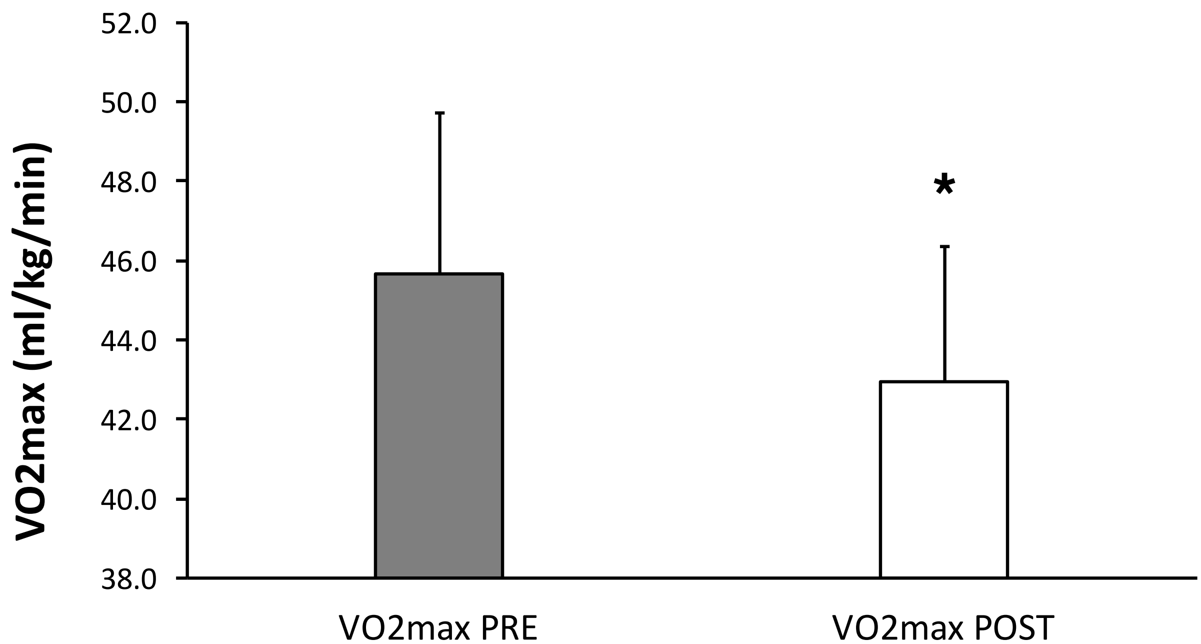

Figure 2. Represents the PRE- and POST soccer match VO_2max responses from the beep test. Means ± SD are presented. *, significantly different (*P*<0.05) from PRE.

Repeated Sprint Ability

Players attained RSA average times (1-6) with 4.44s, 4.33s, 4.43s, 4.46s, 4.48s, and 4.48s before a 90-min soccer match (PRE). They got faster sprint times (1-6) for the POST RSA with 4.32s, 4.19s, 4.22s, 4.36s, 4.35s, and 4.37s.

