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Seasonal Perceived Training Load in NCAA DI Men's Soccer: Is There a Dose-Response Relationship?

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Seasonal Perceived Training Load in NCAA DI Men's Soccer:

Is There a Dose-Response Relationship?

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by

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ABSTRACT

Seasonal Training Loads and Fitness Changes in Male NCAA DI Men's Soccer:

Is there a Dose-Response Relationship?

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The purpose of this dissertation was to determine if a there was a dose-response relationship across an NCAA Division I men's soccer season. Specifically, this dissertation serves to: 1.) assess the validity of duration measurements that have previously been used to calculate session RPE during competitive matches, 2.) determine the degree and magnitude of change in intermittent endurance performance across a season and to observe how change in endurance relates with training load, 3.) determine the degree and magnitude of change in strength and explosiveness across a season, and to see how these strength changes relate to training load. 1.) Minutes played were found to be the most accurate duration for calculating session RPE during men's NCAA Division I soccer matches. 2.) Endurance performance, measured using the Yo-Yo IR1, increased by an average of 14 percent from pre to post season. Furthermore, a large, negative relationship was observed between training load and change endurance performance. These relationships suggest that excessive accumulation of training load can impair endurance performance. The congested NCAA DI match schedule may make it difficult to prevent excessive training loads. 3.) When players were grouped by amount of college soccer experience (upper and underclassmen), upperclassmen jumped significantly higher than underclassmen during the preseason. Moreover, the upperclassmen maintained or increased jump height from pre to post season, while underclassmen experienced a general decrease in jump height from pre to post season. Moderate relationships indicate a positive relationship

between training load from resistance training and changes in strength. Likewise, these same relationships strengthened in the players who received more playing time during matches. Taken together, the high numbers of moderate relationships indicate a high level of individual variability. Dose-response relationships with strength variables were not sufficiently established. The overall findings of this dissertation provide evidence that subjectively and objectively monitoring training load and soccer-related performance variables can assist coaches in making decisions that will promote the welfare of their team.

DEDICATION

This dissertation is dedicated to my family. To my wife, for your constant support and the sacrifices you made to get me here. You selflessly moved several times to help further my education. You never stopped believing in me, even when I may have doubted myself. Thank you, words cannot express my appreciation.

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CHAPTER 1

INTRODUCTION

A scientific approach begins with quantifying training loads, and then observing how those training loads effect physical performance measures (Alexiou & Coutts, 2008; Borresen & Lambert, 2009; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Morgans, Orme, Anderson, & Drust, 2014; Rodriguez-Marroyo & Antonan, 2015). Training loads can be quantified in a number of ways and can be placed in one of two categories: internal or external (Impellizzeri, Rampinini, & Marcora, 2005). External load generally consists of stimuli that are imposed on the athlete (distance covered or duration of activity), while internal loads are the body's physiological response to those stimuli (heart rate or difficulty rating).

One of the simplest methods for quantifying internal training load is called session rating of perceived exertion (session RPE) (Foster et al., 2001). These training loads are presented in arbitrary units as the product of the session difficulty rating on a category ratio 1—10 scale and the session duration (minutes). This simple measure has been found to be a global indicator of training load (Day, McGuigan, Brice, & Foster, 2004; Impellizzeri et al., 2004). Herman et al. (2006) reported session RPE as a reliable measure of easy, moderate, and hard cycling and treadmill exercise using regression analysis ($R^2 = 0.78$). Moreover, Day et al. (2004) reported an intraclass correlation coefficient of 0.88 for session RPE during resistance training. Large to very large correlations have been reported between session RPE and heart rate loading methods for various team sports like men's ($r = 0.71$) (Impellizzeri et al., 2004) and women's ($r = 0.60$-0.82) (Alexiou & Coutts, 2008) soccer, basketball ($r = 0.69 – 0.85$) (Manzi et al., 2010), and rugby ($r = 0.89$) (Gabbett & Domrow, 2007).

Session RPE has been shown to be a viable method for monitoring training load during soccer training (Alexiou & Coutts, 2008; Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013; Impellizzeri et al., 2004), but to the author's knowledge, no study has examined its ability to quantify training load during competitive men's college soccer matches. At the NCAA division I level, rules regarding substitutions differ from the professional level in that players are allowed one re-entry in the second half. This may cause changes in the durations that players are in the game and the corresponding physical loads imposed on them. Under college soccer game conditions, the calculation of session-RPE may be overestimated using the duration of the entire session as a factor to calculate training load. One might wonder if the duration of the warm-up, cool-down, and stoppages should be included in the total duration. Manzi et al. (2010) defined the duration of a professional basketball game as (excluding warm-up) from the start to the end of the game including all stops. Research examining other perceived exertion scores during professional soccer matches excluded warm-up and half time rest periods with no evidence to support this reasoning (Arcos, Martínez-Santos, Yanci, Mendiguchia, & Méndez-Villanueva, 2015; Gil-Rey, Lezaun, & Los Arcos, 2015; Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014). Apart from the few aforementioned studies, much of the previous literature evaluating session RPE during soccer either uses training sessions only (Casamichana et al., 2013; Impellizzeri et al., 2004; Rodriguez-Marroyo & Antonan, 2015; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013) or simply cites the Foster et al. (2001) study (Akubat, Patel, Barrett, & Abt, 2012; Alexiou & Coutts, 2008). Therefore, one aim of this dissertation will be to examine the inclusion or exclusion of warm-up, cool-down, and game stoppages to determine the ideal representation of session RPE during competitive soccer matches. In order to assess the proficiency of session-RPE during competitive soccer matches, data can be compared to external training loads measured using time-motion analysis.

The recent development of time-motion analysis technology such as global positioning systems (GPS) and video analysis has allowed coaches to quantify external training loads during team sport activities. Variables produced by these time-motion systems include total distance covered and distances covered at various velocity bands (Aughey, 2011; Cummins, Orr, O'Connor, & West, 2013). In addition, some GPS devices contain gyroscopes and accelerometers that can provide additional agility-related training load information (Cummins et al., 2013). With all the training load metrics out there, no single training load metric is sufficient by itself. However, when multiple training load variables are combined and observed over time, they can provide a scientific explanation of changes in performance potentially reduce the risk of injury, illness, and nonfunctional overreaching (Halson, 2014). Furthermore, training load data may be combined with fitness test results to create a dose-response relationship. From this, a coach will be able to determine the amount of training that is required to improve performance (Akubat et al., 2012; Gabbett & Domrow, 2007). At present, little is known about the training loads imposed on college soccer players and the changes in fitness that occur across a season. This information could prove useful in reducing injury, illness, preventing overtraining, and helping coaches predict desired training responses.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this paper is to review the literature surrounding the dose-response relationship in soccer. That is, methods for quantifying training loads and measuring fitness. The first section of this paper will briefly review the physical demands of soccer. The measurement of training load is fundamental to the purpose of this dissertation. Therefore, the history of the development of various methods for quantifying training load will be examined in the second section of this literature review. In order to establish a dose-response relationship, both training load information, and physical fitness test scores are needed. As a result, physical fitness tests will be reviewed. Finally, the studies examining the dose-response relationship will be reviewed and a summary will be provided.

Physical Demands of Soccer

At the elite level, soccer players generally cover 10-12 km in a 90-minute match (Bangsbo et al., 2006; Bangsbo et al., 1991; Di Salvo et al., 2007; Di Salvo et al., 2013). About 2500 to 3000 m of this distance is covered at a running pace (>14.4 km h^{-1}) (Di Salvo et al., 2013). The remaining distance is covered at low intensities. Soccer players perform 150-250 brief, high-intensity actions (Mohr et al., 2003). Given these basic demands of a soccer match, higher quality players tend to be characterized by their ability to perform repeated, high-intensity efforts (Mohr et al., 2003). Furthermore, fatigue has been reported to be a factor late in matches, as players tend to cover less distance at high-intensities towards the end of the match (Mohr et al., 2003). The likely cause of this is muscle glycogen degradation (Rico-Sanz et al., 1999). It has been reported that 48 (Rampinini et al., 2011) to 72 (Ispirlidis et al., 2008) hours are needed to recover from a soccer match.

The high physical demands of soccer create situations where overtraining or nonfunctional overreaching may present themselves. By monitoring training load and fitness parameters, coaches can observe the recovery status of their players, so that they can modify training programs to not only avoid injury, but enhance the athlete's performance.

Measurement of Training Load

The general monitoring of athletes seeks to determine the dose-response relationship of overall training and other stressors that are imposed on an athlete (Stone et al., 2007). The dose-response relationship has been well documented in research modeling endurance performance (Banister, 1991; Banister et al., 1999; Morton et al., 1990). However, in a sport such as college soccer where performance is not as easily defined and competition is frequent (2-3 matches per week), opportunities to assess training outcomes are difficult. Thus, understanding the dose-response relationship in soccer players could allow predictions of training effects. In general, exercise 'dose' or training load has been categorized as either internal through the use of session RPE (Foster et al., 2001) or heart rate (Impellizzeri et al., 2005), or external through the use of time-motion analysis (Di Salvo et al., 2007) using cameras or global positioning systems (GPS).

Session RPE

Session RPE was developed by (Foster et al., 2001) as a subjective method for quantifying the internal training load experienced by an athlete. It is presented in arbitrary units as the product of the global intensity of the session and the duration of the session. The intensity is represented by a number selected from a 10-point scale originally proposed by Borg et al. (1987). The session RPE represents a single global rating of the intensity of the entire session (Foster, 1998; Foster et al., 2001; Impellizzeri et al., 2004). Other studies have evaluated other perceived exertion scales based on perceived exertion of the muscle and respiratory systems

(Arcos et al., 2015; Gil-Rey et al., 2015; Los Arcos et al., 2014; Yanci et al., 2014) or perceived effort and perceived physical demands (Rebelo et al., 2012). However, these are beyond the scope of this section as we will primarily focus on studies that have used the Foster et al. (2001) protocol.

Herman et al. (2006) reported session RPE as a reliable measure of easy, moderate, and hard cycling and treadmill exercise using regression analysis ($R^2 = 0.78$). Moreover, Day et al. (2004) reported an intraclass correlation coefficient of 0.88 for session RPE during resistance training. Large to very large correlations have been reported between session RPE and heart rate loading methods for various team sports like men's (r = 0.71) (Impellizzeri et al., 2004) and women's (r = 0.60-0.82) (Alexiou & Coutts, 2008) soccer, basketball (r = 0.69 – 0.85) (Manzi et al., 2010), and rugby (r = 0.89) (Gabbett & Domrow, 2007). For these studies, validation of session RPE was based largely on relationships with summated heart rate training load scores, which itself tends to lack validity across all exercise intensities (Gilman, 1996). While heart rate may be a valid indicator of endurance exercise intensity (Karvonen & Vuorimaa, 1988), and thus be used to estimate training load, it may not be as effective for intermittent activities (Achten & Jeukendrup, 2003; Akubat & Abt, 2011; Tumilty, 1993). To account for this other, non-heart rate derived methods of quantifying training load have been compared with session RPE. Plasma lactate concentration has been shown to be a marker of anaerobic activity. Gabbett and Domrow (2007) reported a very large correlation (r = 0.86) between plasma lactate concentration and session RPE. Others have found weaker, yet large, relationships (r = 0.63) between RPE and blood lactate concentrations during small-sided soccer games (Coutts et al., 2009). Casamichana (2013), reported that session RPE had a stronger relationship with time-motion variables of total distance (r = 0.76) and Player load (0.74) than the Edwards heart rate method (r = 0.57) during training in semiprofessional male soccer players. Likewise, (Scott et al., 2013) found strong relationships between session RPE and the following: distance, high speed running, and player load with correlations of r = 0.81, r = 0.71, and r = 0.83, respectively in team sport athletes that underwent intermittent, high-intensity exercise. In contrast, they found poor reliability with the RPE rating scale (31.9% CV) after short bouts of intermittent running.

Session Duration

Studies that examined the dose-response relationship in soccer athlete populations have found small relationships when session RPE was used to calculate training load (Gabbett & Domrow, 2007). However, other studies have found more convincing dose-response relationships when duration of training and matches were used (Brink et al., 2010; Silva et al., 2011). Thus, it may be possible that using a more time-sensitive method for quantifying session RPE may allow for the determination of a considerable dose-response relationship.

While the intensity rating has received much of the focus, little research has attempted to define the duration of a training session. When calculating session RPE, many authors likely felt that the Foster et al. (2001) definition was sufficient, and thus, do not clearly define their exact methods of determining session duration (Alexiou & Coutts, 2008; Casamichana et al., 2013). Furthermore, all of the aforementioned studies examined session RPE during training. Few studies have included competitions, where there are more things to consider in the total session duration such as a warm-up, cool-down, and game stops (Figure 1). Impellizzeri et al. (2004) assessed session RPE during training and competitive matches, with no exact description of the durations he used for matches. Warm up and half time periods could add another 30 to 45 minutes.

