OFF-SEASON PHYSIOLOGICAL PROFILE OF THE
CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA
NATIONAL COLLEGIATE ATHLETIC ASSOCIATION
DIVISION II MALE SOCCER TEAM

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Daniel Higuera
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ABSTRACT

Improving and refining athletic performance is the foremost intention of off-season training. The paucity of post-season/early off-season physiological data precludes the systematic and thereby effective application of off-season exercise training programs in NCAA Division II (DII) male soccer players. Therefore, the purpose of the present study was to provide the California State Polytechnic University, Pomona (CPP) NCAA DII Men’s Soccer program an in-depth evaluation of their athlete’s physiological and performance capacities in reference to previously established normative data and in comparison to a control cohort comprised of recreationally competitive soccer players. Male subjects were allocated into one of two groups: 1. Collegiate Athletic Group (ATH) (n=21) or 2. Control Group (CON) (n=21). All participants underwent assessments for exercise and health history, anthropometric measurements, body composition, graded maximal treadmill test, isometric knee dynamometry for hamstring to quadriceps contractile ratios, electromyography (EMG) for assessment of maximal voluntary isometric contraction (MVIC) on the dynamometer, Wingate Anaerobic Test (WAnT), vertical jump, 40-yard sprint, and the T-Test. Testing was strategically compartmentalized into 3 testing days with 48 hours between subsequent visits. Height was significantly greater in ATH compared to CON (177.5 ± 6.4 cm vs. 173.9 ± 4.5 cm; p= 0.042). Absolute aerobic capacity was significantly greater in ATH compared to CON (4.0 ± 0.5 L·min⁻¹ vs. 3.6 ± 0.4 L·min⁻¹; p=0.022). Peak Power (PP), PP normalized to total body mass (W·TBM⁻¹) and lean body mass (W·LBM⁻¹) was significantly greater in CON compared to ATH (799.5 ± 114.7 W vs 722.1 ± 116.7 W; p= 0.044, 11.3 ± 1.6 W·kg⁻¹ vs 10.0 ± 1.5 W·kg⁻¹; p= 0.012, 14.2 ±1.5 W·kg⁻¹ vs 12.6 ± 1.9 W·kg⁻¹; p=0.007,
respectively). Reaction time (RT) and T-Test (TT) were significantly greater in ATH compared to CON (0.25 ± 0.11 s vs 0.41 ± 0.11 s; p< 0.0001, 8.8 ± 0.29 s vs 9.2 ± 0.39 s; p< 0.0001, respectively). When comparing ATH values to normative data derived from elite players, ATH compared favorably with some assessments such as aerobic capacity and vertical jump (VJ), however tested unfavorably in assessments such as in the WAnT. The comprehensive pool of data may be used to identify any areas of sport specific fitness that must be maintained or remedied during the off season.
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CHAPTER ONE

INTRODUCTION

The globally recognized sport of soccer is unique in terms of the multiple and diverse physiological and physical demands of play. This remains especially true amongst athletes in advanced to elite levels of competition, i.e. collegiate, professional, and international. Soccer incorporates intermittent periods of high-force, high-power movements interspersed with low-intensity activity across prolonged duration, thereby characterizing the sport as one of the most challenging from a physiological perspective. With that said, competitive soccer players require development of a well-rounded physiological profile which incorporates efficient aerobic and anaerobic bioenergetic capacities, muscular strength, power, and endurance, cardiopulmonary fitness, speed, agility, and optimum body composition.

In National Collegiate Athletic Association (NCAA) sanctioned soccer programs, players undertake critical steps to systematically improve each of the aforesaid components of fitness to expand the physiological foundation on which athletic and soccer-specific skills may be developed. However, the relatively short NCAA soccer season and mandated limitations to total team practices presents a significant challenge for players to advance or maintain these underlying components of soccer fitness during season. As previous data shows, significant detraining effects in soccer players may manifest across the season, conceivably diminishing performance capacities into off-season time periods (Caldwell & Peters, 2009). Correspondingly, a recent study reported that highly conditioned soccer players may experience a reduction in performance at the conclusion of the playing season (Metaxas, Koutlianos, Sendelides, & Mandroukas,
2009). Therefore, it remains imperative for collegiate soccer teams to maximize the off-season period to expand physiological capacities through proper strength and conditioning programming.

It is crucial for the players along with the coaching staff to obtain impartial information about each player’s physiological and athletic capabilities to identify any weaknesses that may compromise individual or team competition (Sporis, Jukic, Ostojic, & Milanovic, 2009). The strive to fully and concurrently maximize each of the aforementioned components of soccer fitness is limited by normal adaptive responses to training. Specifically, muscular endurance and strength/power represent opposite ends of a training adaptation continuum, creating difficulty in achieving maximal capacities in each respective area of fitness. With that said, the focus of off-season training would be to rather, produce the optimum balance among all areas of soccer fitness. The lengthy duration of the NCAA off-season permits a sufficient timeframe to develop and refine anaerobic and aerobic power, muscular strength and power, speed, agility, cardiopulmonary endurance, and body composition (Megal, Smith, Dyer, & Hoffman, 2009). Moreover, during the sanctioned off-season period, NCAA Division II athletes’ activity levels usually remain unsupervised by coaches and staff, and therefore, training programs are self-prescribed and carry a significant amount of variation (D. Miller, Kieffer, Kemp, & Torres, 2011). Thus, it is of great importance for athletes to participate in periodic off-season physiological and performance assessments to objectively support appropriate training modifications. Athletes who are proactive and optimize their off-season preparation may avoid substantial detraining effects, and begin the competitive season with elevated levels of athletic fitness. This provides an advantageous platform for
coaches to devote a larger percentage of the NCAA-allotted practice time to augment soccer-specific skills, heartening overall success of the team (WJ Kraemer et al., 2004).

**Statement of the Problem**

Improving and refining athletic performance is the foremost intention of off-season training. In recent years, a limited pool of soccer-related studies has been published, and less are focused on studying and understanding the spectrum of performance and physiological demands. Therefore, the paucity of post-season/early off-season physiological data precludes the systematic and thereby effective application of off-season exercise training programs in NCAA Division II male soccer players. The lack of normative data for the various physiological and performance capacities specific for this athletic population creates a misguided off-season strength and conditioning program geared towards unsolidified goals. Moreover, less is known regarding the normative standards for various components of soccer fitness especially in collegiate level of competition.

**Purpose Statement**

The purpose of this investigation was to comprehensively evaluate the early off-season physiological and performance capacities of NCAA Division II male soccer players for the development of a player to team-wide athletic profile.

**Specific Aims**

The following specific aims were pursued during the 2016 NCAA Division II Men’s soccer early off-season in active male players eligible for the 2016-2017 season for California State Polytechnic University, Pomona (CPP).

Aim 1: Produce a comprehensive physiological and performance profile by
assessing body composition, aerobic power and capacity, anaerobic capacity, muscular contractile kinematics and electromyography, speed, agility, and lower body power.

Aim 2: Compare physiological and performance testing data from the athletic study cohort to those acquired from an age- and gender-matched control group comprised of recreationally competitive soccer players (i.e. club and recreational league players).

Hypothesis

Aim 1 was completely predicated on descriptive measures, and therefore no hypothesis testing was required.

Aim 2, the null hypothesis ($H_0$) was that there will be no difference in physiological and performance test outcomes between the athletic and control study cohorts.

Significance of the Study

The proposed study was expected to provide the California State Polytechnic University, Pomona (CPP) men’s soccer program an in depth evaluation of the athletes’ physiological and performance capacities in reference to previously established normative data and in comparison to a control cohort comprised of recreationally competitive soccer players. It was also anticipated that the development of soccer-specific physiological profiles would provide data to support the synthesis of test-specific norms for NCAA Division II male soccer players especially during early off-season periods.

Limitations

Limitations to the proposed study included the following: 1) certain performance testing protocols involved treadmill running which may (or may not) have involve
unaccustomed running patterns or form for subjects; 2) certain performance testing
protocols involved a maximal effort cycling bout on a stationary cycle ergometer which
may (or may not) have involve unfamiliar movements for the subjects; 3) team practices,
strength and conditioning sessions, and competitive play were not controlled for which
may have had a carry-over effect into the testing protocols; 4) dietary intake was not
monitored among testing days; 5) a potential learning effect might have existed between
subsequent performance testing trials; and 6) athletes from the control group might have
been composed of non-CPP students and therefore abiding by the original testing
schedule may have been compromised due to scheduling conflicts.