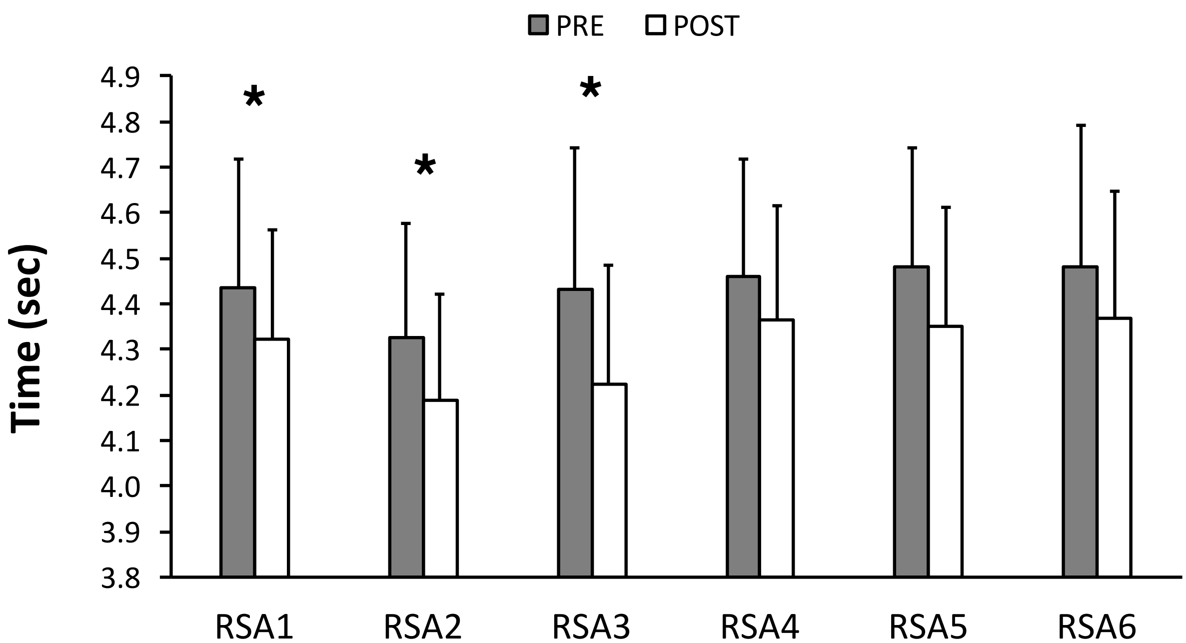

Figure 3. Represents the average sprint times (1-6) in seconds (s) of the RSA PRE and POST soccer match values. Means ± SD are presented. *, significantly different (*P*<0.05) from PRE.

Table 2. Comparison of the RSA from Each Trial Pair.

By looking at RSA data, we also noticed significant changes (YES) (P<0.05) for Pair 1 (.036), Pair 7 (.001), Pair 8 (.001), Pair 9 (.004), Pair 16 (.010), Pair 17 (.043), Pair 22 (.003), Pair 23 (.003), Pair 24 (.001), Pair 25 (.007), Pair 26 (.018) and Pair 27 (.007).

	Comparison	**Significant**	**P value**
PAIR 1	RSA1_PRE-RSA2_PRE	**YES**	**.036**
PAIR 2	RSA1_PRE-RSA3_PRE	NO	.963
PAIR 3	RSA1_PRE-RSA4_PRE	NO	.622
PAIR4	RSA1_PRE-RSA5_PRE	NO	.289
PAIR 5	RSA1_PRE-RSA6_PRE	NO	.342
PAIR 6	RSA2_PRE-RSA3_PRE	NO	.102
PAIR 7	RSA2_PRE-RSA4_PRE	**YES**	**.001**
PAIR 8	RSA2_PRE-RSA5_PRE	**YES**	**.001**
PAIR 9	RSA2_PRE-RSA6_PRE	**YES**	**.004**
PAIR 10	RSA3_PRE-RSA4_PRE	NO	.690
PAIR 11	RSA3_PRE-RSA5_PRE	NO	.508
PAIR 12	RSA3_PRE-RSA6_PRE	NO	.535
PAIR 13	RSA4_PRE-RSA5_PRE	NO	.567
PAIR 14	RSA4_PRE-RSA6_PRE	NO	.638
PAIR 15	RSA5_PRE-RSA6_PRE	NO	.897
PAIR 16	RSA1_POST-RSA2_POST	**YES**	**.010**