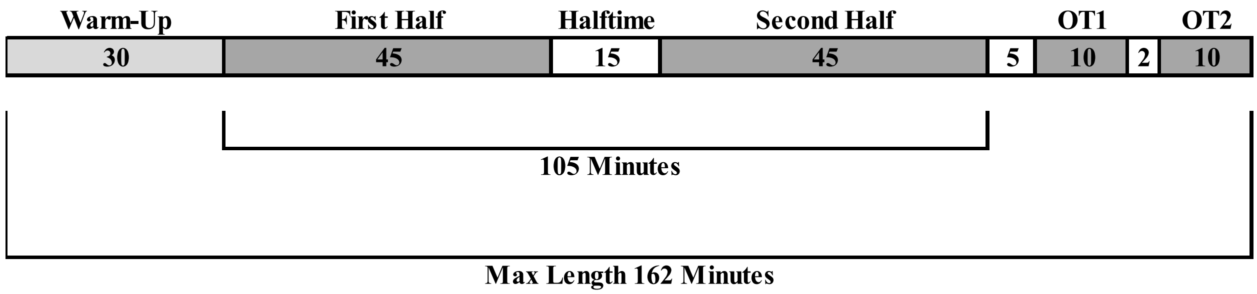

Figure 1. Duration of a National Collegiate Athletic Association soccer match.

In a group of basketball players, Manzi et al. (2010) defined game session duration as the start to the end of the game, which included all game stops, but neglected warm-up and cool down. Other studies using perceived training load scores have defined duration as from the start of the game to the end, not including warm-up or stoppages (Arcos et al., 2015; Gil-Rey et al., 2015; Los Arcos et al., 2014). These methods may be worthy for monitoring professional athletes, where they routinely play the entire match, but for the substitute players, who play a small part of the match; training loads are likely overestimated. Perhaps, the session duration should be the amount of time that they participated in the match. In addition, these methods would be more consistent with time-motion analysis, which tends to exclude periods when players are inactive.

<u>Time-Motion Analysis</u>

Time-motion analysis began as an extremely time consuming and laborious process in soccer about forty years ago (Reilly & Thomas, 1976). Scientists had to review game film and manually record distance and time information for their analysis. Today, technology has immensely improved the usability of these methods. There has been a growing popularity for time motion analysis in soccer via the use of GPS tracking (Catapult) and digital video analysis (ProZone™). In particular, GPS tracking is becoming more common in college soccer. Time-motion analysis via digital video is difficult in college soccer because several cameras must be permanently mounted and calibrated throughout a stadium, whereas GPS is simple to setup and works in all open-roof stadiums. This makes GPS easy to use while traveling.

Variables produced by these time-motion systems include total distance and distances covered at various velocity bands (Aughey, 2011; Cummins et al., 2013). In addition, some GPS devices contain gyroscopes and accelerometers that can provide additional agility-related training load information (Cummins et al., 2013).

The reliability of GPS for monitoring movement is influenced by factors such as sample rate, player running velocity (Rampinini et al., 2015), activity duration, change of direction, and distance (Jennings et al., 2010; Johnston et al., 2014). Early GPS technology had low sample rates (1 to 5Hz) and was not acceptable for the quantification of short, high intensity intermittent running patterns (Jennings et al., 2010).Johnston et al. (2014) found that higher movement speeds resulted in higher levels of error (%TEM = 0.8 – 19.9) with 10 and 15 Hz GPS units. Overall, they found that the 10 Hz unit had the highest validity and interunit reliability. This may be due to the fact that the 15 Hz unit was really a 10 Hz GPS. To achieve the 15 Hz sample rate, data from the 10 Hz GPS were augmented with data recorded using a 100 Hz accelerometer (Aughey, 2011). At present, when calculating displacement, it seems that using GPS data alone is a superior method (Johnston et al., 2014).

The MinimaxX S4 has been found to be a valid and reliable measure of total distance (< 1% error) (Johnston et al., 2014). Measures of high speed running distance (14.0 - 19.9 km/hr) ranged from moderate to good (<10% error). Poor levels of error were evident when measuring distances covered at velocities greater than 20 km/hr (11.5%). Similarly, measures of peak speed were not found to be valid. Overall, the higher velocities caused a reduction in measurement accuracy.

Overall, measures of total distance during games and practices seem to be the most valid and reliable measures of GPS technology (Coutts & Duffield, 2010; Jennings et al., 2010; Johnston et al., 2014). Measures higher velocity running (>14km/hr) with frequent changes in direction tend to produce more error, and therefore are less valid. In addition, measures using accelerometry (Player Load) have been shown to be valid and reliable indicators of physical activity in team sports (Boyd et al., 2011). To date, 10 Hz GPS devices seem to be the most valid and reliable for quantifying team sport activities (Scott et al., 2015).

Physical Fitness Tests

Compared to individual sports like track and field (Halson, 2014), overall soccer performance during competitions is very difficult to objectively assess. Therefore, regular physical fitness assessment is a necessary component of athlete monitoring for soccer. Physical fitness testing can tell a coach what physical abilities an athlete is good at, and what physical abilities need to be improved during future training cycles.

When choosing the right test, coaches need to make sure that the test is both reliable and valid. Furthermore, they need to ensure that the test is measuring physical characteristics that are specific to their sport. Fitness components that are associated with superior performance in soccer include strength (Comfort et al., 2014; Silva et al., 2015; Wisloff et al., 2004) and endurance (Stolen et al., 2005; Wisloff et al., 1998). Strength is the ability to produce force (Stone, 1993; Stone et al., 2004) and can be measured through a variety of dynamic, isokinetic, or isometric exercises. Endurance, on the other hand can be measured in a number of ways on the field or in the lab. In the coming paragraphs we will review two primary strength assessment techniques: the isometric mid-thig pull (IMTP) and vertical jump. In addition, we will review a common endurance field test, the Yo-Yo IR1.

<u>Isometric Strength</u>

The importance of IMTP testing in track cycling (Stone et al., 2004), track and field (Stone et al., 2003), football (McGuigan & Winchester, 2008), sprinting (Sha et al., 2014) and weightlifting (Stone et al., 2005) has been previously demonstrated. Variables that have been considered as important factors for sport performance include: peak force (PF) and rate of force development (RFD) (Taber et al., 2016). RFD at 50 and 90ms has been reported to be large to very large correlated with 60m sprint velocity (r = 0.61 and 0.74, respectively) (Sha et al., 2014). Furthermore, force at 50 and 90ms produced similar relationships (r = 0.58 and 0.69, respectively). These data suggest that multi-joint isometric tests can predict sprint performance.

Haff et al. (1997) reported large to very large correlations between isometric peak force during a IMTP and a dynamic MTP performed at 80, 90, and 100 percent of power clean 1-RM (r = 0.66, 0.77, and 0.80, respectively). Moreover, isometric RFD was very largely correlated with dynamic RFD at 80, 90, and 100 percent of power clean 1-RM (r = 0.84, 0.88, and 0.84, respectively). Furthermore, isometric peak force and RFD have bene identified to be underlying mechanisms related to vertical jump performance (Kraska et al., 2009; Stone et al., 2003). The faster one can produce force, the faster one can accelerate one's body while jumping.

<u>Vertical Jump</u>

Vertical jumps are commonly used to assess strength in soccer players (Arcos et al., 2015; Caldwell & Peters, 2009; Comfort et al., 2014; Gil-Rey et al., 2015; Magal et al., 2009). Jumping tasks are regularly performed during competitive matches (Stolen et al., 2005). Depending on the strength quality one is looking to assess, they can be performed without a stretch-shortening cycle (SSC) by using a static, concentric-only start, or with a SSC, in the form of a countermovement or depth jump. External loads may also be applied. Each type of jump can tell a sport scientist about an athlete's strength qualities. Vertical jumps have been measured using measuring tape, video, force plates, switch mats, jump belts, LED timing gates, etc. (Klavora, 2000). With these various measurement devices, many variables can be measured during a vertical jump: displacement, velocity, flight time, force, power, RFD, and impulse.

The regular assessment of vertical jump can provide the sport scientist with a record of performance across a competitive soccer season, which may be used to establish a dose-response relationship (Arcos et al., 2015; Gil-Rey et al., 2015). In addition, the vertical jump can be used to evaluate training programs, monitor fatigue (Sams, 2014), and evaluate athlete performance.

Vertical jumps have been shown to largely correlate with 10m ($r = 0.72$) and 30m ($r = 0.60$) sprint performance in soccer players (Wisloff et al., 2004). In a group of elite junior track and field athletes, maximum sprinting velocity was very largely related to countermovement jump height ($r = 0.77$) (Young et al., 1995). These results may be due to the fact that sprinting velocity is largely a result of vertical ground reaction forces (Weyand et al., 2000).

Soccer-Specific Endurance

Because soccer is an intermittent sport, soccer-specific endurance tests tend to try to mimic that exercise pattern. Some tests include direction changes (Bangsbo et al., 2008; Hoff et al., 2002; Mizuguchi et al., 2014), while others do not (Leger & Boucher, 1980). Although changes in these test scores generally mean changes in fitness, we cannot say whether improvements in these tests lead to improved soccer performance.

The Yo-Yo intermittent recovery test (IR1) is a popular field test that is used by soccer coaches (Castagna et al., 2006; Impellizzeri et al., 2005; Markovic & Mikulic, 2011; Mohr et al., 2003; Rampinini et al., 2010). The test consists of 20-m shuttle runs of increasing speed interspersed by 10s of an active recovery 5m shuttle (Bangsbo, 1994). The results of the test are expressed as total distance covered (m). Krustrup et al. (2003) assessed the reliability (CV 4.9%) and validity (r = 0.71 with VO_2 max and high intensity running distance during soccer matches) of the Yo-Yo IR1 test. Heart rate data indicated that the test maximally stimulated the cardiovascular system, while muscle biopsy and blood analysis further revealed both aerobic and anaerobic energy system use. Together these outcomes are, to some degree, reflective of the intermittent nature of soccer match play. Likewise, the Yo-Yo IR1 was highly correlated (r = 0.71) with both VO_{2max} and high intensity running distance (>15 km/hr, r = 0.71) during soccer matches (Krustrup et al., 2003). At the youth level, Castagna et al. (2009) reported Yo-Yo IR1 performance was significantly related to match high intensity running distance (r = 0.77, p < 0.001) and total distance (r = 0.65, p = 0.002). In addition, the Yo-Yo IR1 test has been shown to distinguish first division players and junior level players in both men (15.4% difference) and women (48% difference) (Mujika et al., 2009).

Together, regular physical fitness testing results and training load data can be combined to help coaches understand the dose-response relationship for individual players. This can be used to establish future training programs to achieved a desired fitness goal.

Dose-Response Relationship

Seasonal fitness changes in individual sports have reported a positive relationship between training volume and performance (Foster et al., 1996; Foster et al., 1977; Stewart & Hopkins, 2000). However, recent studies have attempted to quantify the training load across a season, and observe the dose-response relationship (Akubat et al., 2012; Arcos et al., 2015; Gil-Rey et al., 2015). Akubat et al. (2012), was one of the first to look at the dose response relationship in soccer players. Nine professional youth soccer players were observed over a six-week period. Training and match load was quantified using session RPE, Banister's TRIMP, Team TRIMP, and an individualized TRIMP (iTRIMP). Pre and post fitness was assessed using a five stage (8, 10, 12, 14, 16 km hr^{-1}) incremental treadmill test. Each stage lasted 4 minutes separated by a 1-inute rest period, where a capillary blood sample was acquired. Heart rate and treadmill velocity were recorded when the subject attained a 2 and 4 mmol L^{-1} blood lactate concentration. Correlations with percent changes in the four aforementioned variables were small to moderate with mean weekly session RPE (r = 0.13 to 0.40). A large, significant correlation occurred between the mean weekly iTRIMP and percent change in velocity at 2 mmol L^{-1} blood lactate concentration. The trivial to moderate relationships between changes and fitness and session RPE may have been due to the use of mean weekly session RPE scores and fitness changes expressed as a percentage. The study took place over a relatively short period of time, thus it is possible that total accumulated session RPE would have produced larger relationships with absolute changes in fitness scores. Taken together, to the author's knowledge, this is the only study that attempted to demonstrate a dose-response relationship using session RPE in soccer players.

Research by Los Arcos et al. (2014), Arcos et al. (2015), and Gil-Rey et al. (2015) used a different method to quantify perceived exertion. They used a method proposed by Pandolf et al. (1975), that utilized subjective ratings of perceived exertion of local muscles and the cardio-pulmonary system. Subjects were simply asked, "how intense was your session for your chest? and How intense was your session for your legs?" Each study took place over a 9-week period.