**Delimitations**

The measure of the analysis was delimited to healthy, male soccer athletes
between the ages of 18-32 competing collegiately (NCAA Division II) or at club or
recreational levels. Participation was denied if subjects reported or exhibited any forms of
pain or injury that removes clearance to participate in team practice or strength and
conditioning sessions. NCAA Division II soccer players must have been eligible to
compete during the 2016-2017 season.

**Operational Definitions**

Aerobic Capacity - The capacity by which oxygen may be consumed by the body for the
aerobic production of cellular energy.

Anaerobic Threshold - The oxygen consumption above which aerobic energy production
is supplemented by anaerobic mechanisms, causing a sustained increase in lactate and
metabolic acidosis (2013; Wasserman, 1986).

Fitness - The quality of being suitable to fulfill a particular role or task.
High Intensity Exercise - Exercise carried out at 81 -90% intensity of VO$_2$ max.
Moderate Intensity Exercise - Exercise carried out at 66 -80% intensity of VO$_2$ max.
Low Intensity Exercise - Exercise carried out at 20 - 65% intensity of maximal oxygen consumption (VO$_2$ max).
Muscular Endurance - The ability of a muscle or muscle group to produce continuous submaximal contractions for a relatively prolonged duration.
Muscular Power - Muscular contractile kinematic as a function of both force and velocity.
Muscular Strength - The maximum force a specific muscle or muscle group may produce during a weight-bearing activity (e.g. resistance exercise). Muscular strength is measured by the greatest load an individual may overcome during an exercise for no more than one repetition.
Oxygen Cost - Oxygen (O$_2$) cost is the rate by which oxygen is used by the body for cellular energy production during a particular task.
Oxygen Consumption (VO$_2$) - Oxygen Consumption (VO$_2$) refers to the submaximal oxygen uptake by the cardiopulmonary system for utilization by cells for energy production.
Recreationally Active - Individuals that participate regularly in competitive soccer games in either a recreational and/or organized soccer club setting.
Stretch-Shortening Cycle - A stretch-shortening cycle (SSC) is an active stretch (eccentric contraction) of a muscle followed by an immediate shortening (concentric contraction) of that same muscle.
Ventilatory Threshold - A deflection point in the relation between ventilation and oxygen
consumption with incremental exercise.

VO₂ Maximum (VO₂ max) - The capacity by which oxygen may be consumed, delivered, and utilized to form cellular energy. VO₂ max may be used interchangeably with “Aerobic Capacity”.
CHAPTER TWO
LITERATURE REVIEW

Soccer demands a constant intermittent cycle between high and low intensities of exercise across a time span up to ninety minutes. Therefore, effective soccer performance relies on multiple inter-dependent factors including the technical and tactical abilities of the player and their physiological capacities. In order to achieve peak performance at all levels of competition, i.e. collegiate, professional, and international, the athlete must train in a manner that targets various, and at times, opposing physiological aspects of fitness. Thus, developing a well-rounded physiological profile which incorporates efficient aerobic and anaerobic bioenergetics, muscular strength, power, and endurance, as well as speed and agility remains the ultimate goal during the yearly sanctioned training periods.

Bioenergetics of Soccer Performance

Aerobic Capacity and Power

Aerobic fitness is characterized by both aerobic capacity and aerobic power. Aerobic capacity (i.e. VO$_2$ max ml·kg$^{-1}$·min$^{-1}$) represents the maximum level of oxygen that the body can consume to support aerobic production of cellular energy or adenosine triphosphate (ATP) (Castagna, Impellizzeri, Chamari, Carlomango, & Rampinini, 2006). Often times VO$_2$ max is used in the context of skeletal muscle metabolism since it is the most metabolically active tissue during exercise. Although aerobic capacity is an important physiological determinant of endurance performance, it is not the most significant. Rather, aerobic power represents the efficiency by which ATP is generated in skeletal muscle via aerobic metabolism to meet the energy demands of actively contracting skeletal muscle (Jansson, Dudley, Norman, & Tesch, 1990). In other words,
aerobic power describes an athlete’s ability to generate cellular energy aerobically as opposed to anaerobically at greater relative exercise intensities (higher percentage of VO$_2$ max). If an athlete is able to effectively derive ATP from aerobic metabolism, a non-fatiguing bioenergetic pathway, prolonged and continuous muscle contractions may be permissible at higher relative intensities. In more practical terms, aerobic power represents the athlete’s capacity to continuously exercise at a greater percentage of their aerobic capacity (i.e. VO$_2$ max) without premature fatigue, i.e. muscular endurance. Both factors related to aerobic metabolism are key determinants for human performance in soccer play, especially at the highly competitive level (i.e. collegiate to professional).

Aerobic capacity and power have shown significant relevancy to optimum performance during soccer competition (J Bangsbo, 1994a, 1994b). Several studies have reported mean VO$_2$ max values between 56 and 65 ml·kg$^{-1}$·min$^{-1}$ for NCAA male soccer players which may be considered comparatively high in reference to normative values of college-aged males (Hoff & Helgerud, 2004). An expansive body of descriptive studies in soccer athletes suggests that development of adequate aerobic fitness is conducive to on-field performance variables such as, total field distance covered, ball possession time, and the number of repeated high power movements (J Bangsbo, 1994a, 1994b; Castagna et al., 2006; Chamari et al., 2005; Gaitanos, Williams, Boobis, & Brooks, 1993). In fact, previous literature reported a positive relationship between team ranking and average team VO$_2$ max in the Hungarian elite division (Wisloff, Helgerud, & Hoff, 1998). To further expound on the relationship between VO$_2$ max and on-field performance, Wisloff et al. (1998) reported a significantly greater mean VO$_2$ max in the four highest ranked
teams versus the remaining lower ranked teams in the Norwegian Premier Division (Wisloff et al., 1998).

Whereas VO\textsubscript{2max} depicts the body’s utmost ability to consume oxygen during vigorous exercise, it is physiologically impossible to sustain prolonged performance at maximal intensity, i.e. at VO\textsubscript{2max}. The highest relative intensity at which exercise can be performed at steady state is denoted by the anaerobic threshold (AT). The AT is the work rate at which aerobic metabolism cannot satisfy the rate at which the active muscles require ATP, and anaerobic metabolism begins to supersede as the primary mechanism of energy production. The AT is also denoted as the onset of blood lactate accumulation (OBLA), lactate being the end-product of anaerobic glycolysis. The AT can also be indirectly determined by an upward deflection point in the direct positive relationship between ventilation (breaths per minute) and oxygen consumption with incremental exercise. This point is referred to as the ventilatory threshold (VT) and is synonymous with the AT since ventilation increases concomitantly with lactate accumulation. The anaerobic threshold and thereby VT is a reliable physiological indicator of the capacity by which an athlete may produce sustainable physical work (i.e. aerobic power).

Moreover, the AT or VT may be used as an effective proxy for overall soccer fitness and a variable to properly prescribe endurance training intensity (Allen, Seals, Hurley, Ehsani, & Hagberg, 1985; Bishop, Jenkins, & Mackinnon, 1998). In regards to soccer performance, a player with a comparatively greater AT, and thus aerobic power, may be able to maintain higher levels of intensity during a match. In highly ranked Finnish soccer club players, the mean AT was approximately 83% of VO\textsubscript{2max}. These findings were further corroborated by data in which elite Norwegian soccer players demonstrated
an AT between 80-86% of VO$_2$ max (Hoff & Helgerud, 2004). Moreover, it has been speculated that AT might be a more reliable measure of muscular endurance than VO$_2$ max, as an improvement of AT may result in enhanced performance independent of any changes to VO$_2$ max (Allen et al., 1985).

Although VO$_2$ max may be an important indicator of aerobic fitness in elite soccer players, the AT remains just as significant especially considering its application to on-field soccer performance. With that reasoning, it is crucial for soccer players, especially in collegiate and professional levels of competition, to undergo comprehensive assessment for VO$_2$ max as well as aerobic power (AT or VT). The widely used gold standard for testing both aerobic capacity and power is the maximal graded exercise test integrated with the use of indirect calorimetry. With an indirect calorimeter, or commonly known as a metabolic cart, the test administrator can acquire oxygen consumption and ventilatory measurements continuously throughout the graded exercise test. The exercise testing protocol calls for the subject to perform continual stages with increasing work rate/intensity until volitional exhaustion. There will be a concomitant increase in oxygen consumption and ventilation with each stage of the test. Subsequently, ventilation and oxygen consumption data can be charted to identify the percentage of VO$_2$ max where the rate by which ventilation rises supersedes that of oxygen consumption. This percentage of VO$_2$ max is used to identify the VT and is referred to as the V-slope method (Beaver, Wasserman, & Whipp, 1986).