PAIR 17	RSA1_POST-RSA3_POST	**YES**	**.043**
PAIR 18	RSA1_POST-RSA4_POST	NO	.128
PAIR 19	RSA1_POST-RSA5_POST	NO	.560
PAIR 20	RSA1_POST-RSA6_POST	NO	.320
PAIR 21	RSA2_POST-RSA3_POST	NO	.122
PAIR 22	RSA2_POST-RSA4_POST	**YES**	**.003**
PAIR 23	RSA2_POST-RSA5_POST	**YES**	**.003**
PAIR 24	RSA2_POST-RSA6_POST	**YES**	**.001**
PAIR 25	RSA3_POST-RSA4_POST	**YES**	**.007**
PAIR 26	RSA3_POST-RSA5_POST	**YES**	**.018**
PAIR 27	RSA3_POST-RSA6_POST	**YES**	**.007**
PAIR 28	RSA4_POST-RSA5_POST	NO	.766
PAIR 29	RSA4_POST-RSA6_POST	NO	.960
PAIR 30	RSA5_POST-RSA6_POST	NO	.664

400-Meter Sprint Times

The soccer match was stressful enough to induce decreased 400-meter sprint times. There were significant difference between PRE and POST 400-meter sprint tests (*P*<0.05).

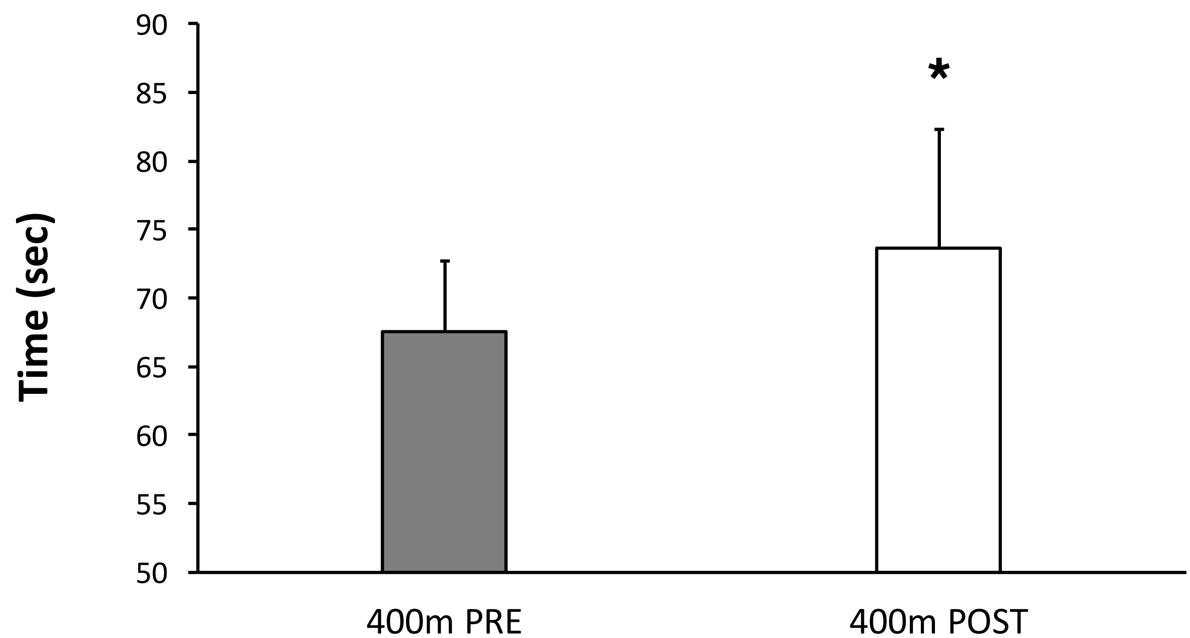

FIGURE 4: represents changes in 400-meter sprint times from PRE to POST soccer match. Means ± SD are presented. *****, significantly different (*P*<0.05) from PRE.