Los Arcos reported large, negative correlations between accumulated muscle session RPE and relative changes in 15m sprint running velocity (r = -0.59). Likewise, correlations between total training time and changes in vertical jump performance were large (r = -0.62).

Arcos measured fitness utilizing four unilateral and bilateral countermovement jump variations, 5 and 15m sprint times, and a 4-stage (12, 13, 14, and 15km h^{-1}) lactate test (Gorostiaga et al., 2009) in 14 professional male soccer players. No significant correlations between changes in fitness parameters and respiratory session RPE (mean weekly and summated over entire study duration) were reported. However, mean weekly muscle session RPE produced significant relationships with single leg dominant and non-dominant countermovement jump variables (r = -0.54 and -0.52, respectively). Likewise, total accumulated muscle session RPE largely correlated with single leg dominant and non-dominant countermovement jump variables (r = -0.61 and -0.53 respectively). Mean weekly muscle session RPE was also significantly correlated with blood lactate concentration at 13km h^{-1} (r = -0.57). Remaining significant correlation occurred between training volume measured in minutes and the fitness variables: countermovement jump with arm swing (r = -0.51, 5m sprint (r = -0.54), and 15m sprint (r = -0.64). These negative relationships between training volume and changes in fitness suggested that excessive training volume may impair performance on physical fitness tests. In contrast to previous individual sport studies (Foster et al., 1996; Stewart & Hopkins, 2000), this study demonstrates the second soccer study that found a negative association between training load and changes in fitness parameters.

Gil-Rey et al. (2015) measured pre and post fitness utilizing two countermovement jump variations (with and without arm swing, a 5 and 15m sprint, and a Universite de Montreal track test (Leger & Boucher, 1980) in a group of 28 elite and non-elite Junior Spanish players.

Changes in countermovement jump heights demonstrated only trivial and small relationships with subjective training loads and volume measured using total match and training durations (r = -0.02 to 0.25). Likewise, sprint results produced similar relationships with training load and training volume (r = -0.02 to 0.23). In contrast, changes in the Universite de Montreal track test were very largely and positively correlated with respiratory session RPE (r = 0.71). Similarly, large, positive correlations were reported between changes in the aforementioned track test, and both muscle session RPE (r = 0.69) and total training volume in minutes (r = 0.67). These results were the first to provide considerable evidence subjective ratings of perceived exertion could be used to predict changes in aerobic-related fitness in soccer layers. The trivial to small correlations with anaerobic variables demonstrate the difficulty in establish a dose-response relationship with anaerobic type variables. It is possible that the increases in the Universite de Montreal track test scores came at the expense of the some of the sprint and jump performance characteristics (Wilson et al., 2012).

These studies provide evidence that subjective ratings of perceived exertion can be used to establish a dose-response relationship. Some of the variability in these studies could be explained in part by the Law of diminishing returns (Hirschey, 2008; Peterson et al., 2005), where athletes that are less trained may require relatively small amounts of training load to achieve large increases in performance. As players become well-trained, large amounts of training load are required to achieve small increases in performance. In addition, the nature of soccer requires athletes to possess high levels of both cardiovascular endurance and explosive strength (Jones et al., 2016). The high training volumes required to maintain or increase cardiovascular endurance may cause the accumulation of fatigue. It is well-understood that strength and explosive characteristics are attenuated with accumulated fatigue (Fyfe et al., 2014), and performance may be attenuated for multiple weeks (Sams, 2014). In contrast aerobic performance does not seem to respond in a similar fashion. Thus, it is the role of the sport scientist to plan training that will allow the athlete to manage fatigue and concurrently maintain all fitness qualities related to soccer performance. Furthermore, if one wishes to assess explosive strength for regular monitoring purposes, they must do so when the athlete is in a recovered or unfatigued state.

Summary

Session RPE may be the most researched method of training load quantification. It has been shown to be a reliable and valid measure of training load in soccer. Monitoring systems that combine session RPE with recently developed, 10 Hz GPS and Heart Rate technology seem to be most effective.

Vertical jump is one of the most utilized athletic performance tests. In addition, effective maximal strength tests like the IMTP seem to provide a safe way to assess many maximal strength-related variables related to athletic performance. Furthermore, the Yo-Yo IR1 test is a viable test for measuring changes in soccer-related endurance. These tests have been frequently cited in the literature and are ideal for monitoring soccer athletes.

At present, there is little evidence that we can establish a dose-response relationship using session RPE. Many studies have found small to moderate relationships between training load and changes in various fitness parameters. It seems likely that session RPE may be a better predictor of endurance-related changes in fitness, as opposed to strength-related changes. Some have found large dose-response relationships by simply using training durations. Thus, future research exploring more time-sensitive calculations of session RPE is warranted. As a result of this review, the purpose of this dissertation is to refine the session RPE method for quantifying training load during competitive matches and examine the dose-response relationship throughout a competitive soccer season.

CHAPTER 3

ESTABLISHING AN ACCURATE DURATION MEASURE FOR THE CALCULATION OF SESSION RATING OF PERCEIVED EXERTION IN NCAA DIVISION I MEN'S SOCCER

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ABSTRACT

Objectives: The purpose of this study was to determine the most accurate measure of session RPE during NCAA Division I men's competitive soccer matches. **Design and Methods:** 20 NCAA DI male soccer players participated in the study during the 2014 and 2015 competitive seasons. Players completed 15.20 ± 1.05 matches for a total of 304 individual data points and 29.90 ± 1.89. training sessions for a total of 598 individual data points. GPS variables (total distance, HODO, and Player load) were compared with session RPE using Pearson product-moment correlations. To evaluate various methods of session RPE, "match duration" was recorded using eight different definitions: total game duration including warm-up and half-time, total game duration and warm-up, total game duration and half-time, total game duration only, minutes played including warm-up and half-time, minutes played and warm-up, minutes played and half-time, and minutes played only. A one-way ANOVA with repeated measures was used to determine if differences existed between the eight session RPE calculations. **Results:** Results from the ANOVA showed that all session RPE measures were significantly different from one another ($P < 0.05$). Very large correlations were reported between session RPE calculated using minutes played and total distance (0.81), while session RPE calculated using game duration showed less magnitude (0.57). **Conclusions:** Minutes played should be used to calculate session RPE as it was found to most closely reflect the actual workloads incurred during competitive matches.

INTRODUCTION

"Optimizing training first involves quantifying what the athlete is currently doing [1]." One of the most common methods for quantifying training load is the session rating of perceived exertion (RPE) method [2]. Session RPE is calculated by multiplying the athletes rating on a 10-point scale by the duration of the training session. Much of the evidence regarding the validity of session RPE as a tool to monitor soccer performance has been provided via relationships with summated heart rate scores as criterion measures [3-5]. Although there is a large aerobic component to soccer [6], heart rate in itself may not be the most meaningful indicator of training load for such an intermittent-type sport [7]. Thus, additional methods may be required to assess session RPE as a global estimate of training load during soccer training [4, 5, 8].

A Global Positioning System (GPS) is a space-based navigation system that provides location and time information [9]. GPS technology has been improving over the last several years [9] and many researchers have reported that GPS data is a viable indicator of external training loads imposed on athletes in team sports [10-12]. In order to improve measurements of change-of-direction and contact activities, GPS units have been equipped with additional gyroscope and triaxial accelerometer technology [13]. The information provided from GPS is much more objective compared to session RPE. Few studies have observed the relationship between session RPE and external loads measured using GPS technology [3, 8]. These studies have reported significant correlations between session RPE and both GPS and accelerometer derived variables ($r = 0.71$-0.84; $P < 0.01$).

One potential problem with the session RPE method is in how one calculates the duration of a competitive match. A National Collegiate Athletic Association Division I men's soccer can span an entire period of 162 minutes. One must decide if they will include the warm-up, halftime, cool-down, or any stoppages that may occur in their session RPE calculation. Using an entire period of 162 minutes to calculate a session RPE would surely overestimate training load. This overestimation of training load may cause coaches to wrongly prescribe post-match recovery and training. Frequent substitutions are common at this level, creating situations where many players do not play the entire match. It is logical to assume that the most accurate measure of duration will reflect the amount of time that the player was in the game. An accurate session RPE calculation during matches is required to supply information concerning post-match recovery and training strategies. In addition session RPE can be used to provide a scientific explanation for changes in performance [14], prevent over training [15], and reduce injury[16].

Therefore, the purpose of this study was to determine the most accurate measure of session RPE during NCAA Division I men's competitive soccer matches. Specifically, the study was designed to validate duration measurements that are used to calculate session RPE compared with GPS and accelerometry-based external training load scores as criterion measures. The authors hypothesize that using minutes played instead of total session duration would produce higher correlations with external training load variables measured using wearable GPS and accelerometer technology.

METHODS

This study used a descriptive correlational design. Session RPE, a popular subjective indicator of internal training load, was recorded after each session. In addition, players' training and competitive match activities were quantified using GPS technology. The relationships between the session RPE training load and commonly used GPS and accelerometer-based external training load quantification methods were used to examine the criterion validity of session RPE calculated using minutes played and total game definitions.

Athletes

This study involved retrospective analysis of archived monitoring data from an NCAA Division I men's soccer team. Data were collected as a normal part of the team's monitoring program during the fall 2014 and 2015 competitive seasons. In order to be included in the study, athletes had to meet the following inclusion criteria: play in at least 12 games and complete at least 25 training sessions in one full season. If players played more than 12 games and 25 training sessions, their most recent training sessions were used for analysis. This allowed early sessions to serve as a familiarization period. Overall, 20 (means ± standard deviations for: age 21.5 ± 1.3 y, height 177.6 ± 6.5 cm, body mass 74.3 ± 5.9 kg) out of a total of 32 eligible field players met the inclusion criteria for the study. Goalkeepers were excluded from this study. Players completed 15.20 ± 1.05 matches for a total of 304 individual data points and 29.90 ± 1.89. training sessions for a total of 598 individual data points.

Data Collection Procedures

The players' external load was monitored and quantified by means of portable GPS devices (MinimaxX, v.4.0, Catapult Innovations, Soresby, Australia) operating at a sampling frequency of 10 Hz and incorporating a 100 Hz triaxial accelerometer. Each player wore a special harness that enabled this device to be fitted to the upper part of his back. The GPS devices were activated 15 minutes before the start of each training session, in accordance with the manufacturer's instructions. Training session GPS data collection included the warm-up and all drills within the session, while data was discarded during between-drill recovery periods, and within-drill benchings. During matches, GPS data was recorded during the warm-up and match play (warm-up, first half, second half, and optional overtime periods). Data were discarded from half-time rest periods and within-match benchings. At the conclusion of the training session or match, raw data were downloaded to a personal computer and analyzed using the software package Logan Plus v.5.1 (Catapult Innovations, Soresby, Victoria, Australia 2014). The device has been reported to be both reliable and valid in previous studies [10, 12].

The team completed four to seven sessions per week, with a mean of 75.1± 23.5 minutes played per match and training session duration of 68.5 ± 17.3 minutes. All of the observed training sessions were designed by the team's head coach and sport scientist. During recovery periods, the players were allowed to drink fluids as needed. After training sessions and matches players consumed Muscle Milk® Collegiate Formula, a protein and carbohydrate drink. They were also told to eat a high carbohydrate meal shortly after training throughout the entire season.

GPS and accelerometer data collection included: total distance, high-intensity running distance (HODO), and Player load. HODO was defined as distance traveled above 14.4 km·hr-1 [17]. Player load is a vector quantity developed by the manufacturer and is expressed in arbitrary units. To calculate Player load, the square root of the sum of squared instantaneous rates of change in the three planes of motion are taken:

$$Player\ Load = \sqrt{((aca_{t=i+1} \quad aca_{t=1})^2 + (act_{t=i+1} \quad act_{t=1})^2 + (acv_{t=i+1} \quad acv_{t=1})^2)}/100$$

where *aca* is the acceleration in the anteroposterior axis, *act* is the acceleration in the transverse axis, *acv* is the acceleration in the vertical axis, *i* is the current time, and *t* is time.

The internal training load was assessed using session RPE [2]. Approximately ten minutes after the conclusion of each session, a sport scientist asked each player "how do you rate this session?". While Foster et al. [2] recommends a 30-minute time period before the recording of sRPE, subject availability did not always allow for this methodology. There is some evidence that this time period has little effect on RPE selection [18, 19]. Players then rated their RPE using a

10-point Borg scale, which was multiplied by the duration of the session according to Foster et al. [2]. Training session duration was recorded individually from the beginning of the training session (including warm-up and recovery periods) to the end of the session (excluding cool-down period). In order to determine the most accurate representation of match session RPE, "match duration" was recorded using eight different definitions: total game duration including warm-up and halftime, total game duration and warm-up, total game duration and halftime, total game duration only, minutes played including warm-up and halftime, minutes played and warm-up, minutes played and halftime, and minutes played only. Minutes played was determined using Stat Crew v1.13 (Stat Crew Software, Inc. Cincinnati, Ohio).