Although the importance of optimum aerobic capacity and power in collegiate soccer is well supported, there are other key bioenergetic factors for performance. For example, the athletes’ ability to derive ATP from immediate anaerobic pathways is also
favorable for on-field performance. This is due to the diverse nature of metabolic demands during soccer play. That is, players must demonstrate efficient production of cellular energy via aerobic metabolism to sustain overall activity while concurrently being able to effectively generate ATP during intermittent scenarios requiring an immediate, high-rate demand of energy (i.e. sprinting).

**Anaerobic Capacity and Power**

Soccer competition has developed into a faster and more intense level of play. Regardless of playing style and position, soccer demands intermittent, sporadic periods of high and low intensity activity. In fact, a full length match is comprised of approximately one-thousand distinct movements merged with rapid and continuous alterations in direction and pace (Mohr, Krstrup, & Bangsbo, 2003). Adding to the mercurial nature of soccer, various features of the game are performed in an acyclic manner with a change in intensity or type of activity approximately every four to six seconds (Drust, Reilly, & Rienzi, 1998). Across the 90-minute match, a player performs an average of 18-20 maximal effort sprints interspersed across 75 or more high intensity runs (J Bangsbo, 1994b).

When inclusively examining the physical demands of a match, there are frequent, intermittent moments of high intensity activity in which performance is largely dependent on “fast” bioenergetic pathways to meet the high rate at which active muscles require energy/ATP. These specific pathways include the ATP-Phosphocreatine systems (ATP-PCr) and fast glycolysis which are classified as anaerobic metabolism (Spencer, Bishop, Dawson, & Goodman, 2005). These ATP producing mechanisms are efficient in that they provide ATP at a very high rate however, also considered inefficient in the sense that
ATP production is short-lived and thus fatigue-inducing (Spencer et al., 2005). Thus, these pathways predominate overall energy production in skeletal muscle during exercise requiring a high rate of ATP supply. In soccer, these moments of high intensity anaerobic exercise are largely in the form of sprinting.

The ATP-PCr system is the main bioenergetic pathway responsible for the energy needs during maximal effort sprints and is thus known as the main determinant for anaerobic power output (McCartney et al., 1986). Intramuscular phosphocreatine (PCr) provides the phosphate needed to convert adenosine diphosphate to ATP through the enzymatic actions of creatine kinase. There is approximately 80 mmol·kg$^{-1}·$dm$^{-1}$ of PCr stored intramuscularly (Gaitanos et al., 1993). During maximal effort activities such as sprinting, there is significant depletion of PCr at a turnover rate of about 9 mmol ATP ·kg$^{-1}·$dm$^{-1}·$s$^{-1}$ (Hultman & Sjöholm, 1983) such that about 50% of total PCr is depleted during a 5-6 second sprint (Gaitanos et al., 1993). However, in a scenario involving repeated sprints, the amount of PCr replenished during the recovery periods determines the capacity by which the ATP-PCr system contributes to ATP production. It is known that the half-life of PCr to be 20-60 seconds (Harris et al., 1976), and while competing, there are multiple situations when recovery period is well under the required timespan for adequate PCr replenishment. Although sizeable PCr replenishment occurs within the first 20-60 seconds of recovery, approximately 4 minutes are required for adequate PCr recovery (Spencer et al., 2005). Thus, with repeated sprints, intramuscular PCr levels will eventually deplete consequently reducing sprint and overall performance.

Although the ATP-PCr system is the predominate energy supplier during maximal intensity exercise, other anaerobic bioenergetics systems are contributing proportionately
to the ATP demand rate. In general, high intensity activity also stresses the fast glycolytic system which involves the production of ATP via substrate level carbohydrate metabolism. Thus, during a soccer match with intermittent variations in intensity, the efficiency of the fast glycolytic system is of importance for overall performance in addition to the ATP-PCr system (Chamari et al., 2005). Within the spectrum of high to maximal intensity exercise (e.g. run to sprint) within a match both fast glycolysis and the ATP-PCr system play an integral role in supporting the energy needs.

The assessment of anaerobic capacity is a major consideration in preparing athletes for high-level competition (J Siegler, Gaskill, & Ruby, 2003). The Wingate Anaerobic Test (WAnT) is both a validated and reliable assessment for overall anaerobic capacity as the protocol stresses both the ATP-PCr and the fast glycolytic systems during performance (WJ Kraemer et al., 2004). Briefly, the WAnT involves the subject cycling with maximal effort against a determined resistance (6-8% of bodyweight) for 30 seconds while power output data is simultaneously acquired. The WAnT essentially tests the efficiency by which the ATP-PCr and the fast glycolytic system provides ATP during maximal effort muscular activity (i.e. sprinting). This is indirectly determined by power output data during the test. Peak power output, typically observed during the first 5 seconds of the cycling sprint, has been used as a proxy for the ATP-PCr system’s efficiency while the mean power across the entire 30 seconds demonstrates the capacity for the entire anaerobic system in general (ATP-PCr and fast glycolysis). Also, the rate of power decline or fatigue index provides insight as to how well a subject is able to maintain power output during maximal effort sprinting. Thus, the WAnT and the data acquired may be translatable to soccer performance and is an important component of a
soccer player’s physiological and athletic profile.

Neuromuscular Factors of Soccer Performance

Muscular Power: Speed, Agility, Vertical Jump

By definition, muscular power (not to be confused with aerobic power) is equivalent to the rate of producing physical work (Laird & Rozier, 1979). Power is the product of two performance variables, strength/force and speed/velocity, and is a measure of one’s ability to apply the greatest amount of muscular force as fast as possible i.e. force \cdot time^{1}. Therefore, optimum sprint and jump performance as well as agility, all components of soccer play, depend on muscular power. The capacity by which one produces muscular power relies on the efficiency of the stretch reflex mechanism. In brief, the stretch reflex involves a stretch-induced stimulation of a sensory neural signal from the muscle which subsequently travels towards the central nervous system (CNS) and then relays back to the same muscle causing an involuntary, i.e. reflexive contraction (Harrison, Keane, & Coglan, 2004). In relation to high power athletic movements, the stretch reflex mechanism manifests in the form of the stretch shortening cycle (SSC) phenomenon. The SSC may be compartmentalized into three specific phases that are present in all high power movements like sprinting, jumping, and rapid change of direction. The first phase involves an eccentric contraction and rapid stretch of the agonist muscle (e.g. landing step or countermovement) (Figure 1a) (Komi, 2000). During this phase, a sensory neural signal is produced at the agonist muscle as indicated above. Then during phase 2, this neural signal is transmitted towards the central nervous system where it relays back to the agonist muscle via the alpha motor neuron (Komi, 2000). No movement is produced during this phase and is referred to as the amortization or in more
practical terms, the pause between landing and take-off (Figure 1b). Subsequently, during phase 3, the neural signal reaches the agonist muscle which stimulates an involuntary concentric contraction (Komi, 2000). In addition to the voluntary contractile signals, a high powered movement may be achieved (Figure 1c). Sprint and jump performance and agility heavily depends on the athlete’s ability to complete the three phases of the SSC in the shortest timeframe possible. With that said, the efficiency of the SSC may be critical to optimum soccer performance.

Figure 1. Illustration of the Stretch Shortening Cycle. A. Eccentric phase B. Amortization phase C. Concentric phase (Kenny, Wilmore, & Costil, 2012)

Athletic movements such as sprinting, jumping, and changing direction are well supported to be one of the most decisive factors during competition (Bissas & Havenetidis, 2008; Meylan et al., 2009; Wisloff, Castagna, J, Jones, & Hoff, 2004). Executing any combination of these movements are critical for match scenarios such as widening the gap between opposing players, maintaining positional advantage while altering pace and direction, and dominating the aerial game. Well-developed lower body power is important for soccer players as it largely influences sprinting or jumping performance as well as agility. Moreover, Hennessy and Kilty speculated that power
expressed during jumping is the best indicator for sprint performance and agility
(Hennessy & Kilty, 2001). Sprint, vertical jump, and agility testing may offer a valid
platform for assessing lower body muscular power and may infer one’s ability to
effectively produce high-powered movements during soccer play.

A wide array of validated field tests have been regularly utilized to objectively
assess muscular power of the lower limbs. The 40-yard dash through the use of
strategically placed optical timing gates provide valid and precise measurements of
multiple athletic qualities such as acceleration and top sprint speed (Williams, 2013).
Moreover, as a method of evaluating agility, the T-Test is a validated timed assessment
that incorporates four sport specific direction changes with three different movement
patterns (Haman & Garhammer, 2008). Finally, counter-movement vertical jump testing
to assess maximal vertical jump distance have demonstrated a high degree of specificity
to sprint parameters such as velocity at start and quickness during stop and go movements
(Bret, Rahmani, Dufour, Messonnier, & Lacour, 2002; Hennessy & Kilty, 2001; Osinski,
1988).