	VO$_2$max PRE	VO2max POST	ABSOLUTE CHANGE	% CHANGE
VO$_2$max (ml/kg/min)	45.65 $\pm$ 4.05	42.95 $\pm$ 3.41	-2.7	-6.3
400M TEST (sec)	67.57 $\pm$ 5.15	73.61$\pm$ 8.72	-6.04	-8.21

TABLE 3. Illustrates subject's VO$_2$max average before (pre) and after (post) 90-min match of the beep test. VO$_2$max (ml·kg·min^{-1})

Chapter V: Discussion

The purpose of this investigation was to examine 3 different tests which included the beep test, repeated sprint ability, and the 400-meter sprint test. We looked at the effect of player performance before and after a full 90-minute soccer match.

400-Meter Sprint

Significant decrease ($P<0.05$) in 400-meter sprint times occurred between PRE and POST 90-minute match (67.57sec and 73.61sec). This can be due to decreased performance related to energy system fatigue and/or muscle damage during the soccer match. Anaerobic glycolysis peaks at five seconds on average and lasts up to sixty seconds depending on a person's training; this may be why we see a decline in glycogen levels after performing a 400-meter sprint after a full 90-minute match. Gaitanos et al. (1993) found a lack of significant lactate production signaled a fatiguing of anaerobic glycolysis for energy productions, hence, a reduction in performance. Based on the results of Gaitanos et al. (1993) and similar investigations, there might be a correlation between a fatigued glycolytic system and the decline in 400-meter sprint times.

Renstroem and Johnson (1985) stated over-use injuries in sports are typically the result of repeated micro-traumas, resulting from a multitude of causes, one of which is improper overload, such as increased frequency, intensity and volume without proper recovery. Dowdle (2014) stated that overtraining can cause injuries such as compartment syndrome and soreness in muscles, stress fractures in bones, and bursitis in over-stressed joints. While overtraining does not always cause injury, we can see the many complications caused by overusing the muscles in a soccer match that will decrease a player's physical performance after a full 90-minute match. "The variability from person to person therein is the difficulty of isolating a mechanism(s) which can cause one to become over-trained as exhibited by decrements in performance" (Dowdle, 2014). Dowdle (2014) identified many factors involved in overtraining, such as loss of motivation, loss of appetite, and insomnia. By familiarizing ourselves with these concepts we can prevent our athletes from overtraining and burning out.

Repeated Sprint Ability

Figure 3 shows that players increased in RSA after a full 90-minute match. Paired sample test revealed there was a significance difference for sprint 1 ($p< 0.045$), sprint 2 (0.036), and sprint 3 (0.013). Even though the players attained faster times for Post soccer match, Dowle et al, (2014) noticed a steady decline in performance may have indicated a limited supply of rapid energy in the initial stages of sprinting. By looking at Table 2, we also noticed significant changes for Pair 1 (.036), Pair 7 (.001), Pair 8 (.001), Pair 9 (.004), Pair 16 (.010), Pair 17 (.043), Pair 22 (.003), Pair 23 (.003), Pair 24 (.001), Pair 25 (.007), Pair 26 (.018) and Pair 27 (.007). "During the initial stages of sprinting the anaerobic glycolytic system is responsible for a significant amount of energy to support sprints lasting from two to roughly sixty to seventy-five seconds, dependent once again on training status" (Dowle et al, 2014). The short supply of energy from the anaerobic system would indicate a substantial dependence on ATP-PC and oxidative systems for energy. This can be one of the reasons initial sprint times increased followed by a slight decrease in time through subsequent sprints.

There are numerous reasons for the decline of physical performance after strenuous activity. "Fatigue is a reduction of organism forces following excessive work, too long a duration of work, or a defective functional state" (Sesboue & Guincestre, 2006). These researchers looked at overtraining as being one of the reasons that muscle fatigue occurs. "Many studies proved that the increased physical load can lead to an overtraining syndrome, marked by a decreased capacity for the physical exercise and by behavioral disturbances" (Sesboue & Guincestre, 2006). Players who play at the collegiate level or higher tend to push themselves past their limits to increase their speed and strength, but in many cases are causing overtraining syndrome to occur that causes them to have energy imbalances.