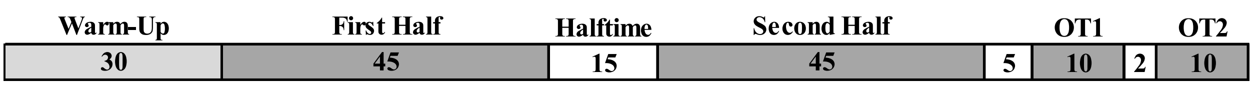

Figure 1. Distribution of durations (minutes) for a National Collegiate Athletic Association soccer match with overtime periods (OT).

Data and Statistical Analysis

Descriptive results are presented as means ± standard deviations. A one-way analysis of variance with repeated measures was used to determine if there were differences between the eight session RPE calculations during matches. The relationships between the various session RPE and GPS-based training loads were analyzed using Pearson's product-moment correlation coefficients. The magnitude of the relationships was described as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$), and perfect ($r = 1$) [20]. All of the statistical analyses were performed using Statistics Package for the Social Sciences (version 22.0, SPSS Inc. Chicago, IL) for Windows. Statistical significance was set at $P < 0.05$.

RESULTS

Means and standard deviations for training and matches are shown in Tables 1 and 2. Significant differences were found between all eight session RPE calculations during matches F (7, 133) = 886.761, $p < 0.001$. Training session RPE correlation coefficients were 0.80, 0.81, and 0.73 for total distance, Player load, and HODO, respectively. Match correlations were very large for session RPE calculations that used minutes played and large for total session variables as shown in Table 3.

Table 1. Means and standard deviations of measured variables during training and matches.

	Training	Matches
Variables	Mean ± SD	Mean ± SD
RPE (AU)	2.6 ± 1.2	6.2 ± 1.6
Time (min.)	68.8 ± 17.3	75.1 ± 23.5
Session RPE (AU)	387.9 ± 153.5	487.4 ± 227.3
Total Distance (m)	3556.7 ± 1464.9	11341.35 ± 2966.1
Player load (AU)	429.2 ± 330.5	1138 ± 298.1
HODO (m)	193.0 ± 119.7	1897.1 ± 654.2

Table 2. Means and standard deviations for calculated session RPEs during matches.

	Session RPE	Mean ± SD
Minutes Played		
	Minutes Played	487.4 ± 227.3*
	Halftime Added	580.6 ± 247.6*
	Warm-Up Added	673.8 ± 268.5*
	Halftime & Warm-Up Added	766.9 ± 289.8*
Game Duration		
	Total Game Duration	599.0 ± 191.4*
	Halftime Added	692.1 ± 212.9*
	Warm-Up Added	785.3 ± 234.7*
	Halftime & Warm-Up Added	878.4 ± 256.9*

* Indicates significant difference at the p = 0.05 level.

Table 3. Correlations between the various session RPE calculations and GPS variables during competitive matches.

	Session RPE	Total Distance	Player Load	HODO
Minutes Played				
	Minutes Played	.808**	.785**	.570**
	Halftime Added	.796**	.774**	.567**
	Warm-Up Added	.785**	.763**	.563**
	Halftime & Warm-Up Added	.774**	.752**	.559**
Game Duration				
	Total Game Duration	.566**	.547**	.477**
	Halftime Added	.573**	.554**	.479**
	Warm-Up Added	.578**	.559**	.481**
	Halftime & Warm-Up Added	.581**	.562**	.482**

* Indicates a significant correlation at the p = 0.05 level.

** Indicates a significant correlation at the p = 0.01 level.

DISCUSSION

The purpose of this study was to determine the most accurate measure of session RPE during NCAA Division I men's competitive soccer matches. The results support the use of minutes played as the most accurate indicator of duration when calculating session RPE during competitive matches.

Another interesting finding from this study was that incorporating warm-up periods were found to decrease the magnitude of correlation between minutes played session RPE and GPS variables despite the fact that warm-up was included in GPS data analysis. These findings suggest that the warm-up may be perceived as much less strenuous than in-game activities. During the warm up, players generally cover approximately 1600m, very little of which is at a HODO pace. The warm-up consisted of about 10 minutes of dynamic movement preparation, 10 minutes of possession in a 10m x 5m grid, and some shooting or defensive shifting exercises.

GPS data was discarded during halftime periods, which was reflected by the reduced correlation coefficients when halftime periods were included in the minutes played session RPE calculations. In contrast, relationships became slightly stronger when halftime duration was added to total match duration. This stronger relationship to training load that was not quantified via GPS indicates that match duration may not be a good measure for session RPE calculation.

The results of this study showed that the session RPE method was significantly ($p < 0.01$) correlated with all indicators of external load during training and matches (Table 3). HODO had the lowest relationship among the GPS variables with session RPE during training ($r = 0.73$ and matches ($r = 0.56 – 0.57$). This suggests that session RPE may be less effective at representing soccer activities that are composed of more high intensity movements, which has been found to result in session RPE underestimating training load [8].

As shown in Table 2, session RPEs can almost double depending on how one defines the duration of a competitive match. When quantifying training load, it is important for the practitioner to be able to use session RPE to quantify both training and matches. The relationships between session RPE and total distance during training ($r = 0.80$) and matches that use minutes played (0.81) suggests that these methods have a similar relationship with total distance. These relationships were weaker when the total duration of the session was used to calculate session RPE ($r = 0.57$-0.58), and this may cause an overestimation of training load. Likewise, similar results were found with the relationship between session RPE and both Player load and HODO. Thus, if sport scientists can more accurately monitor game training loads using measures that are similar to measures during training, then they can get a better idea of actual weekly and seasonal training loads. As a result, they should be able to more precisely plan training, prevent overtraining, and enhance overall athlete performance.

Previous research examining the relationship between session RPE and external training loads during training has reported large to very large relationships. Similar to the results of the present study, Scott et al. [8] reported session RPE to be highly correlated with total distance (r = 0.80), Player load (r = 0.84), and HODO (r = 0.65) in professional soccer players. In addition, Casamichana et al. [3] examined the relationship between session RPE and total distance (r = 0.76) and Player load (r = 0.74). It appears that total distance, HODO, and Player load may be viable indicators of training load in NCAA Division I soccer players. Additionally, session RPE may be used as a global indicator of exercise intensity.

The very high correlations reported in this study provide evidence for considering session RPE as a global indicator of individual training response in soccer training and competitive matches. Due to the higher correlation coefficients observed with GPS variables, we suggest that minutes played serve as the "duration" when calculating session RPE. This may allow coaches to determine post-match recovery and training strategies, that more accurately reflect fatigue levels produced by the competitive match.

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CHAPTER 4

TRAINING LOAD INFLUENCE ON INTERMITTENT ENDURANCE TEST PERFORMANCE IN NCAA DIVISION I MEN'S SOCCER

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ABSTRACT

Objectives: The purpose of this study was threefold: 1) to determine if changes in Yo-Yo IR1, body mass, and body composition occur from pre to postseason, 2) to determine if these aforementioned preseason variables differ a) between players based on minutes played and b) between college soccer experience, and 3) to determine the relationships between accumulated training load (from games, field training, and resistance training) and changes in the aforementioned variables across a soccer season. **Design and Methods:** 30 NCAA DI male soccer players completed pre and postseason testing which included the Yo-Yo IR1, body mass, and body composition. During the season, training loads were quantified using session RPE, which was categorized into soccer training, resistance training, and matches. A paired samples t-test was used to determine changes in Yo-Yo IR1 and anthropometric measures across the season with a p value of 0.05. Two independent samples t-tests were used to determine whether differences in pre-season test scores existed a) between college soccer experience and b) between playing time groups. Pearson's product-moment correlation coefficients were used to examine the relationships between total training load and change in Yo-Yo IR1 and anthropometric measures. **Results:** Yo-Yo IR1 scores significantly increased from pre to postseason ($P < 0.01$). No changes occurred with body composition ($P = 0.25$) and body mass ($P = 0.23$). High and low-minute playing groups had a significant increase in Yo-Yo IR1 score form pre to postseason ($P < 0.01$). Results showed large, inverse relationships between total in-season session RPE and change in Yo-Yo IR1 score (-0.51). This relationship was higher within the high-minute group (-0.69) as opposed to the low-minute group (-0.40). **Conclusions:** Yo-Yo IR1 performance increased by approximately 14% from the beginning to the end of the season. No differences in preseason Yo-Yo IR1, body mass, and body composition existed when players were grouped

based on playing time or training age. A large, negative relationship was found between session RPE and changes in Yo-Yo IR1 score, which suggests that excessive accumulation of session RPE may impair Yo-Yo IR1 performance.

INTRODUCTION

The ability to quantify internal training load and detect changes in soccer-specific intermittent endurance are an essential part of a scientific approach to the enhancement of soccer performance. This information can be used to determine a dose-response relationship, which may reveal the amount of training required to develop a certain physical performance outcome. With this information, coaches may evaluate their periodization strategies and training load distribution, identify poor responders, and modify the training process to reach a specific training outcome [1].

Session rating of perceived exertion (RPE) is a popular method of monitoring training load in soccer players [2-4]. Session RPE is the product of session duration (minutes) and an intensity rating from a 10-point scale [5]. Previous research has not been able to demonstrate a substantial relationship between session RPE and changes endurance test performance specifically measured using in velocity at lactate threshold[6] and interval endurance capacity[7, 8]. However, some studies have provided evidence that performance changes relate to the amount of training time [7, 9]. Thus, accurate measures of training time are likely important for establishing these relationships.

The Yo-Yo intermittent recovery test (IR1) is a popular field test that is used by soccer coaches world-wide [1, 10-13]. The test consists of repeated 20-m shuttle runs of increasing speed interspersed by 10s periods where athletes perform a recovery 5m shuttle [14]. Athletes are scored based on their total distance covered (m) during the test. Krustrup et al. [15] assessed the reliability (CV 4.9%) and validity ($r = 0.71$ with VO_2max and high intensity running distance during professional soccer matches) of the Yo-Yo IR1 test. Heart rate data also indicated that the test maximally stimulated the cardiovascular system, while muscle biopsy and blood analysis further revealed both aerobic and anaerobic energy system use. Together these outcomes are, to some degree, reflective of the intermittent nature of soccer match play. Furthermore, the Yo-Yo IR1 was highly correlated (r = 0.71) with both VO_2max and moderate speed running distance (>15 km hr^{-1}) during professional soccer matches [15]. At the youth level, Castagna et al. [16] reported Yo-Yo IR1 performance was statistically related to match high intensity running distance (r = 0.77) and total distance (r = 0.65), but found a moderate relationship with VO_2max (r = 0.46). The Yo-Yo IR1 test has been shown to distinguish first division (male 23.8 ± 3.4 and female 23.1 ± 2. years old) and junior level players (male 18. 4± 0.9 and female 17.3 ± 1.6 years old) in both men (15.4% difference) and women (48% difference) [17].

With the day-to-day use of session RPE and seasonal Yo-Yo IR1 testing, coaches are hopeful to get a better idea of the dose-response relationship. This information could aid in the development of more effective training programs. Thus, the purpose of this study was threefold: 1) to determine if changes in Yo-Yo IR1, body mass, and body composition occur from pre to postseason, 2) to determine if these aforementioned preseason variables differ a) between players based on minutes played, and b) between college soccer experience, and 3) to determine the relationships between total training load (from games, field training, and resistance training) and changes in the aforementioned variables across a soccer season.

METHODS

This study involved retrospective analysis of archived monitoring data from a National Collegiate Athletic Association Division I men's soccer team. Data were collected as a normal part of the team's monitoring program during the fall 2013-2015 competitive seasons.

Athletes

In order to be included in the study, athletes had to meet the following inclusion criteria: complete both pre (August) and post (November) season testing, and not miss more than two consecutive weeks of in-season training. Thirty players met these criteria (age 21.1 ± 1.2 y, height 178.24 ± 6.72cm, body mass 73.9 ± 7.32kg).

Data Collection Procedures

In mid-August, on the first day of pre-season all players completed anthropometric and Yo-Yo IR1 testing. Then at the conclusion of the season (4 to 5 days after their final match) in mid to late November, players repeated the testing. The distances covered (m) during both Yo-Yo tests were used for analysis. Pre and post testing was conducted on the same training surface. Anthropometric data included height, body mass, and body composition measures. Height was measured using a stadiometer. Body mass was measured using a scale (Tanita Body Composition Analyzer, BF-350 Arlington Heights, IL). Skinfold thickness was measured using Lange (Beta Technology, Santa Cruz, CA) skinfold caliper. Body density was estimated using the Jackson and Pollock [18] 7-site equation. The Siri [19] equation was used to estimate percent body fat.