During a full length 90-minute match, muscular contractions that propel the sport,
rely on both aerobic and anaerobic processes. Research suggests these aforementioned
neuromuscular factors are highly developed in players competing at elite levels of soccer
(Davis, Brewer, & Atkin, 1992a; Mangine, Noyes, Mullen, & Barber-Westin, 1990). As
such, tests of soccer performance must enable athletes and coaches to evaluate muscular
power. Improvements in vertical jump, sprinting speed, or agility may be an indication of
higher power output and therefore improved performance may be observed on the field.
Conclusion and Future Research

Integrating appropriate physiological assessments can identify both strength and weaknesses in players in relation to their teammates and across other teams. In so doing, weaknesses in any particular element of soccer-specific fitness may be systematically remedied by executing appropriate training programs. During various time points throughout the year, especially the early off-season, it is of great importance to obtain impartial information about a player’s physical and physiological status to objectively identify those elements that require improvement or maintenance. Thus, the implementation of standardized performance and physiological tests and resulting data may properly guide coaches and strength and conditioning specialist in designing both short- and long-term training regimens. Although previous research has focused on developing physiological profiles for highly competitive soccer athletes, there is currently a lack of data to support normative performance and physiological criteria in NCAA Division II male soccer players especially during the early off-season period. Therefore, future studies to acquire physiological and performance data in NCAA Division II soccer programs is warranted.
CHAPTER THREE

METHODOLOGY

Experimental Design

We implemented a parallel group experimental design for the proposed study. Subjects visited the Human Performance Research Laboratory (HPRL) at California State Polytechnic University, Pomona (CPP) (43-202b) on three separate occasions, with each visit dedicated to a specific battery of physiological and/or performance testing procedures (Figure 2). Subjects were allocated into one of two groups: 1. Collegiate Athletic Group (ATH) or 2. Control Group (CON). ATH was comprised of NCAA Division II male soccer players from CPP eligible for the 2016 season and CON consisted of age- and sex-matched recreationally competitive soccer players (i.e. club or non-collegiate league level). During the first laboratory visit, subjects initially underwent assessment for exercise and health history, anthropometric measures, and body composition via dual energy x-ray absorptiometry (DXA). Afterwards, subjects underwent a graded maximal treadmill test and indirect calorimetry to determine VO$_2$ max and other related metabolic variables. Approximately 48 hours following the first visit, subjects returned to the HPRL for isometric knee dynamometry and electromyography (EMG) for assessment of maximal voluntary isometric contraction (MVIC) and hamstring to quadriceps contractile ratios. Afterwards, subjects performed the Wingate Anaerobic Test (WAnT) to assess anaerobic capacity. After 48 hours of recovery, subjects visited the laboratory for their final visit during which time vertical jump, 40-yard sprint, and the T-Test was administered to assess jump height, sprint speed, and agility, respectively.
Subjects

We recruited 21 NCAA Division II male soccer players of CPP (ATH) (age = 20.6 ± 1.7 years old; bodyweight = 72.8 ± 6.3 kg; height = 177.5 ± 4.6 cm) and 21 recreationally competitive healthy male soccer players (CON) (age = 21.6 ± 2.7 years old; bodyweight = 70.8 ± 11.1 kg; height = 173.9 ± 6.5 cm) to participate in this study (Table 1). Inclusion criteria for ATH were as followed: 1) active NCAA student-athlete of the CPP Men's soccer program, and 2) eligible for the 2016 NCAA Division II men’s soccer season. The recreationally competitive control group (CON) must have met the following inclusion criteria to participate in the research study: 1) male, 2) age = 18-32 years, 3) recreationally competitive soccer players in club or non-collegiate league play, and 4) recreationally active (i.e. 3-6 hours/week of aerobic exercise, resistance exercise, concurrent training (combination of aerobic and resistance) or recreational sports within the past 6 months). Subjects were excluded from participation if they reported or exhibited: 1) a history of medical or surgical events in which the study’s protocols would be contraindicated or confound the interpretation of the results. These included, but were not restricted to, cardiovascular, metabolic, pulmonary, renal, or kidney diseases, hypertension, or musculoskeletal impediments; 2) use of any medication including those
with cardiovascular, pulmonary, thyroid, hyperlipidemia, hypoglycemic, hypertensive, endocrinologic, psychotropic, neuromuscular, neurological, or androgenic implications; or 3) daily use of ergogenic aids or dietary sports supplements within 6 weeks prior to the study.

**Physiological and Performance Assessments**

**Anthropometric and Body Composition Testing**

During the first visit, investigators initially assessed the subjects’ height (m) and bodyweight (BW) (kg) using a standard medical grade stadiometer and scale. Body composition was measured by whole-body dual-energy x-ray absorptiometry (DXA) (Hologic Discovery-QDR Series Densitometer, Bedford, MA). Using the Hologic Discovery system, DXA scans were typically 7-10 minutes in duration and was a non-invasive procedure with <5 uSV radiation, which is less than half a day of natural background exposure and less than half the dose of a standard x-ray scan. Total body mass (TBM) was quantified through the scan. A 3-compartment model of body composition was applied through which FM (kg) and non-bone LBM (i.e. fat free mass – bone mineral content) (kg) was analyzed for the whole body. Data for body fat percentage (BF%) was also acquired from DXA measurements. The DXA machine was calibrated before each scan using a manufacturer-provided phantom. All DXA measurements and analyses were conducted by a single certified technologist.

**Maximal Graded Exercise Test**

The measurement of maximal oxygen consumption (VO$_2$ max) during the first visit was performed using a maximal graded treadmill exercise test protocol and an open-circuit indirect calorimeter metabolic cart (ParvoMedics TrueOne® 2400; Salt Lake City,
Utah, USA). The assessment was administered in a thermo-neutral (~24°C) room. For the maximal graded exercise test assessment, subjects reported to the HPRL following at least 8 hours of no strenuous activity and rested quietly in a seated position for 10 minutes before testing. During that period, blood pressure (BP) and resting heart rate (HR) was measured for precaution to ensure the subject were under safe cardiovascular conditions prior to the test. Subjects were then fitted with a rubber (non-latex) ventilated mask covering their nose and mouth. The mask was interfaced with the indirect calorimeter/metabolic cart through a corrugated plastic tube. Subjects then began a 5-minute low intensity walk on a treadmill as a warm-up and to ensure normal responses by the metabolic cart. Following 5 minutes of warm-up, the subjects then underwent a modified Bruce treadmill test composed of a series of 3 minute stages with increasing speed and incline until maximal oxygen consumption was achieved (Scott, Roe, Coats, & Piepoli, 2003). After each stage, the subjects were asked to report a Rating of Perceived Exertion (RPE) which is a numbered index with each number corresponding to a level of exertion. Also after each stage, subjects were asked to provide a hand signal that corresponded to their level of exertion. Thumbs up indicated proceed to next stage, thumbs down indicated exhaustion approaching, cutting motion indicated stopping of the test. Subjects were verbally encouraged to reach maximal effort. The test was terminated upon the following conditions: 1) RPE greater or equal to 18, respiratory exchange ratio (RER) (measure provided by the metabolic cart) greater than 1.0, and 80% of maximal HR (max HR= 220-age) or 2) volitional termination by the subject. A true VO₂ max result was determined by the presence of the first condition listed above.
Isokinetic Knee Dynamometry and Electromyography

Isometric muscular tests were administered to evaluate torque output during maximal voluntary isometric contractions (MVIC) of the knee extensors and flexors under static conditions by using an isokinetic dynamometer (Biodex System 3 Pro; Shirley, New York, USA). Knee dynamometry testing was preceded by a 5-minute warm-up activity consisting of a low-speed treadmill walk. Subjects were then seated comfortably on the dynamometer chair, with the hip joint positioned at approximately 90° of flexion. The dynamometer lever arm specific for the subjects’ tested limb was attached 2-3 cm above the lateral malleolus. To minimize extraneous bodily movements during muscle contractions and therefore to avoid contributions from non-tested muscle groups, straps were securely fastened across the subjects’ chest, pelvis, and mid-thigh of the tested limb. The subjects’ lateral femoral epicondyle was aligned with the center of rotation of the dynamometer attachment. Prior to each test, the dynamometer underwent auto-calibration and torque acquisition which was gravity-corrected by an intrinsic device within the dynamometer. Subjects performed each contraction with arms across the chest and with each hand grasping the opposite shoulder. Isometric testing was administered on both limbs separately with the dynamometer arm fixed to allow 60° of static knee flexion, which has been shown to be the optimum joint angle for maximal isometric torque production. Subjects performed a single isometric knee extension and flexion reciprocally across three separate trials. Each trial was preceded by one practice contraction for the knee extensors and flexors. During each trial, Subjects were provided lay instructions to produce maximal static contractions as fast and forcefully as possible and then to maintain each contraction for five seconds. Two minutes of recovery was
provided between trials. The greatest isometric peak torque (Nm) value acquired from all trials for both extensors and flexors were used for analysis. Data was computed by manufacturer acquisition software and evaluated as absolute and normalized (i.e. to TBM and LBM) values.