"With fatigue, less calcium is released and limits the number of attached actin-myosin bridge connections of actin-myosin" (Sesboue & Guincestre, 2006). The researchers state that the decrease of bridging function is responsible for 20 percent of the loss of isometric force in tired muscles, causing it to temporarily switch to a slower type of muscle. This may be one major cause for players attaining lower RSA times.

According to Twist and Eston (2005), "Muscle damaging exercise appears to affect dynamic muscle function during maximal intensity intermittent exercise."

This study concluded that maximal intensity cycling and impaired acceleration were the cause of fast twitch fibers being damaged during plyometric exercise. “Of the many symptoms that accompany muscle damage, including soreness, increased blood myofiber proteins, swelling and decreased range of motion, perhaps the most significant factor is the long-lasting impairment of muscle function” (Twist & Eston, 2005). Our study compred with Twist and Eston, in which the subjects attained lower RSA times due to fatigue. After high-intensity performance players will deplete their energy system, causing muscles to fatigue.

According to Macaluso et al. (2012), “Our study shows that plyometric exercise mainly affects fast-twitch fibers, damaging the sarcolemma as well as the sarcomere at the site of the Z disk (microtrauma).” Current study might guide coaches and athletic trainers to provide efficient training methods before and after competition within the sport context to prevent as much muscle damage. This will help athletes perform to the best of their abilities during a soccer match.

Maximal Oxygen Consumption (VO_2max)

The VO_2max test is one of the most popular performance tests used in sports. “In soccer, a significant correlation was observed between Yo-Yo Beep Test performance and the amount of high-intensity exercise for professional players during a game, which has been suggested to be the best measure of endurance performance during a soccer game” (Bangsbo et al., 2008). Endurance is an important factor to be successful in soccer among athletes.

Having a high VO_2max will improve athlete performance in a full 90-minute soccer match.

For the beep test we noticed a decline in players' VO_2max after a 90-minute soccer match. Players attained an average VO_2max of 45.647 ml/kg/min before the match. After the match players reached a VO_2max average of 42.593 ml/kg/min. This was an absolute change of 2.694 ml/kg/min and a 6.272 ml/kg/min percent change.

"During endurance exercise, problems of energy provisioning, especially, will involve fatigue" (Sesboue & Guincestre, 2006). Muscular fatigue will depend on the balance of receiving and releasing of energy. In order for muscles to prolong fatigue, it is necessary to maintain a stable state such as central factors like pulmonary volume and perfusion, blood pressure, hemoglobin content, cardiac flow, and blood volume. Seabees states, "The other limiting factor of endurance exercise is the fuel used. For efforts of short duration, with the hydrolysis of ATP and anaerobic glycolysis, maximum speed is about 10 m/s. The oxidative metabolism makes it possible to reach speeds of only about 5 m/s if one uses carbohydrates, at the time oxidation of lipids can ensure only a quick pace of about 2 m/s without being known why the oxidation of lipids is so slow" (Sesboue & Guincestre, 2006). Muscular glycogen content is an important factor when it comes to providing sufficient energy to the muscles to perform at maximum capacity. If a soccer player doesn't have enough glycogen or carbohydrates to use as fuel it will cause the muscles to fatigue. Players should have a proper balanced nutrition in order to have sufficient fuel to perform throughout a full match.

Conclusion

Soccer players use both aerobic and anaerobic energy systems in a soccer match. “A player utilizes the aerobic system to provide constant energy to move around the soccer field at a medium level of intensity. However, when a player is either defending or attacking, a soccer player would use the anaerobic energy system” (Stonebraker, 2018). It’s fascinating how our body can change and adapt to physical activity. “Our bodies extract energy from ingested sources of fuel such as protein, carbohydrates, and fats” (Stonebraker, 2018). Whenever the body needs energy it uses ATP molecules. ATP provides energy to muscle fibers to power muscle contractions. Creatine phosphate is like ATP and is also stored within a cell. Cells must constantly replenish both ATP and CP to sustain physical activity. “The mechanisms of fatigue are still far from being completely understood: none of the metabolic variations, taken individually, can explain all fatigue: fatigue probably results from a combination of changes and the variations of local concentrations inside the cell” (Sesboue & Guincestre, 2006).