The internal training load was assessed using session RPE [20]. Approximately ten minutes after the conclusion of each session, an investigator asked each player "how do you rate this session?". While Foster et al. [20] recommends a 30-minute time period before the recording of session RPE, athlete availability did not always allow for this methodology. There is evidence that this time period has little effect on RPE selection [21, 22]. Players then rated their RPE using a 10-point Borg scale, which was multiplied by the duration of the session according to Foster et al. [20]. Training session duration was recorded individually from the beginning of the training session (including warm-up and recovery periods) to the end of the session (excluding cool-down period). For session RPE calculation during competitive matches, duration was defined as the number of minutes played. Minutes played was determined using specialized software (Stat Crew v1.13, Stat Crew Software, Inc. Cincinnati, Ohio) during each competition.

Statistical Analysis

Descriptive results are presented as means ± standard deviations. A paired samples t-test was used to assess whether changes in body mass, body composition, and Yo-Yo IR1 score occurred from pre to postseason. Effect size (ES) was calculated using Cohen's d[23]. Effect sizes were considered trivial: <0.2, small: 0.2–0.6, moderate: 0.6–1.2, large: 1.2–2 and very large: 2.0–4.0.

The second purpose of this study was to determine if preseason Yo-Yo IR1 and anthropometric variables differ a) between players based on minutes played, and b) between college soccer experience. Thus, a preliminary assessment was used to ensure that college soccer experience and playing time did not affect body composition, body mass, and Yo-Yo IR1 performance. To do this, players were grouped by level of college soccer experience and playing time. The college soccer experience groups consisted of underclassmen (<2 years at college level) and upperclassmen (>2 years at college level). Playing time groups consisted of high (>60% of total gameplay) and low (<40% total gameplay) minute players. Two independent samples t-tests were used to determine whether differences in pre-season test scores existed a) between college soccer experience and b) between playing time groups. As shown in Table 1, no significant differences were found. However, as expected, significant differences between high and low-minute groups were found with accumulated session RPE from soccer training, matches, and total (Figure 1). Because of the differences found in accumulated session RPE between high and low-minute groups, correlation analysis was performed on both of these groups individually and on pooled data from the entire sample (n = 30)

Table 1. P-values comparing the player experience (upperclassmen and underclassmen) and playing time (high and low-minute) groups.

	Upper vs Under	High vs Low
Yo-Yo IR1	0.59	0.18
Body Mass	0.89	0.69
Body Fat	0.53	0.41

* indicates a significant difference (P < 0.05) between groups.

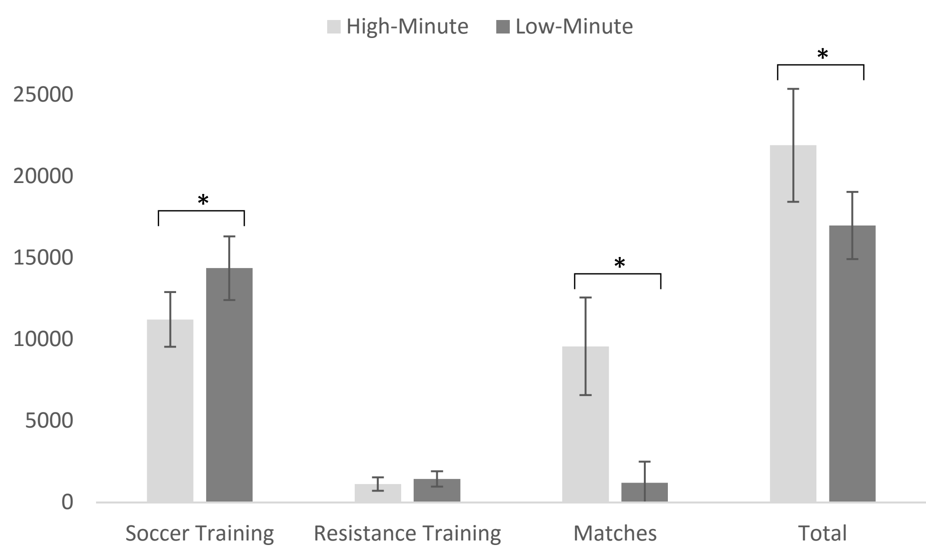

Figure 1. Accumulated session RPE (AU) for high and low-minute playing time groups.
* indicates a significant difference (P < 0.05) between the high and low minute groups.

To achieve the third purpose of this study, which was to determine the relationships between total training load and changes Yo-Yo IR1 and anthropometrics, Pearson's product-moment correlation coefficients were used to examine the relationship between total training load and change in Yo-Yo IR1 score. The magnitude of the relationships was described as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$), and perfect ($r = 1$). Statistical significance was set at $p \leq 0.05$ [24].

RESULTS

Pooled data from all 30 subjects indicated that Yo-Yo IR1 scores statistically increased from pre to postseason ($P < 0.01$, Table 2). No changes occurred with body composition ($P = 0.25$) and body mass ($P = 0.23$). Likewise, data from both high and low-minute playing groups indicated a statistically significant increase in Yo-Yo IR1 score form pre to postseason ($P < 0.05$, Table 3). In addition, a statistically significant reduction in body composition occurred in the high minute group ($P \leq 0.05$).

Table 2. Changes in Yo-Yo Intermittent Recovery 1 test and anthropometric variables for pooled data (n = 30).

	Pre	Post		
	Mean ± SD	Mean ± SD	P-Value	Cohen's d
Yo-Yo IR1 (m)	2148 ± 360	2456 ± 347	0.00*	0.87
Body Fat (%)	10.0 ± 3.5	9.7 ± 3.1	0.25	0.11
Body Mass (kg)	74.3 ± 7.3	74.7 ± 7.9	0.23	0.06

* indicates a statistical difference ($P < 0.05$) between pre and post testing.

Table 3. Changes in Yo-Yo Intermittent Recovery 1 test and anthropometric variables for high (n = 10) and low-minute (n = 16) playing time groups.

		Pre	Post		
	Group	Mean ± SD	Mean ± SD	P-value	Cohen's d
Yo-Yo IR1 (m)	High-Minute	2232 ± 366	2460 ± 398	0.01*	0.60
	Low-Minute	2148 ± 388	2503 ± 343	0.00*	0.97
Body Fat (%)	High-Minute	9.1 ± 2.3	8.5 ± 2.5	0.03*	0.27
	Low-Minute	9.3 ± 3.4	9.3 ± 2.8	0.96	0.01
Body Mass (kg)	High-Minute	72.0 ± 7.0	72.2 ± 7.7	0.82	0.02
	Low-Minute	73.9 ± 7.4	74.8 ± 8.4	0.07	0.12

* indicates a statistical difference ($P < 0.05$) between pre and post testing.

Large, statistically significant, inverse relationships were found between total in-season session RPE and change in Yo-Yo IR1 score ($P < 0.01$) (Table 4). Likewise, a moderate correlation was observed with accumulated session RPE from matches and change in Yo-Yo IR1 score ($p < 0.05$). Changes in body mass demonstrated a moderate relationship with session RPE from soccer training ($p<0.05$). Trivial and small correlations were found between all other training load variables (Table 4). Similar to pooled data, correlation analysis within the high-minute group revealed a large, positive relationship between session RPE and change in percent fat (Table 5). For the high-minute group, correlation analysis revealed significant, large inverse relationships between Yo-Yo IR1 scores and both match ($P <0.05$) and total session RPE ($P <0.05$). However, in the low-minute group, match and total session RPE demonstrated moderate relationships with changes in Yo-Yo IR1 scores. Furthermore, despite the higher sample size, no significant correlations were observed in the low-minute group.

Table 4. Correlations between total session RPE and changes in Yo-Yo intermittent recovery test and anthropometric parameters for pooled data (n = 30).

	Soccer Training	Resistance Training	Matches	Total
Yo-Yo IR1	-0.01	-0.05	-0.42*	-0.51**
Body Fat	0.10	0.19	-0.17	-0.11
Body Mass	-0.37*	-0.31	0.15	-0.10

* indicates statistically significant correlation at the P < 0.05 level. ** indicates statistically significant correlation at the P < 0.01 level.

Table 5. Correlations between total session RPE and changes in Yo-Yo intermittent recovery test and anthropometric parameters for both high (n = 10) and low-minute (n = 16) playing time groups.

		Soccer Training	Resistance Training	Matches	Total
Yo-Yo IR1	High-Minute	-0.20	-0.34	-0.64*	-0.69*
	Low-Minute	-0.18	0.00	-0.36	-0.40
Body Fat	High-Minute	-0.20	-0.24	0.63	0.41
	Low-Minute	-0.01	0.17	-0.11	-0.04
Body Mass	High-Minute	-0.29	-0.32	-0.45	-0.56
	Low-Minute	-0.42	-0.16	0.28	-0.25

* indicates statistically significant correlation at the P < 0.05 level.

DISCUSSION

The primary findings of this study were 1) Yo-Yo IR1 performance increased from pre to postseason, 2) no differences were observed on groups based on a) college soccer experience, and b) playing time, and 3) a large, negative dose response relationship was found between total training load and change in Yo-Yo IR1 score.

In agreement with previous research using endurance-related testing [9, 25, 26], pooled data indicated that Yo-Yo IR1 scores substantially increased by an average of about 14.3% following the competitive season (Table 2). When comparing preseason scores the team generally ranked in the sub-elite fitness category (2144.71 ± 399.27m) based on Bangsbo et al. [27]. However, by the end of the season, the team score ranked in top-elite (2441.176 ± 417.15m) fitness category.

When players were grouped by playing time during matches, the high-minute players accumulated significantly more session RPE from matches, while the low-minute group accumulated significantly more session RPE from soccer training. As for total session RPE, a significant difference was found ($p < 0.01$) between groups (figure 1). Mean total session RPE for the high and low-minute groups were 21901 and 16985 arbitrary units, respectively. Despite having 22% less session RPE training load across a season, the low-minute group still experienced a 16.5% increase in Yo-Yo IR1 score, while the high minute group experienced only a 10.2% increase. Although the low-minute group had a lower mean pre Yo-Yo IR1 score, their post score was higher than the high-minute group. These results are contradictory to previous studies that have found a positive relationship between training time and improvements in fitness test scores [7, 28]. Regardless of the overall lower total session RPE, it appears that the additional session RPE from soccer training received by the low-minute group may have served as a sufficient training stimulus to increase Yo-Yo IR1 score. It is important to note that on days after competitive matches, low-minute players had a hard training session, where they played small-sided games (6 versus 6). Due to the lower total training load and higher post-season Yo-Yo IR1 scores it is likely that the low-minute group was better-recovered than the high-minute group. It is possible that the competitive match schedule, where players often played two games per week, resulted in an accumulation of fatigue throughout the season [29]. As a result, accumulated fatigue may have reduced the magnitude of improvement in Yo-Yo IR1 performance at the end of the season. It is likely that further reductions in training load would have promoted better Yo-Yo IR1 performance.

The main finding of the present study was that the total accumulated session RPE were inversely related to changes in Yo-Yo IR1 test scores when data were pooled from all thirty subjects (r = -0.51). Thus, these results suggest that players who accumulated greater session RPE training loads exhibited a decrease in Yo-Yo IR1 performance improvement from preseason to postseason. The magnitude of this association indicates that only about 22% of the variance in Yo-Yo IR1 changes can be explained by total accumulated session RPE. This may limit its practical use as a tool to prescribe exercise in order to elicit a specific response to training.

Similar to the present study, Arcos et al. [22] found a negative association between perceived training load scores. Specifically, they assessed respiratory and muscle RPE. They reported similar average weekly training loads (~1500 arbitrary units), which may suggest that the weekly dose (session RPE) of training given to the athletes was excessive. However, Gil-Rey et al. [28] reported a similar average weekly training load of approximately 1500 arbitrary units and found a positive dose-response relationship with endurance capacity (r = 0.71). This suggests that subjective measures of training load may provide some use in establishing a dose-response relationship. Although the previous studies provided similar perceived training load stimuli, the previous two studies completed only one match per week over a 9-week period, while the approximately half of the weeks in the present study contained two competitions. Akubat et al. [8] observed 9 professional youth players (age 17 ± 1 years) over a 6-week period and found trivial relationships between session RPE and modified five-stage lactate threshold test on a treadmill (r = 0.13). These results may have been due to the small sample size, and to the fact that many of the players were on different schedules.