During the test, electromyography (EMG) activity was recorded utilizing wireless EMG sensors (Delsys Trigno Wireless EMG) which were placed on the rectus femoris and bicep femoris, of the subject’s left and right limb. In order to minimize signal artifact, the anatomical site where the sensor was placed were shaven, abraded and cleaned with isopropyl alcohol. EMG signals were acquired using the manufacturer’s acquisition software. The signal for the concentric phase for each trial was analyzed. The amplitude of the signals was expressed as root mean square values.

**Wingate Anaerobic Test**

The Wingate Anaerobic Test (WAnT) was performed on a computer-integrated cycle ergometer (Monark 874E, Monark Exercise AB, Vansbro, Sweeden). Prior to the WAnT, subjects performed 5 minutes of self-selected stretching followed by 5 minutes of low-intensity cycling. Subjects were fitted to the ergometer appropriately and instructed of the subsequent procedures. Subjects then began cycling at 60 RPMs against no resistance for 5 minutes. At the end of the 5-minute stage subjects immediately pedaled with maximal effort against no resistance for 3 seconds. After the 3 seconds, a resistance commensurate to 7.5% of their bodyweight was applied instantaneously and the subjects continued to pedal with maximal effort for 30 seconds. Afterwards, subjects cooled-down for 5-10 minutes. Power output data was acquired using factory-specific data acquisition software at sampling frequency of 50Hz.
Vertical Jump

Three trials were performed on the Vertec (Jump USA, Sunnyvale, California, USA) vertical jump measuring equipment. Subjects stood strategically beneath the horizontal flags, they were then instructed to, under their own volition, utilize a countermovement jump (CMJ) allowing the subjects to swing their arms freely without taking any preparatory steps before the jump. Standing reach was measured and subtracted from jump scores to determine the actual height attained. Vertical jump height was measured to the closest 1cm.

40-Yard Sprint

Smart Speed optical timing sensors (Fusion Sports Inc. Sumner Park, QLD, Australia) were strategically positioned at 10- and 40-yard marks on a neatly groomed grass field. Subjects took a 2-point athletic stance where the dominant foot (DF) was firmly placed on a sensor release pad, and the non-dominant foot (NDF) was roughly placed 12 inches in front of the DF. Timing was initiated via release of pressure from the DF on the sub-surface triggering pad. Subjects were instructed to start their sprint in response to an auditory and visual cue initiated within a random time frame upon stepping on the trigger pad. 10- and 40-yard sprint times were computer recorded as the subject passed through the optical timing gates. Three trials were performed, and the fastest time was recorded.

T-Test

Agility was measured with the T-Test (Figure 3) (D. Miller et al., 2011). Subjects took a 2-point stance, and under their own volition, sprinted forward from cone A to cone B placed 10 yards ahead of them. They then side shuffled to the left to cone C 5 yards
away, then shuffled 10 yards to the right to cone D, then shuffled back to the cone B, and finally sprinted backwards 10 yards to cone A. Smart Speed optical timing sensors (Fusion Sports Inc. Sumner Park, QLD. Australia) were placed at the starting/ending point to initiate and stop time.

Figure 3. Illustration of the T-Test for Agility Assessment. Subjects sprinted forward from A to B, shuffled (keeping 1 foot from crossing over the other) from B to C, shuffled from C to D, shuffled from D to B, then sprinted backwards from B to A.

Statistical Analyses

Mean comparisons between the two groups (ATH vs. CON) for all dependent variables were analyzed using an Independent T-Test via Statistical Package for Social Science (SPSS, version 14.0 Chicago, Illinois). Significance was determined if $p < 0.05$. All data are expressed as mean ± SD.
CHAPTER FOUR

RESULTS

Descriptive, Anthropometric, and Body Composition Measures

Age, anthropometric, and body composition comparisons betweenATH and CON are indicated in Table 1. Specifically, height (HT) was significantly (p= 0.042) greater in the ATH compared to the CON. There was no between-group difference for age, total body mass (TBM), lean body mass (LBM), body fat % (BF%), body mass index (BMI), or lean body mass index (LBMI).

Table 1. Age, Anthropometric, and Body Composition Comparisons between Athlete and Control Group

<table>
<thead>
<tr>
<th></th>
<th>AGE (y)</th>
<th>HT (cm)</th>
<th>TBM (kg)</th>
<th>LBM (kg)</th>
<th>FM (kg)</th>
<th>BF% (%)</th>
<th>BMI (kg·m²)</th>
<th>LBMI (kg·m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATH</td>
<td>20.6 (1.7)</td>
<td>177.5 (6.4) *</td>
<td>72.8 (6.3)</td>
<td>57.8 (5.8)</td>
<td>12.1 (1.8)</td>
<td>16.5 (2.6)</td>
<td>23.3 (1.3)</td>
<td>18.3 (1.1)</td>
</tr>
<tr>
<td>CON</td>
<td>21.6 (2.7)</td>
<td>173.9 (4.5)</td>
<td>70.8 (11.1)</td>
<td>55.9 (6.8)</td>
<td>13.1 (5.5)</td>
<td>17.9 (4.7)</td>
<td>23.1 (3.2)</td>
<td>18.2 (2.1)</td>
</tr>
</tbody>
</table>

Data presented as mean (SD). Athlete Group (ATH), Control Group (CON), HT= Height, TBM= Total Body Mass, LBM= Lean Body Mass, FM= Fat Mass, BF%= Body Fat Percentage, BMI= Body Mass Index, and LBMI= Lean Body Mass Index.

*significantly different than CON (p= 0.042)

Bioenergetics

Aerobic Capacity and Power

Mean group comparisons for variables measured during the maximal graded treadmill test are shown in Table 2. Absolute VO₂ max (L·min⁻¹) was significantly (p= 0.022) greater in ATH compared to the CON (Table 2). There were no other between-group differences for normalized VO₂ max (ml·kg⁻¹·min⁻¹), respiratory exchange ratio (RER), max HR (MHR), ventilatory threshold (VT), or peak ventilation (PV).
Table 2. Comparison between Athlete and Control Groups for Indirect Calorimetry Variables Measured During the Maximal Graded Treadmill Test

<table>
<thead>
<tr>
<th></th>
<th>VO\textsubscript{2} max (L·min\textsuperscript{-1})</th>
<th>VO\textsubscript{2} max (ml·kg\textsuperscript{-1}·min\textsuperscript{-1})</th>
<th>RER</th>
<th>MHR (BPM)</th>
<th>VT (% VO\textsubscript{2} max)</th>
<th>PV (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATH</td>
<td>4.0 (0.5)*</td>
<td>53.6 (6.4)</td>
<td>1.1</td>
<td>193.7</td>
<td>69.2 (6.3)</td>
<td>101.7</td>
</tr>
<tr>
<td>CON</td>
<td>3.6 (0.4)</td>
<td>51.6 (7.7)</td>
<td>1.1</td>
<td>196.3</td>
<td>69.4 (12.7)</td>
<td>94.0</td>
</tr>
</tbody>
</table>

Data presented as mean (SD). Athlete Group (ATH), Control Group (CON), RER= Respiratory Exchange Ratio, MHR= Max Heart Rate, VT= Ventilatory Threshold, PV= Peak Ventilation.
*significantly different than CON (p= 0.022)