This investigation shows that a 90-minute soccer match significantly decreases oxygen consumption and increases 400-meter sprint time. However, with a brief recovery, repeated sprint ability performance significantly and consistently improved following the soccer match. We suggest soccer coaches should implement sprint interval training early in soccer season and focus on training athletes' anaerobic glycolytic systems by having them sprint intervals of 200m-400m. Nutrition intervention in the form of carbohydrate ingestion and fluid intake before, during, and after a soccer match might be a key variable for improved performance.

References

Andrzejewski, M., Chmura, J., Pluta, B., & Konarski, J. (2015). Sprinting activities and distance covered by top level Europa league soccer players. *International Journal of Sports Science & Coaching*, 10 (1), 39-50.

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, 24 (7), 665-674.

Bangsbo, J., Iaia, F., & Krustrup, P. (2008). The yo-yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, 38 (1), 37-51.

Bangsbo, J. (2000). Muscle oxygen uptake in humans at onset of and during intense exercise. *Acta Physiologica Scandinavica*, 168(4), 457-464.

Castagna, C., Impellizzeri, F., Ciwvialli, K., Carlomagno, D., & Rampinini, E. (2006). Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: A correlation study. *Journal of Strength & Conditioning Research* (Allen Press Publishing Services Inc.), 20(2), 320-352.

Cavaco, B., Sousa, N., Machado dos Reis, V., Garrido, N., Saavedra, F., et al. (2014). Short-term effects of complex training on agility with the ball, speed, efficiency of crossing and shooting in youth soccer players. *Journal of Human Kinetics*, 43, 105-112.

Chatterjee, P., Banerjee, A., Das, P., & Debnath, P. (2009). A regression equation to predict vo_2 max of young football players of Nepal. *International Journal of Applied Sports Sciences*, 21(2), 113-121.

Da Silva, C., Bloomfield, J., & Marins, J. (2008). A review of stature, body mass and maximal oxygen uptake profiles of u17, u20 and first division players in Brazilian soccer. *Journal of Sports Science & Medicine*, 7(3), 309-319.

Dowdle, C., Sokmen, B., Carlton, B. E., Bryan, R. (2016). The effects of traditional, contrast, and pre-exhaustive training methods on performance variables. Medicine & Science in Sports & Exercise, 48, pp.20-24.

Gil, S., Gil, J., Ruiz, F., Irazusta, A., & Irazusta, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: Relevance for the selection process. *Journal of Strength & Conditioning Research* (Allen Press Publishing Services Inc.), 21(2), 438-445.

Galy, O. Zongo, P. Chamari, K. Chaouachi, A. Michalak, E. Dellal, A. Castagna, C. Hue, O. (2015). Anthropometric and physiological characteristics of Melanesian futsal players: A first approach to talent identification in Oceania. *Biology of sport*, 32(2) 135-141.

Gaitanos, G. C., Williams, C. C., Boobis, L. H., & Brooks, S. S. (1993). Human muscle metabolism during intermittent maximal exercise. *Journal of Applied Physiology*, 75(2), 712-719.

Gioldasis, A., Bekris, E., & Gissis, I. (2014). Playing position: Anthropometric and fitness demands in youth soccer. *Sport Science Review*, 23(3/4), 151-168.

Hoff, J., Wisløff, U., Engen, L., Kemi, O., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine*, 36(3), 218-221.

Lattier, G. (2004). Fatigue and recovery after high-intensity exercise part ii: Recovery interventions. *International Journal of Sports Medicine*, 25(7), 509-515.