Of the three session RPE categories displayed (match, field, resistance) in Table 4, the only significant relationship occurred between changes in Yo-Yo IR1 scores and session RPE from matches (r = -0.42, $P < 0.05$). Trivial relationships were seen between other session RPE variables. Therefore, the greater amounts of training at higher intensities (matches) produced more fatigue, which potentially, hindered performance increases on the Yo-Yo IR1 test. In addition, the congested NCAA Division I soccer schedule requires that players play approximately 19-22 games in a 13 or 14-week period. As a result, players compete twice a week for several weeks in a row. Evidence suggests that 48-72 hours may be required for an athlete to fully recover from a soccer match [30-32]. Therefore, this may result in an accumulation of fatigue that can potentially hinder performance as the season progresses. Thus, a less congested match schedule could potentially allow for better fatigue management, and result in a positive dose-response relationship.

Despite overall increases in Yo-Yo IR1 performance, session RPE did not fit a positive, dose-response relationship. One potential explanation for the results of the present study is "the law of diminishing return", which simply states that as the quantities of an input increase, the resulting rate of output increase eventually decreases [33]. In our case the input is session RPE and the output is the athlete's change in Yo-Yo IR1 score. Therefore, relatively deconditioned players require less training stimulus (accumulated session RPE) and experience greater increases in Yo-Yo IR1 performance than fit players. A fit player may require high amounts of session RPE to achieve rather minor increases in Yo-Yo IR1 performance. This phenomenon may result in high variability between individual responses, which may help explain why correlation coefficients in this study were less than 0.70.

This study produced only one significant correlation coefficient when observing session RPE and changes in body mass (Table 3). Soccer training was moderately correlated with changes in body mass (r = -0.37), which indicates that greater levels of soccer training resulted in a decrease in body mass. Given that this correlation only explains about 13% of the variance, session RPE may not be a good indicator for coaches who want to influence the body mass of their players. Taken together, no significant changes in body mass occurred across the season, which is common in the literature [22, 25, 26]. For a soccer player this may be ideal, so that they maintain muscle mass.

After grouping players by playing time, larger correlations were observed with Yo-Yo IR1 test results in the high-minute group. This was likely due to the fact that session RPE from matches demonstrated the largest relationship with change in Yo-Yo IR1 score, and many of the players in the low minute group had very little playing time. The high-minute group demonstrated large correlations with changes and Yo-Yo IR1 scores and both match ($r = -0.64$) and total ($r = -0.69$) session RPE, while the low-minute group demonstrated weaker relationships with match ($r = -0.36$) and total ($r = -0.40$) session RPE. The large correlation from the high-minute group was able to explain almost 50% of the variance between Yo-Yo IR1 changes and total session RPE. This demonstrates promise for the use of session RPE as a practical tool for monitoring training load in groups of players that play at least 60% of the total match time during a season. When we displayed change in Yo-Yo IR1 as a percent, a large relationship was observed with total session RPE ($r = -0.68$, $P < 0.01$). However, this was the only large relationship with session RPE when observing percent changes in the Yo-Yo IR1 test. Although this was not part of the purpose of the present study, percent change may be useful in other research.

CONCLUSION

In conclusion, results of the present study demonstrated an increase in Yo-Yo IR1 performance from the beginning to the end of the season. In our sample, no differences in preseason Yo-Yo IR1, body mass, and body composition existed when players were grouped based on playing time or training age. The main finding from this study was a large, negative relationship between session RPE and changes in Yo-Yo IR1 score. These relationships suggest that excessive accumulation of session RPE can impair Yo-Yo IR1 performance. Furthermore, high-playing time groups produced larger correlations between session RPE and changes in Yo-Yo IR1 performance. Despite these findings, no correlations reached a magnitude that was able to explain 50% of the variance between the variables. Therefore, a substantial dose-response cannot be reported in this study.

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CHAPTER 5

TRAINING LOAD AND CHANGES IN MEASURES OF STRENGTH AND EXPLOSIVENESS IN NCAA DIVISION I MEN'S SOCCER

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ABSTRACT

Objectives: The purpose of this study was 1), to determine if strength and anthropometric variables change from pre to post season, 2), to determine whether the strength and anthropometric preseason variables differ a) between players based on minutes played and b) between players based on college soccer experience, and 3), to determine the correlation between accumulated session RPE and changes in the strength and anthropometric variables across a competitive soccer season. **Design and Methods:** 32 NCAA DI male soccer players completed pre and post season testing which included vertical jumps, IMTP, body mass, and body composition. During the season, training loads were quantified using session RPE, which was categorized into soccer training, resistance training, and matches. A paired samples t-test was used to determine changes in strength measures across the season with a p value of 0.05. Two independent samples t-tests were used to determine whether differences in pre-season test scores existed a) between college soccer experience and b) between playing time groups. Pearson's product-moment correlation coefficients were used to examine the relationships between total training load and change in strength measures. **Results:** Analysis of pooled data and data grouped by playing time indicated no significant changes in strength and anthropometric variables from pre to post season. When data were grouped by player experience, significant decreases in CMJ 0kg within the underclassmen and significant decreases in IPFa within the upperclassmen were found. Moderate, positive correlations were observed between session RPE from resistance training and 20KG CMJ (0.36) and between session RPE from resistance training and RFD at 200ms (0.38). All other correlations were trivial. Most correlations were positive between strength measures and session RPE from resistance training. **Conclusions:** Strength was maintained throughout the season. It appears that player experience (more than two years of

periodized training) results in slight increases in vertical jump performance across a season, while fewer than two years of training results in slight decreases in jump performance across a season. Although a positive dose-response relationship was demonstrated, moderate relationships indicate that session RPE may not be a good indicator of changes in strength characteristics.

INTRODUCTION

The ability to both quantify internal training load and detect changes in strength characteristics are an essential part of a scientific approach to soccer performance enhancement. This information can be used to determine the dose-response relationship, which can help coaches evaluate their periodization strategies and training load distribution, identify poor responders, and modify the training process to reach a specific training outcome [1].

Session rating of perceived exertion (RPE) is a popular method of monitoring training load in soccer players [2-4]. Session RPE is the product of session duration (minutes) and an intensity rating from a 10-point scale [5]. Chapter 3 of this dissertation provided evidence that using minutes played as a 'session duration' during matches gives a more accurate measure of training load. However, previous research has not been able to demonstrate a considerable relationship between accumulated perceived exertion measures of training load and changes in vertical jump performance [6, 7]. Gil-Rey et al. [7] reported small to trivial ($r = 0.06 – 0.37$) relationships between changes in vertical jump height and perceived training load after 9 weeks of training. Similarly, Arcos et al. [6] reported mostly small to moderate ($r = 0.17 – 0.51$) correlations with bilateral jumping after 9 weeks. These studies used respiratory and muscle ratings of perceived exertion, [8] and did not divide training loads into a resistance training, soccer training, and match categories.

Strength is an important characteristic of soccer players [9, 10] and has been defined as the ability to produce force [11]. Stronger players tend to be more fatigue resistant [12-14], less prone to injury [15], and perform better during sprinting activities [10, 16]. One component of strength that we can test is maximal strength. While maximally-loaded dynamic movements such as a squat or deadlift can place tremendous strain on the body [17], isometric tests are often simple to administer, may provide more information to coaches [18, 19], and may have lower injury risk. A common maximal strength test is the isometric mid-thigh pull (IMTP) [20]. The IMTP requires the athlete to be in an upright athletic stance with large knee and hip angles [19, 20]. Haff et al. [21] reported test-retest reliability with high peak force (r = 0.93) and rate of force development (r = 0.92) measured using an IMTP. The IMTP seems to be a respected and commonly used test for monitoring strength in athletes [22, 23].

Although maximal isometric strength is important for athletes, other dynamic strength characteristics should be assessed as well. Dynamic strength can be characterized by the type of muscle action involved in the movement. Explosive exercises have been defined as exercises where the initial rate of concentric force production is maximal, and this maximal force production is maintained throughout the exercise [11]. Thus, the static and countermovement vertical jumps are often employed to assess both concentric and plyometric strength, respectively. In addition, to assess force-velocity characteristics of the musculature involved in jumping, various load conditions can be used [24].

With the day to day use of session RPE and regular strength and explosiveness testing, coaches may obtain a better understanding of the dose-response relationship. This information can aid in the development of more effective training programs that help athletes maintain or increase strength parameters. Thus, the purpose of this study was 1), to determine if strength and anthropometric variables change from pre to post season, 2), to determine whether the aforementioned preseason variables differ a) between players based on minutes played and b) between players based on college soccer experience, and 3), to determine the correlation between total session RPE and changes in the aforementioned variables across a competitive soccer season.

METHODS

Athletes

This study involved retrospective analysis of archived monitoring data from a National Collegiate Athletic Association Division I men's soccer team. Data were collected as a normal part of the team's monitoring program during the fall 2013-2015 competitive seasons. In order to be included in the study athletes had to meet the following inclusion criteria: complete both pre (August) and post (November) season testing, and not miss more than two consecutive weeks of in-season training. Thirty-two players met these criteria (age 21.2 ± 1.3 y, height 178.2 ± 6.7 cm, body mass 74.2 ± 7.3 kg).

Data Collection Procedures

Session RPE was calculated by multiplying duration of training by the athletes' intensity rating on a 10-point scale[25]. For competitive matches duration was defined as minutes played. For all soccer training sessions duration included warm-up and stoppages, but excluded the cool-down. Resistance training session RPE was calculated using the duration of the warm-up and total time the athlete was in the weight room, excluding the cool-down.

In mid-August, on the first day of pre-season all players completed explosiveness, strength, and anthropometric testing. Players repeated the testing at the conclusion of the season (4 to 5 days after their final match) in mid to late November.

Methods for the vertical jump and IMTP tests were replicated from Kraska et al. [26]. Testing for the IMTP was performed on two parallel force plates (45.5 cm x 91 cm, RoughDeck HP; Rice Lake Weighing Systems, Rice Lake, WI, USA) in a custom power-rack (Sorinex, Irmo, SC, USA) that allows for fixation of the bar at any height. The subject was positioned so that their knees were bent at a 125°-135° angle. Subjects were told to use a minimal amount of tension in order to remove as much slack from the body as possible prior to initiation of the pull. Subjects received a 3-2-1 countdown, and then initiated the pull based on the trial (e.g. 50% effort). For 100% effort trials, subjects were instructed to pull "as fast and as hard as you can" to ensure maximal rate of force development in the early parts of the pull[27].

Analog data from each force plate were amplified and filtered (low-pass at 16 Hz), and sampled at 1000 Hz (DAQCard-6063E, National Instruments, Austin, TX, USA). A digital filter (low-pass 10 Hz, 2nd order Butterworth) was applied, signals from each force plate were summed, and data were analyzed in custom LabVIEW software (LabVIEW 2010, National Instruments, Austin, TX, USA). Only 100% trials were used for analysis. Variables collected from the force plate were peak force, allometrically scaled peak force [28], and rate of force development (RFD) during the first 200ms. Allometric scaling was performed using body mass to the power of 0.67 [29].

Vertical jumps were performed with a static start and with a countermovement using two different load conditions: 0 kg (unloaded) and with a 20 kg load. Static jumps required the participant to hold a 90-degree knee angle position for a three second countdown prior to jumping. Countermovement jumps were performed to a self-selected depth. Jump height was calculated from flight time using the following formula:

$$Jump\ Heig\ \ t = (g \times flig\ \ t\ time^2) \div 8$$

Where g represents acceleration due to gravity and flight time is measured in seconds [30].

For the entire duration of the study a single rater measured skinfold thickness using a Lange (Beta Technology, Santa Cruz, CA, USA) skinfold caliper. Body density was calculated using the Jackson and Pollock [31] 7-site equation. The Siri [32] equation was used to calculate percent body fat.

Reliability Analysis

Test-retest reliability was assessed using intraclass correlation coefficients (ICC) and coefficients of variation (CV). Isometric mid-thigh pull, vertical jump, and body composition data were analyzed from players that participated in the spring 2015 season. Isometric mid-thigh pull analysis was performed on 24 players. Test-retest ICCs for peak force were 0.94, and CV ranged from 0.2% to 7.7% with a mean of 3.0%. Furthermore, ICC for RFD at 200ms were 0.80, and CV ranged from 1.9% to 27.5% with a mean of 11.7%. Although peak force was reliable, RFD at 200ms had a lot of within-subject variation. Test-retest analysis performed on 18 players from the spring 2015 season were high (ICC = 0.94 to 0.99) for both types of vertical jumps at the zero and 20kg loads. Coefficients of variation were acceptable ranging from 0.0% to 9.4% with a mean of 2.0% for all jump variables. Reliability analysis for body composition was performed on a sample of 26 players was good (ICC = 0.98, while CVs averaged 1.2% with a range of 0.0 to 4.2%.