**Anaerobic Capacity and Power**

Peak power (PP) was significantly (p= 0.044) greater in CON compared to the ATH (799.5 ± 114.7 W vs. 722.1 ± 116.7 W) (Figure 4). There was no significant difference between groups for average power (AP) (600.7 ± 74.2W vs. 568.0 ± 93.1W) (Figure 4). Peak power normalized to TBM (11.3 ± 1.6 W·kg\textsuperscript{-1} vs 10.0 ± 1.5 W·kg\textsuperscript{-1}; p= 0.012) and LBM (14.2 ± 1.5 W·kg\textsuperscript{-1} vs 12.6 ± 1.9 W·kg\textsuperscript{-1}; p= 0.007) mass was significantly greater in CON compared to ATH (Figure 5). No between-group differences were detected for average power normalized to TBM (8.5 ± 1.1W·kg\textsuperscript{-1} vs. 7.8 ± 1.2W·kg\textsuperscript{-1}) and LBM (10.7 ± 1.1W·kg\textsuperscript{-1} vs. 9.9 ± 1.5W·kg\textsuperscript{-1}), fatigue index (FI) (53.9 ± 12.1% vs. 47.9 ± 6.1%), or time to PP (4.4 ± 2.8 s vs 3.6 ± 1.1 s).
Figure 4. Peak and Average Power Comparisons between Athlete and Control Groups. Data presented as mean (SD). PP= Peak Power, AP= Average Power
*significantly different than Athlete Group (p = 0.044)

Figure 5. Peak and Average Power Normalized to Total Body Mass and Lean Body Mass Comparisons between Groups. Data presented as mean (SD). PP/TBM = Peak Power normalized to Total Body Mass, PP/LBM= Peak Power normalized to Lean Body Mass, AP/TBM= Average Power normalized to Total Body Mass, AP/LBM= Average Power normalized to Total Body Mass.
*significantly different than Athlete Group (p = 0.012)
^significantly different than Athlete Group (p = 0.007)
**Knee Flexor and Extensor Maximal Torque**

There was no between-group difference in electromyography (EMG) activity for left or right rectus and biceps femoris during the MVIC (Table 3). Peak torque (PT), average torque (AT) (Table 4), or hamstring (H) quadriceps (Q) contractile ratios (H/Q) in either limb failed to differ between groups (56.2 ± 12.1 % vs 53.9 ± 8.0 % for the left, 52.6 ± 12.0 % vs 51.5 ± 10.0 % for the right).

<table>
<thead>
<tr>
<th>Table 3. Comparison of Electromyography Activity for Left and Right Rectus and Biceps Femoris between Athlete and Control Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LB</strong></td>
</tr>
<tr>
<td><strong>F</strong></td>
</tr>
<tr>
<td>(mV)</td>
</tr>
<tr>
<td><strong>ATH</strong></td>
</tr>
<tr>
<td><strong>CON</strong></td>
</tr>
</tbody>
</table>

Data presented as mean (SD). Athlete Group (ATH), Control Group (CON), LBF= Left Biceps Femoris, LRF= Left Rectus Femoris, RBF= Right Biceps Femoris, RRF= Right Rectus Femoris.

<table>
<thead>
<tr>
<th>Table 4. Maximal Voluntary Isometric Contractions for Left and Right Knee Extensors and Flexors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LKT</strong></td>
</tr>
<tr>
<td><strong>PT</strong></td>
</tr>
<tr>
<td>(Nm)</td>
</tr>
<tr>
<td><strong>ATH</strong></td>
</tr>
<tr>
<td><strong>CON</strong></td>
</tr>
</tbody>
</table>

Data presented as mean (SD). Athlete Group (ATH), Control Group (CON), LKT PP= Left Knee Towards Peak Torque, LKT AT= Left Knee Towards Average Torque, LKA PT= Left Knee Away Peak Torque, LKA AT= Left Knee Away Average Torque, RKT PT= Right Knee Towards Peak Torque, RKT AT= Right Knee Towards Average Torque, RKA PT= Right Knee Away Peak Torque, RKA AT= Right Knee Away Average Torque.

**Speed and Agility**
Reaction time (RT) was significantly (p<0.0001) greater in the ATH compared to the CON (0.25 ± 0.11s vs. 0.41 ± 0.11s) (Figure 6). There was no between-group difference for vertical jump (VJ) (60.5 ± 8.6cm vs. 60.7 ± 8.2cm), 10-yard (10Y) (1.7 ± 0.20s vs 1.6 ± 0.15s), or 40-yard (40Y) (5.6 ± 0.15s vs 5.6 ± 0.27s) sprint speed. T-Test (TT) performance was significantly (p<0.0001) greater in ATH compared to CON (8.8 ± 0.29s vs. 9.2 ± 0.39s) (Figure 7).

*significantly different than CON (p< 0.0001)

Figure 6. Reaction Time and 10-Yard and 40-Yard Sprint Times Comparison between Athlete and Control Groups. Data presented as mean (SD). 10Y= 10 Yard Sprint, 40Y= 40 Yard Sprint Speed.
*significantly different than CON (p< 0.0001)
Figure 7. T-Test Performance Comparisons between Athlete and Control Groups. *significantly different than CON (p < 0.0001)
CHAPTER FIVE

DISCUSSION

The overall objective of this investigation was to comprehensively examine the postseason and early off-season physiological and performance capacities of a nationally ranked NCAA Division II male soccer team. Our findings highlight the physiological and performance limitations of these collegiate athletes following a competitive season. Such knowledge may provide insight as to the specific areas of soccer fitness that may require attention during off-season training for sufficient preparation prior to the subsequent competitive season. For instance, the collegiate soccer players (ATH) presented with inadequacies for body composition and anaerobic bioenergetic capacity when compared to recreational soccer players (CON) as well as mean values previously reported for elite level (i.e. professional) soccer teams.

First off, aerobic capacity and anaerobic threshold (AT) was similar between ATH and CON which was in line with our hypothesis. Moreover, it may initially indicate that the metabolic capacities for the athlete cohort to be substandard for optimum and competitive soccer performance. However, the mean VO$_2$ max of 54 ml$^{-1}$kg$^{-1}$min$^{-1}$ demonstrated by ATH falls only slightly below the average range of 55-65 ml$^{-1}$kg$^{-1}$min$^{-1}$ previously reported for elite professional and NCAA Division I soccer players (Vanfraechem & Thomas, 1993). Thus, it may be reasonably argued that aerobic capacity (i.e. VO$_2$ max) for male Division II soccer players is maintained at an adequate level during the competitive season and may not be a significant performance-limiting factor in the off-season. In fact, several prior investigations have reported no change in VO$_2$ max throughout the competitive season (Edwards, Clark, & Macfadyen, 2003; W. Kraemer et
al., 2004; T. Miller et al., 2007; Silvestre et al., 2006). Perhaps the rigor of physiological and metabolic demands of frequent soccer play and practice during the playing season sufficiently upholds aerobic capacity at an adequate, above-satisfactory level. Certainly, there are individual players who may need improvement in aerobic capacity over the off-season. However, from a team-wide perspective, at least for Division II soccer, the core metabolic training focus may be the improvement of AT as opposed to VO₂ max. To reiterate, AT reflects an intensity level relative to VO₂ max (i.e. percentage of VO₂ max) where bioenergetic contributions switch from aerobic to anaerobic metabolism. This is the point at which fatiguing mechanisms resulting from anaerobic metabolism is initiated. Thus, improving AT and the ability to sustain work at a higher percentage of VO₂ max would be advantageous for performance and fatigue resistance. Our collegiate athlete cohort compared similarly to the recreational control group in terms of AT. A multitude of prior investigations suggest that AT is the primary performance limiting factor for athletes of sports similar in nature to soccer (e.g. basketball). The mean AT for ATH was approximately 69% of VO₂ max which may be considered average for recreational athletes but far below the 80-85% reported by Finnish and Norwegian professionals (Hoff & Helgerud, 2004). However, there is a lack of data that provides insight as to the standard AT range for optimum performance in soccer at all competitive levels, especially for Division II NCAA male soccer and during early off-season periods.

Unlike aerobic capacity, our hypothesis was not supported when comparing the anaerobic bioenergetics between our two study cohorts. Unexpectedly, CON tested greater in peak power (PP) even when normalized to TBM and LBM compared to their age- and sex-matched athlete counterpart. At first glance, these results are unanticipated
because anaerobic power and capacity play a pivotal role in metabolically supporting
decisive moments of the game such as sprinting, jumping, and tackling. However, it is
important to note that reports demonstrated a reduction in anaerobic performance in
athletes at the conclusion of the competitive season likely due to a possible acute
overtraining syndrome (WJ Kraemer et al., 2004). Although the importance of
developing peak anaerobic power is well substantiated, anaerobic training programs
should primarily focus on improving the athlete’s anaerobic capacity or overall power
output throughout short-term, high-intensity muscular activity. In our present study, the
two cohorts presented no differences in mean power (MP) or fatigue index (FI) which is a
measure of anaerobic capacity. Since soccer is best characterized as a sport of repeated
sprints, having an adequate MP and FI would allow the athlete to continue competing at
high levels without premature fatigue. To further explain, the accumulation of blood
lactate, a byproduct of the glycolytic system, initiates overall fatigue and impedes
muscular contraction ultimately diminishing athletic performance. The ATH substandard
anaerobic power and capacity evidently leave a significant gap between their status and
that of normative values for soccer professionals (Davis, Brewer, & Atkin, 1992b;
Kalinski, Norkowski, Kerner, & Tkaczuk, 2002; J. Siegler, Robergs, & Weingart, 2006).
The off-season provides enough time to train anaerobic pathways that would concurrently
benefit other areas of soccer related fitness that are predominately fueled by those same
bioenergetic mechanisms.