Lopez, E., Smoliga, J., & Zavorsky, G. (2014). The effect of passive versus active recovery on power output over six repeated wingate sprints. *Research Quarterly for Exercise & Sport*, 85(4), 519-526.

López-Segovia, M., Marques, M., Vam den Tillaar, R., & González-Badillo, J. (2011). Relationships between vertical jump and full squat power outputs with sprint times in u21 soccer players. *Journal of Human Kinetics*, 30, 135-144.

Macaluso, F., Isaacs, A. W., & Myburgh, K. H. (2012). Preferential type II muscle fiber damage from plyometric exercise. *Journal of Athletic Training*, 47 (4):414–420.

Macpherson, T., & Weston, M. (2015). The effect of low-volume sprint interval training on the development and subsequent maintenance of aerobic fitness in soccer players. *International Journal of Sports Physiology & Performance*, 10(3), 332-338.

Mohamed, M., Ali, S., & Mohamad, S. (2014). The effectiveness of plyometric training on muscle strength for soccer players. *Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health*, 14(2), 163-169.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, 21(7), 519-528.

Mohr, M., Krustrup, P., Nielsen, J., Nybo, L., Rasmussen, M., et al. (2007). Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. *American Journal of Physiology: Regulatory, Integrative & Comparative Physiology*, 61(4), R1594-R1598.

National strength and conditioning association 2015 conference abstracts. (2016). *Journal of Strength and Conditioning Research*, 30, S1-S171.

Neto, A., Mascarenhas, L., Bozza, R., Ulbrich, A., de Vasconcelos, I., et al. (2007). Vo_2max e composicao corporal durante a puberdade: Comparacao entre praticantes e nao praticantes de treinamento sistematizado de futebol. *Brazilian Journal of Kineanthropometry & Human Performance*, 9(2), 159-164.

Pivovarniček, P., Pupiš, M., Tonhauserová, Z., & Tokárová, M. (2013). Level of sprint and jump abilities and intermittent endurance of elite young soccer players at different positions. *SportLogia*, 9(2), 186-200

Renstroem, P.P. & Johnson, R. J. (1985). Overuse injuries in sports: A review. *Sports Medicine*, 2(5), 326-333.

Rahnama, N., Lees, A., & Reilly, T. (2006). Electromyography of selected lower-limb muscles fatigued by exercise at the intensity of soccer match-play. *Journal of Electromyography and Kinesiology*, 16(3), 257-263.

Sesboue, B., & Guincestre, J. (2006). Muscular fatigue. *Annales de Réadaptation et de Médecine Physique*. 49(6), 348-354.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, 35(6), 501-536.

Stonebraker, M., Peter. (2018) Private Communication. PhD. *UC Berkeley Extension*.

Strauss, A., Jacobs, S., & Van Den Berg, L. (2012). Anthropometric, fitness and technical skill characteristics of elite male national soccer players: A review. *African Journal for Physical, Health Education, Recreation & Dance*, 18(2), 365-394.

Twist, C., & Eston, R. (2005). The effects of exercise-induced muscle damage on maximal intensity intermittent exercise performance. *European Journal of Applied Physiology*, 94, 5-6, 652-658.

Welsh, R., Davis, J., Burke, J., & Williams, H. (2002). Carbohydrates and physical/mental performance during intermittent exercise to fatigue. *Medicine & Science in Sports & Exercise*, 34(4), 723-731.

Wisloff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. *Medicine & Science in Sports & Exercise*, 30(3), 462-467.

Wong, P., Chaouachi, A., Castagna, C., Lau, P. C., Chamari, K., & Wisløff, U. (2011). Validity of the Yo-Yo intermittent endurance test in young soccer players. *European Journal of Sport Science*, 11(5), 309-315.

Wong, P., Chamari, K., Dellal, A., & Wisløff, U. (2009). Relationship between anthropometric and physiological characteristics in youth soccer players. *Journal of Strength & Conditioning Research* (Lippincott Williams & Wilkins), 23(4), 1204-1210.