Statistical Analysis

Descriptive results are presented as means ± standard deviations. A paired samples t-test was used to assess differences between pre and postseason testing. Effect size (ES) was calculated using Cohen's d[33]. Magnitudes were categorized as: trivial < 0.2, small 0.2–0.6, moderate 0.6–1.2, large 1.2–2, and very large 2.0–4.0.

A preliminary assessment was used to ensure that college soccer experience and playing time did not affect preseason strength and anthropometric test results. Thus, players were separated into groups based on college soccer experience and playing time. The college soccer experience groups consisted of underclassmen (<2 years of college soccer experience, n =16) and upperclassmen (>2 years of college soccer experience, n = 16). Playing time groups consisted of high (>60% of total gameplay, n = 12) and low (<40% total gameplay, n = 16) minute players. A preliminary independent samples t-test was used to determine if significant differences in test scores existed between the groups.

No significant differences in strength and anthropometric variables were found between high and low-minute groups (Table 1). In contrast, significant differences were found between under and upperclassmen with static jump variables. Therefore, for the static jump variables, Pearson correlations were run on the two experience groups individually. In addition, significant differences in session RPE between high and low-minute groups were found (Figure 1). Because of the differences found in accumulated session RPE between high and low-minute groups, correlation analysis was performed on both of these groups individually and on pooled data from the entire sample.

Table 1. P-values comparing the player experience (upperclassmen and underclassmen) and playing time (high and low-minute) groups.

	Upper vs Under	High vs Low
CMJ 0kg	0.46	0.81
CMJ 20kg	0.06	0.68
SJ 0kg	0.04*	0.16
SJ 20kg	0.00*	0.32
Peak Force	0.37	0.22
IPFa	0.25	0.13
RFD 200ms	0.96	0.43
Body Mass	0.99	0.99
Body Composition	0.50	0.62

* indicates a statistical difference ($P \leq 0.05$) between groups.

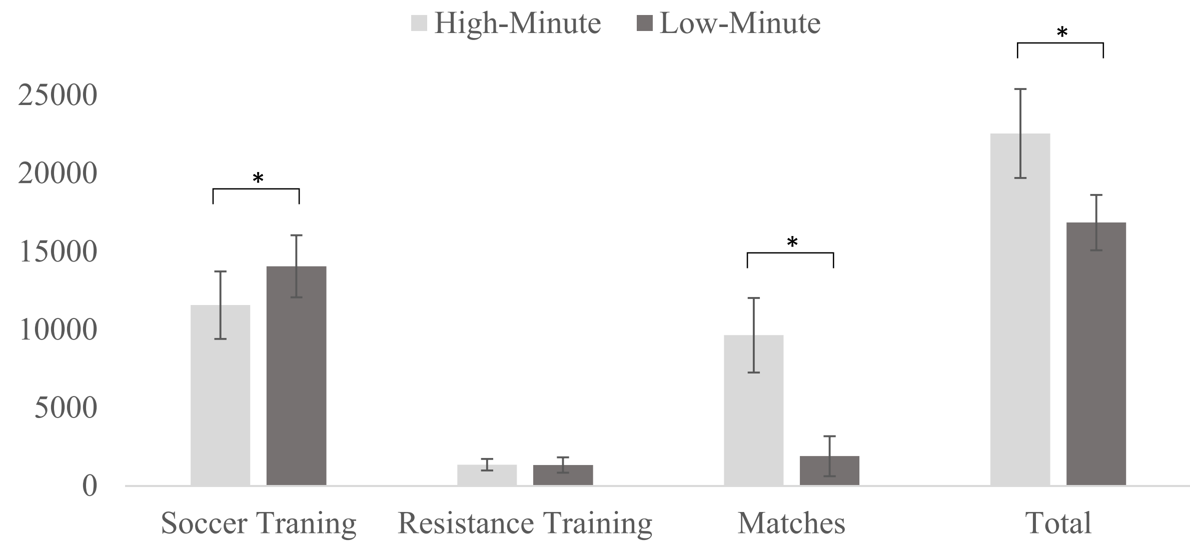

Figure 1. Accumulated session RPE (arbitrary units) for high and low-minute playing time groups. * indicates a statistical difference ($P < 0.05$) between the high and low minute groups.

Pearson's product-moment correlation coefficients were used to examine the relationship between in-season accumulated training load and change in strength and explosiveness parameters. The magnitude of the relationships was described as trivial ($r < 0.1$), small ($0.1< r <0.3$), moderate ($0.3 < r <0.5$), large ($0.5 < r <0.7$), very large ($0.7 < r <0.9$), nearly perfect ($r > 0.9$), and perfect ($r = 1$). Statistical significance was set at $p \leq 0.05$ [34].

RESULTS

As shown in Table 2, analysis of pooled data indicated no significant changes in explosiveness, strength, and anthropometric variables from pre to post season. All effect sizes were trivial. Table 3 displays no significant changes in strength and anthropometric variables when players were separated into high and low-minute playing groups. Table 4 displays significant decreases in CMJ 0 kg within the underclassmen and significant decreases in IPFa among the upperclassmen. Furthermore, the upperclassmen tended to increase in all jump measures from pre to post season, while underclassmen did not.

Table 2. Changes in strength and anthropometric variables for pooled data (n = 32).

	Pre	Post		
	Mean ± SD	Mean ± SD	P-value	Cohen's d
CMJ 0kg (cm)	34.6 ± 4.0	34.1 ± 3.9	0.41	0.13
CMJ 20kg (cm)	26.0 ± 3.3	25.9 ± 3.0	0.84	0.03
SJ 0kg (cm)	31.3 ± 3.2	31.2 ± 4.1	0.84	0.03
SJ 20kg (cm)	23.9 ± 2.9	24.2 ± 3.4	0.56	0.10
Peak Force (N)	3642 ± 662	3553 ± 546	0.23	0.15
IPFa (N $kg^{-0.67}$)	205.9 ± 31.3	201.2 ± 28.7	0.26	0.15
RFD 200ms (N/s)	6989 ± 2040	6642 ± 1879	0.33	0.18
Body Mass (kg)	74.0 ± 7.5	74.2 ± 8.1	0.49	0.03
Percent Fat	9.5 ± 3.3	9.8 ± 3.5	0.27	0.09

* indicates a significant difference ($P \leq 0.05$) between pre and post testing.

Table 3. Changes in strength and anthropometric variables for high (n = 12) and low-minute (n = 16) playing time groups.

		Pre	Post		
	Group	Mean ± SD	Mean ± SD	P-value	Cohen's d
CMJ 0kg (cm)	High-Minute	35.1 ± 4.2	34.9 ± 3.2	0.86	0.01
	Low-Minute	34.7 ± 3.9	34.1 ± 4.2	0.42	0.01
CMJ 20kg (cm)	High-Minute	26.5 ± 3.0	26.2 ± 1.9	0.73	0.12
	Low-Minute	26.0 ± 3.6	26.0 ± 3.4	0.95	0.01
SJ 0kg (cm)	High-Minute	32.6 ± 3.4	31.9 ± 3.4	0.47	0.20
	Low-Minute	30.8 ± 3.1	31.0 ± 4.7	0.75	0.07
SJ 20kg (cm)	High-Minute	24.7 ± 2.6	25.3 ± 3.2	0.49	0.21
	Low-Minute	23.5 ± 3.2	23.8 ± 3.8	0.72	0.09
Peak Force (N)	High-Minute	3820 ± 817	3581 ± 705	0.08	0.31
	Low-Minute	3508 ± 508	3524 ± 447	0.85	0.03
IPFa (N $kg^{-0.67}$)	High-Minute	215.7 ± 38.7	202.8 ± 35.3	0.07	0.35
	Low-Minute	198.6 ± 20.4	199.7 ± 23.7	0.84	0.05
RFD 200ms (N/s)	High-Minute	7319 ± 1775	7156 ± 1731	0.74	0.09
	Low-Minute	6745 ± 1985	6298 ± 1921	0.42	0.23
Body Mass (kg)	High-Minute	74.2 ± 7.0	74.1 ± 7.3	0.87	0.01
	Low-Minute	73.7 ± 8.3	74.2 ± 9.1	0.26	0.06
Percent Fat	High-Minute	9.9 ± 3.7	9.7 ± 3.3	0.64	0.05
	Low-Minute	9.2 ± 3.0	9.9 ± 3.5	0.10	0.20

* indicates a significant difference ($P \leq 0.05$) between pre and post testing.

Table 4. Changes in strength and anthropometric variables for upper (n = 16) and underclassmen (n = 16) playing time groups.

	Group	Pre Mean ± SD	Post Mean ± SD	P-value	Cohen's d
CMJ 0kg (cm)	Upperclassmen	35.2 ± 4.3	35.9 ± 3.7	0.40	0.24
	Underclassmen	34.1 ± 3.8	32.4 ± 3.4	0.05*	0.59
CMJ 20kg (cm)	Upperclassmen	27.1 ± 3.5	27.2 ± 3.1	0.90	0.04
	Underclassmen	24.9 ± 2.9	24.6 ± 2.4	0.56	0.14
SJ 0kg (cm)	Upperclassmen	32.6 ± 3.5	32.6 ± 3.7	0.98	0.01
	Underclassmen	30.2 ± 2.5	30.0 ± 4.1	0.79	0.08
SJ 20kg (cm)	Upperclassmen	25.4 ± 2.7	25.8 ± 3.1	0.58	0.15
	Underclassmen	22.4 ± 2.5	22.7 ± 3.1	0.75	0.11
Peak Force (N)	Upperclassmen	3747 ± 739	3520 ± 644	0.42	0.50
	Underclassmen	3259 ± 571	3587 ± 440	0.53	0.19
IPFa (N $kg^{-0.67}$)	Upperclassmen	212.2 ± 36.1	200.4 ± 33.9	0.05*	0.49
	Underclassmen	199.1 ± 24.7	202.2 ± 22.9	0.59	0.18
RFD 200ms (N/s)	Upperclassmen	7007 ± 1748	7037 ± 1932	0.95	0.02
	Underclassmen	6969 ± 2375	6220 ± 1788	0.20	0.59
Body Mass (kg)	Upperclassmen	74.0 ± 6.5	73.7 ± 6.5	0.42	0.07
	Underclassmen	74.0 ± 8.6	74.8 ± 9.7	0.10	0.11
Percent Fat	Upperclassmen	9.9 ± 3.7	9.9 ± 4.0	0.90	0.01
	Underclassmen	9.1 ± 2.9	9.8 ± 3.0	0.16	0.25

* indicates a significant difference ($P \leq 0.05$) between pre and post testing.

With pooled data from all 32 subjects, significant moderate correlations were observed between resistance training and 20KG CMJ and between resistance training and RFD 0-200ms (Table 5). All other correlations were trivial. Our preliminary analysis revealed a need to perform individual correlation analysis on the upper and underclassmen groups for the static jumps, and individual analysis on the high and low-minute groups for all variables. Thus, correlation analysis revealed no significant relationships in upper or underclassmen groups (Table 6). In addition, Table 7 shows one large, significant correlation between resistance training and IPFa in the high-minute group, and one large significant correlation between match session RPE and body mass in the low-minute group.

Table 5. Correlations between accumulated session RPE and changes in strength and anthropometric variables for pooled data (n = 32).

	Soccer Training	Resistance Training	Matches	Total
CMJ 0kg	-0.11	0.25	0.02	0.07
CMJ 20kg	-0.13	0.356*	-0.14	-0.16
SJ 0kg	0.00	-0.08	0.00	-0.08
SJ 20kg	0.20	-0.04	0.05	0.04
Peak Force	0.09	-0.15	-0.28	-0.25
IPFa	0.06	-0.18	-0.29	-0.26
RFD 200ms	0.04	0.384*	-0.10	0.13
Body Mass	-0.33	-0.10	0.11	0.02
Percent Fat	0.35	0.04	-0.19	-0.11

* indicates significant correlation at the P ≤ 0.05 level.

Table 6. Correlations between accumulated session RPE and changes in static jump height for under (n = 16) and upperclassmen (n = 16) experience groups.

	Group	Soccer Training	Resistance Training	Matches	Total
SJ 0kg	Underclassmen	-0.01	-0.17	0.01	-0.13
	Upperclassmen	0.03	0.01	-0.03	-0.01
SJ 20kg	Underclassmen	0.27	-0.09	-0.09	-0.11
	Upperclassmen	-0.01	0.05	0.29	0.37

* indicates significant correlation at the P ≤ 0.05 level.

Table 7. Correlations between accumulated session RPE and changes in strength parameters for both high (n = 12) and low-minute (n = 16) playing time groups.