A significant relationship has been observed between anaerobic power, sprinting,
and jumping performance in elite soccer players (Schmidtbleicher, 1992). Similar
morphological and biochemical determinants of acceleration, maximal speed, and agility
(i.e. fiber type proportion) have led to the assumption that these qualities are closely related (Baker & Nance, 1991). The requirement of high power production during each of the speed disciplines, which itself partly depends upon leg strength and fiber type proportion, could indicate that these two variables are interrelated (Little & Williams, 2005). However, research concerning this interconnection of speed qualities have been inconsistent in previous findings (Little & Williams, 2005). For example, some studies have found significant positive correlations between performance in agility T-Test and 40Y sprint time (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000). In contrast, another study reported no significant correlations between sprinting and agility test performance (Buttifant, Graham, & Cross, 1999; Young, Hawken, & McDonald, 1996). These results were mirrored in our present study. ATH tested similarly to CON in the 10Y and 40Y sprint times, but tested better in agility. Furthermore, ATH tested favorably in 10Y and 40Y sprint times compared to other semi-professional and professional European soccer players but worse in agility assessments (Brewer & Davis, 1992; Cometti, Maffiuletti, & Pousson, 2001; Davis et al., 1992b; Hof & Helgerud, 2004). The disparity with previous research may be partly attributable to the various methods of assessment for different speed-related variables. As of yet, no criterion tests exist for acceleration, maximum speed, or agility. Further work is necessary to address this presently unresolved issue.

In addition to the aforementioned performance limitations highlighted by our data, body composition has previously shown to impact performance in sports that require an element of optimum endurance, anaerobic power, and agility (Silvestre et al., 2006). More specifically, BF% and LBM are key considerations in the physical make-up

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of professional soccer players (Sutton, Scott, Wallace, & Reilly, 2009). Maintaining adequate levels of these body composition variables may facilitate the generation of muscular power needed to overcome body inertia in a multitude of stop-and-go movements (Chena Sinovas et al., 2015). A disruption in balance between the two variables, i.e. excessive adiposity, may augment the energy and forces needed to accelerate and decelerate the body during competition and therefore elicit a negative impact on bioenergetic efficiency and overall rate of fatigue. The mean BF% of ATH (16.5%) was on average greater than that of Turkish professionals (6.4%) and other elite level soccer players (13.9%) (Kalapotharakos et al., 2006; W. Kraemer et al., 2004; Mujika, Santisteban, Impellizzeri, & Castagna, 2009). Given ATH’s comparatively high level of adiposity, it could be reasonably argued that the less than optimal BF% may have been a significant performance limiting factor during the competitive season. Adding further support, previous studies have reported lower BF% at the end of the season due to the high and compounding volume of practice, training, and competition during season (Casajús, 2001; Edwards et al., 2003). Initial reactions to these results may incline coaches to enforce strict nutritional diets and implement fat loss training regimens, however data suggest that these interventions should target LBM growth as opposed to body fat loss (Milsom et al., 2015). Adopting this approach and improving LBM may be advantageous for performance and injury prevention (Chena Sinovas et al., 2015). There is a connection between cross-sectional area of skeletal muscle and its potential for force development (Schmidtbleicher, 1992). However, for many soccer players, an increase in bodyweight as a result of skeletal muscle growth may be undesirable because the player must transport a higher amounts of body weight. In addition, an increase in LBM does
not necessarily increase high velocity strength (i.e. muscular power). Therefore, a soccer player must methodically train to increase functional LBM while concurrently reducing fat mass to augment muscular strength and power. Our ATH cohort reported LBM values similar to their recreational counterpart, however compared unfavorably against English professionals (Milsom et al., 2015). Due to the lack of existing normative data for both optimal BF% and LBM, it may be an over-speculation to state that ATH exhibits substandard body composition. Nonetheless, it is well warranted that ATH could better optimize both BF% and LBM to augment on-field performance.

After examining a multitude of physiological and performance markers and taking into account soccer’s mercurial nature, an ideal physique and physiology may not be sufficient to excel in the sport. Other components such as technique, tactics, and strategy of the coach play a key role in the finals results. However, profiling may be useful in a player’s selection and development for specific training programs. Experienced coaches may use the impartial data to avoid possible errors and maximize the chance of preparing the team well. Furthermore, knowing which markers are statistically known to diminish, remain unchanged, or improve after the playing season allows for a sophisticated approach to an off-season training program geared towards achieving normative values. Athletes who are proactive and avoid any significant detraining during the off-season enter the competitive season with higher levels of sport specific fitness. This places the team in an overall advantageous position which enables coaches to allocate a larger fraction of the allowed practice time to the technical and tactical development of players. The ultimate goal of athlete profiling research should be centered on producing sufficient data to support the synthesis of normative values across a spectrum of standardized or
experimental testing protocols, especially in a manner specific to sex and competitive levels.
REFERENCES


APPENDIX A

Informed Consent Form

California State Polytechnic University, Pomona
Informed Consent Form for Research Involving Human Subjects

Approved by the Cal Poly Pomona Institutional Review Board under protocol #16-39

You are being invited to participate in a research study, which the Cal Poly Pomona Institutional Review Board (IRB) has reviewed and approved for conduct by the investigators named here. This form is designed to provide you - as a human subject/participant - with information about this study. The investigator or his/her representative will describe this study to you and answer any of your questions. You are entitled to an Experimental Research Subject’s Bill of Rights and a copy of this form. If you have any questions about your rights as a subject or participant, complaints about the informed consent process of this research study, or experience an adverse event (something goes wrong), please contact the Research Compliance Office within Cal Poly Pomona’s Office of Research at 909.869.4215. More information is available at the IRB website, http://www.cpp.edu/~research/irb/index.shtml.

Project Title: NCAA Men’s Soccer Physiological Testing

Principal Investigator (PI)
Dr. Edward Jo
California State Polytechnic University, Pomona
Email: ejo@cpp.edu
Office Phone: (909) 869-5499

Research Assistant
Daniel Higuera
California State Polytechnic University, Pomona
Email: higuera@cpp.edu

Participant’s printed name: _____________________________________________

This is a research study. Research studies include only those who want to take part. This form gives you information about this research, which will be discussed with you. It may contain words or procedures that you do not understand. Please ask questions about anything that is unclear to you. You may discuss it with others and take time to make your decision.

You are being offered the opportunity to take part in this research because you are: 1) 18-32 years old male and 2) either a recreationally active (i.e. 3-6 hours/week of aerobic exercise, resistance exercise, concurrent training (combination of aerobic and resistance) or recreational sports within the past 6 months) or a student-athlete of the Cal Poly Pomona (CPP) Men’s Soccer program. You will be excluded from participation if you: 1)
have a history of medical or surgical events in which the study protocols would be contraindicated or confound the interpretation of results. These include, but are not restricted to, cardiovascular, metabolic, pulmonary, renal, or kidney diseases, hypertension, or musculoskeletal impediments; 2) use any medication including those with cardiovascular, pulmonary, thyroid, hyperlipidemic, hypoglycemic, hypertensive, endocrinologic, psychotropic, neuromuscular, neurological, or androgenic implications; 3) are pregnant; 4) use daily ergogenic aids or dietary sports supplements within 6 weeks prior to the study (use of nutritive supplements, e.g. whey protein, will be permissible).

Approximately 50 people (25 athletes and 25 recreationally active control) will be recruited to participate in this study.

**Purpose of the research**
The purpose of this study is to develop a comprehensive physiological profile on the CPP men’s soccer team and compare their results to a control group composed of recreationally trained college aged males.

**Procedures to be followed**
Participation in this study will require you to visit the Human Performance Research Lab (Building 43, Room 202b) at California State Polytechnic University, Pomona 3 times across approximately 2 weeks with each visit lasting 1-2 hours. During your first visit to the lab, you will be given this Informed Consent Form to sign and an exercise and health history questionnaire to complete before you can participate. You will also be tested for your body weight and height and lower and upper limb circumference and length using simple and standard testing procedures. Next you will undergo testing for body composition. This procedure will involve dual energy x-ray absorptiometry (DXA) which emits very low dose x-ray radiation (see below for minimal risks). This test will require you to lay flat on your back on a cushioned machine for about 5-10 minutes while the DXA analyzer scans your entire body. A licensed x-ray technician will administer this procedure. Afterwards, you will perform a VO$_{2\,\text{MAX}}$ test which involves treadmill running while wearing a rubber (non-latex) mask connected to a metabolic gas analyzer called a metabolic cart via plastic tubing. During the test you will be asked to run with increasing incline or speed with progressive stages. The test may last approximately 10-15 minutes depending your performance. Prior to the test, we will administer basic tests to assess your heart rate and blood pressure to ensure these measures are within safe parameters.

After your first visit, you will be asked to return to the lab in 2 days. During the second visit you will be tested for leg strength on a machine called an isokinetic dynamometer, which is a commonly used device for therapy and muscle testing. After a light warm-up activity, a trained researcher will position you properly on the seat of the machine and strap you in securely. You will perform 2 practice repetitions of an exercise that requires you to extend your lower leg and then bring it back towards you. These motions will be performed one after the other with full effort. Then, you will perform the exercise for 5 more repetitions of each motion. You will perform 3 sets each with slightly different speed of motion. You will then perform 3 trials of the same motions against an immovable device attached to the dynamometer with full effort. You will be provided
sufficient rest time between each strength test. Afterwards, you will perform a Wingate Anaerobic Cycling Test. During this test, you will be asked to cycle against a resistance equal to 7.5% your body weight with maximal effort for 30 seconds. You will be given sufficient time for warm-up as well as cool-down.

You will then return to the lab at least 2 days later for your third visit. During this visit, you will perform a series of performance tests which include: 1) dynamic weight squat jumps, 2) vertical jump, 3) 40 yard dash, and 4) T-test (agility test). Each test will require lower body exercise with maximal effort. You will be provided sufficient warm-up and cool-down periods. Upon completion of visit 3, you will have completed the entire study.

**Minimal discomforts and risks**
The risks associated with the procedures are minimal and the selected protocol has been implemented in previous research studies. There is a possibility that muscle soreness or musculoskeletal injury will occur from the exercise testing protocols. The risk of soreness will be minimized by implementing proper warm-up and adequate recovery periods. The exercise testing protocol will also be supervised and administered by a certified strength and conditioning specialist (CSCS) (PI and Research Assistant) who is qualified to ensure proper and safe exercise conditions for the participant. There is a minimal risk of hypoglycemia and/or cardiac complications during the protocol. To minimize this risk, researchers will 1) exclude participants who demonstrate or report cardiovascular/pulmonary and metabolic health conditions during pre-screening procedures, 2) monitor heart rate (HR) and blood pressure before exercise to ensure that it is within safe parameters to begin exercise and 3) have glucose incorporated drinks (Gatorade) available in the event hypoglycemic symptoms are observed. All researchers will be cognizant of overt signs of pain and discomfort that is unusual to normal levels elicited by the protocol. There are no notable risks associated with any laboratory testing procedures; although, DXA testing will involve exposure to radiation. However, the amount of radiation averaged over the entire human body is equivalent to 1/30 of the amount of natural background radiation and is too small to measure. It is of little consequence when compared to other everyday exposure risks. Participation is voluntary and you can withdraw at any time without penalty. The nitrate supplement contains blood pressure lowering ingredients. However this effect has not been shown to be potent enough to elicit a harmful drop in blood pressure. To minimize the risk of dangerously low blood pressure, hypotensive individuals will be excluded from participation.

**Possible Benefits to the Participant**
Possible benefits you may experience from participating in this research includes: 1) free laboratory assessments of body composition (~$100 value) and performance and 2) learning about your body’s physiology and fitness level.

**Other options that could be used instead of this research**
You do not have to take part in this research study.
**Time duration of the procedures and study**
If you agree to take part in this study, your involvement will last a total of 2 weeks. You will be asked to visit the laboratory for testing on 3 separate occasions. Each visit to the laboratory will take approximately 1 to 2 hours.

**Statement of Confidentiality**

*a. Privacy and confidentiality measures*
Your research records that are reviewed, stored, and analyzed at California State Polytechnic University, Pomona will be kept in a secured area in a locked office with access only to the principal investigator. You will be assigned a subject code number and all records and data sheets acquired from this study will only be associated with the subject code and none of your personal information. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

**Costs for Participation**
There will be no direct cost to you for participation in this study.

**Compensation for Participation**
There will be no monetary compensation for participation.

**Voluntary Participation**
Taking part in this research study is voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. If you are a student of Cal Poly Pomona, withdrawal from this study or decision not to participate will not negatively affect anything related to your academic grades or classes nor will participation have any beneficial effect on any class or grades.

**Contact information for questions or concerns**
You have the right to ask any questions you may have about this research. If you have questions, complaints or concerns contact Dr. Edward Jo at (909) 869-5499 or ejo@cpp.edu.

**Signature and Consent/Permission to be in the Research**
Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

**Participant:** By signing this consent form, you indicate that you are voluntarily choosing to take part in this research.

<table>
<thead>
<tr>
<th>Signature of Participant</th>
<th>Date</th>
<th>Time</th>
<th>Printed Name</th>
</tr>
</thead>
</table>

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**Person Explaining the Research:** Your signature below means that you have explained the research to the participant/participant representative and have answered any questions he/she has about the research.

<table>
<thead>
<tr>
<th>Signature of person who explained this research</th>
<th>Date</th>
<th>Time</th>
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<td>Printed Name</td>
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**Principal Investigator**

<table>
<thead>
<tr>
<th>Dr. Edward Jo</th>
<th>Date</th>
<th>Time</th>
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(Only approved investigators/research coordinators and those trained in obtaining research informed consent and familiar with this research may explain the research and obtain informed consent.)
APPENDIX B

Data Collection Sheet

<table>
<thead>
<tr>
<th>SUBJECT #</th>
<th>SUBJECT (initials):</th>
<th>GROUP (circle one): Athlete / Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESTER (initials):</td>
<td>DATE:</td>
<td>TIME OF ARRIVAL:</td>
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### ANTHROPOMETRIC MEASUREMENTS

<table>
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<tr>
<th>MEASURES</th>
<th>LBS</th>
<th>KG</th>
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<tbody>
<tr>
<td>Total Body Weight</td>
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<tr>
<td>Height</td>
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<tr>
<td>Body Mass Index</td>
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- Perform DXA scan and attach report

### VO₂ MAX GRADED MAXIMAL TEST

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Incline (%)</th>
<th>VO₂ (l/m)</th>
<th>VO₂ (ml/kg/min)</th>
<th>HR (BPM)</th>
<th>RER</th>
<th>RPE</th>
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If a plateau is not reached, all of these criteria must be met in order to claim VO₂max was reached.

1) ± 10 beats of maximal heart rate max (220-age)
2) RPE of ≥ 18
3) RER of over 1.1
## ISOKINETIC AND ISOMETRIC DYNAMOMETRY (Biodex)

### PRE-TEST CHECKLIST:
1. EMG Set-up
2. 5-minute warm-up activity completed
3. Dynamometer position set

### DYNAMOMETER POSITION SETTINGS

<table>
<thead>
<tr>
<th>Lateral Arm Position</th>
<th>Forward Seat Position</th>
<th>Back Support Position</th>
<th>Attachment Length</th>
<th>Dominant Side</th>
</tr>
</thead>
</table>

### ISOMETRIC TESTING: 60°

### JOINT MOVEMENT

<table>
<thead>
<tr>
<th>PEAK TORQUE (Nm)</th>
<th>RELATIVE PEAK TORQUE (Nm/TBM kg)</th>
<th>RELATIVE PEAK TORQUE (Nm/LBM kg)</th>
<th>AVG POWER (W)</th>
<th>RELATIVE AVG POWER (W/TBM kg)</th>
<th>RELATIVE AVG POWER (W/LBM kg)</th>
</tr>
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<tbody>
<tr>
<td>Knee Extension</td>
<td>L R L R L R L R L R L R</td>
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<tr>
<td>Knee Flexion</td>
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### WINGATE ANAEROBIC TEST

### ERGOMETER SETTINGS

- Seat Height: 
- Resistance (7.5% BW): 

### POWER AND AGILITY

<table>
<thead>
<tr>
<th>40 Yard Dash (s)</th>
<th>T-Test (s)</th>
<th>Vertical Jump (in)</th>
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