	Group	Soccer Training	Resistance Training	Matches	Total
CMJ 0Kg (cm)	High-Minute	-0.26	0.21	0.17	0.03
	Low-Minute	-0.05	0.30	-0.17	0.04
CMJ 20kg (cm)	High-Minute	-0.49	0.52	0.07	-0.20
	Low-Minute	0.05	0.29	-0.34	0.02
SJ 0kg (cm)	High-Minute	-0.29	-0.09	0.50	0.34
	Low-Minute	-0.03	-0.09	0.05	-0.08
SJ 20kg (cm)	High-Minute	-0.09	-0.14	0.33	0.28
	Low-Minute	0.39	0.01	-0.11	0.24
Peak Force (N)	High-Minute	-0.43	-0.19	0.08	-0.31
	Low-Minute	-0.06	-0.16	-0.05	-0.06
IPFa (N)	High-Minute	-0.41	-0.16	0.06	-0.32
	Low-Minute	-0.13	-0.23	0.05	-0.07
RFD 200ms (N/s)	High-Minute	0.02	.65*	-0.40	-0.29
	Low-Minute	-0.01	0.29	-0.05	0.21
Body Mass (kg)	High-Minute	0.25	0.26	-0.28	-0.05
	Low-Minute	-0.45	-0.30	.61*	-0.14
Percent Fat	High-Minute	0.15	-0.29	0.02	0.09
	Low-Minute	0.16	0.18	-0.12	0.06

* indicates significant correlation at the $P \leq 0.05$ level.

DISCUSSION

The primary findings of this study are 1) strength, explosiveness, and anthropometrics variables were maintained throughout the season, 2) the upperclassmen jumped significantly higher than the underclassmen, and 3) a moderate positive dose-response relationship existed between strength and explosiveness characteristics and training load from resistance training.

Preliminary analysis of preseason SJ 0 kg and SJ 20 kg revealed that upperclassmen jumped significantly higher than underclassmen (Table 1). This was likely due to the fact that upperclassmen had two or more years of supervised, periodized resistance training experience, compared to the underclassmen who had less than two years of experience. It is also important to note that a majority of the underclassmen were freshmen, with little resistance training experience.

Analysis of pooled data revealed no significant changes in strength and anthropometric variables across the competitive season. Numerous other studies have found similar results with vertical jump performance [7, 35-37] and anthropometrics [38]. However, these results suggest that player strength qualities were maintained throughout the season. Furthermore, training experience seemed to have a beneficial effect on jump performance across a season. The upperclassmen group maintained or slightly increased jump performance, while underclassmen generally slightly decreased performance (Table 4). It is likely that these results would not have happened without a periodized training strategy [39], with a goal to maintain strength. The assessment of training effectiveness was not included in the present study, but it must be noted that training was carefully planned by a sport scientist. In addition, the head coach met with the sport scientist on a daily basis and was very willing to comply with adjustments needed in the training program.

The authors were unable to find studies that used the IMTP test to determine pre and postseason strength changes in male soccer players. However, for comparison purposes a previous study found NCAA DI soccer players to have a IPFa of 259 ± 28 $N/kg^{0.67}$ [40]. Other studies have observed pre and post season changes using various isokinetic tests with varying results [37, 39]. Isokinetic tests are often performed with single joint knee flexion and extension, which may not be as specific to soccer performance as other tests [41]. Silva et al. [37] observed no changes in isokinetic knee flexor and extensor strength across a season (~11 months) in a group of professional Portuguese male soccer players. Kraemer et al. [39] found a significant decrease in isokinetic strength of the knee extensors (1.05 $rad \cdot sec^{-1}$) in NCAA Division I starters (-12%) and nonstarters (-10%; $P \leq 0.05$). The large decrements in knee extensor strength may be indicative of overtraining, which the authors attributed to the intense preseason training. In alignment with other studies body mass and body composition did not change[38, 42, 43]. In contrast, other studies have found mixed results using both short (9-week) and long (10 months) time periods, concluding that body mass did not change during the season, but percent fat significantly decreased [6, 44].

The largest correlations reported in this study were moderate for pooled data (Table 5) and large for grouped data (Table 6). Arcos et al. [6] reported small to large correlations (r = -0.17 to -0.61) between respiratory/muscle session RPE and change in CMJ height across a 9-week period in professional male soccer players. Interestingly, their highest correlations occurred between muscle session RPE and changes in single leg CMJ height (r = -0.61 and -0.53), while bilateral CMJ performance demonstrated a weaker relationship (r = -0.17 and -0.38). Gil-Rey et al. [7] also observed the correlations between respiratory/muscle session RPE and change in CMJ height across a 9-week period in 28 junior Spanish first and third division players. The CMJ was performed with and without arm swing. Correlations between changes in CMJ performance and respiratory/muscle session RPE ranged from small to trivial, and demonstrated negative relationships with CMJs performed without arm swing (r = -0.06 and -0.17) and positive relationships for CMJs performed with arm swing (r = 0.25 and 0.17). Despite the differences in methodologies between studies, loaded or unloaded bilateral CMJs seem to have a trivial to small relationships with subjective measures of training load. Therefore, they may have little use in establishing a training dose-response relationship.

CONCLUSION

It appears that training experience had a statistically significant positive effect on vertical jump performance. This higher vertical jump height was observed during the preseason. Although only one statistical change occurred from pre to postseason, the upperclassmen maintained or increased jump height while underclassmen maintained or experienced slight decreases in jump height (Table 4). When all data were pooled together, no changes in strength and anthropometric variables were observed across a NCAA Division I men's soccer season. This is reflective of the maintenance training program that the players completed during the season. When players were divided into high and low-minute groups, no significant differences in strength and anthropometric variables were found. However, minor trends were observed towards a slight decrease in strength variables for the high-minute group and a slight increase in strength variables for the low-minute group. Therefore, the accumulation of training load from matches (fatigue) likely contributed to strength losses measured at the end of the season. Player rotation and perhaps more resistance training is warranted in order to prevent strength and explosiveness decrements.

Among pooled data the largest correlations between strength variables and total session RPE were moderate. These moderate (or close to moderate, $r > 0.27$) relationships demonstrated positive relationships with resistance training, and negative relationships with both matches and soccer training. All moderate or greater relationships in this study were positive between resistance training and strength variables, indicating a positive dose-response relationship. Despite having a positive dose-response relationship, very few large correlations between strength variables and session RPE were observed. As a result, the authors recommend that session RPE alone, not be used as the sole indicator of training load prescribed to achieve changes in strength.

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CHAPTER 6

SUMMARY AND FUTURE RESEARCH

The purpose of this dissertation was to determine if a there was a dose-response relationship across an NCAA Division I men's soccer season. Specifically, this dissertation serves to: 1.) assess the validity of duration measurements that are used to calculate session RPE during competitive matches, 2.) determine the degree and magnitude of change in endurance performance across a season and to see how this change in endurance relates with training load, 3.) determine the degree and magnitude of change in strength across a season, and to see how these strength changes relate to training load. Particularly, the first study validated the durations used to calculate session RPE by comparing them to a criterion measure (GPS). The calculation of session RPE using minutes played was significantly different from other calculations, and had the highest (very large) correlation with the criterion measure. The second and third studies had similar goals: to determine the changes in fitness across a season, and if those changes in fitness related to training load. The second study revealed a statistically significant change in endurance (Yo-Yo IR1) performance from pre to post season. A moderate effect size indicated a practical change. In addition, these endurance changes largely correlated to total training load from matches, soccer training, and resistance training. When players were divided into groups based on minutes played during matches, larger correlation coefficients were observed for the high-minute group with both matches and total training load. However, all correlations with endurance performance were negative, suggesting that greater amounts of training load caused a decrease in endurance performance. The third study revealed no significant changes in fitness with pooled data. However, when players were grouped based on playing experience, statistically significant decreases in CMJ 0kg for underclassmen and IPFa for upperclassmen were observed. Furthermore, small effect sizes between these variables indicate little practical significance to these changes in fitness. Relationships between training loads and changes in fitness ranged from trivial to moderate with pooled data. However, training load from resistance training showed moderate, positive relationships with changes in CMJ 20kg and RFD at 200ms. Some of these relationships increased when players were divided into high and low-minute playing groups; the high-minute group experienced large correlations with CMJ 20kg and RFD at 200ms. Thus, it appears that resistance training fits a positive dose-response relationship in soccer, and should be a part of an athlete's overall in-season training program.

Practical Applications

Session RPE is one of the most commonly used methods for quantifying training load in soccer players. Even when expensive technology is available, it still proves to be useful. By using minutes played to calculate session RPE, coaches will be able to determine post-match recovery and training strategies that more accurately reflect fatigue levels produced by a competitive match.

High perceived effort during matches and excessive accumulation of training load can impair several fitness parameters that are believed to be reflective of on-field soccer performance. The fact that no correlations were 'very large' (0.70, which indicates that less than 50% of shared variance between the two variables) indicates the presence of substantial individual (between-player) responses in the reported correlations. Thus, it is recommended that training load be monitored using a combination of methods instead of session RPE alone. Session RPE does not appear to fit a positive dose-response relationship with endurance performance. However, positive dose-response relationships were found between resistance training load and a majority of the strength parameters. This indicates that in-season resistance training is important for the maintenance of strength in soccer.

Future Research

Future research should continue to examine minutes played as a method for calculating session RPE in other populations of soccer players. Session RPE should be validated during matches using heart rate methods as well as GPS technology.

This and several other studies have found it difficult to clearly demonstrate a dose-response relationship in soccer players. Future studies should objectively quantify training and incorporate preparedness and fatigue scores in their models as these variables likely influence our response to training.

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APPENDICES

Appendix A: ETSU Institutional Review Board Approval

EAST TENNESSEE STATE
UNIVERSITY

Office for the Protection of Human Research Subjects • Box 70565 • Johnson City, Tennessee 37614-1707
Phone: (423) 439-6053 Fax: (423) 439-6060

IRB APPROVAL – Initial Expedited Review

April 13, 2016

Andrew Pustina

Re: THE RELATIONSHIP BETWEEN TRAINING LOAD AND PHYSICAL PERFORMANCE ACROSS A DIVISION I SOCCER SEASON
IRB#:c0316.5sw
ORSPA #:

The following items were reviewed and approved by an expedited process:

- new protocol submission form, PI CV, References, List of variables

On **March 31, 2016**, a final approval was granted for a period not to exceed 12 months and will expire on **March 30, 2017**. The expedited approval of the study will be reported to the convened board on the next agenda.

A **waiver or alteration of informed consent** has been granted under category 45 CFR 46.116(d). The research involves no more than minimal risk because it involves a retrospective analysis of data only. The waiver or alteration will not adversely affect the rights and welfare of the subjects as the athletes whose data is involved have already given consent to have their data added to the research repository whereby data may be drawn for research purposes. The research could not practicably be carried out without the waiver or alteration as many of the athletes in the study population are no longer with ETSU. Providing participants additional pertinent information after participation is NOT appropriate.

The following **enclosed stamped, approved Informed Consent Documents** have been stamped with the approval and expiration date and these documents must be copied and provided to each participant prior to participant enrollment:

- n/a retrospective

Federal regulations require that the original copy of the participant's consent be maintained in the principal investigator's files and that a copy is given to the subject at the time of consent.

Accredited Since December 2005

Projects involving Mountain States Health Alliance must also be approved by MSHA following IRB approval prior to initiating the study.

Unanticipated Problems Involving Risks to Subjects or Others must be reported to the IRB (and VA R&D if applicable) within 10 working days.

Proposed changes in approved research cannot be initiated without IRB review and approval. The only exception to this rule is that a change can be made prior to IRB approval when necessary to eliminate apparent immediate hazards to the research subjects [21 CFR 56.108 (a)(4)]. In such a case, the IRB must be promptly informed of the change following its implementation (within 10 working days) on Form 109 (www.etsu.edu/irb). The IRB will review the change to determine that it is consistent with ensuring the subject's continued welfare.

Sincerely,
Stacey Williams, Chair
ETSU Campus IRB

cc: Kimitake Sato

Appendix B: Informed Consent Document

PRINCIPAL INVESTIGATOR: Michael H. Stone

TITLE OF PROJECT: Sports Science Research Repository

INFORMED CONSENT DOCUMENT (ICD)

This Informed Consent will explain about being a participant in a research repository. It is important that you read this material carefully and then decide if you wish to be a volunteer.

What is a research repository?
A research repository is a database (data bank) that is a collection of information from the records of many individuals. The database is used to store data for future use. The databank includes codes that identify each person whose information is collected. If you decide to join this research repository, the repository may keep your athletic monitoring information and share it with researchers who study sports science.

What is the purpose of this repository?
Information in the Sports Science Research Repository will be used to help researchers learn more about the field of sports science, including training and monitoring athletes.

What am I being asked to do and how long will it last?

You are being asked to do the following: allow the information obtained during your athletic monitoring to be stored in this database that will be used for research purposes.

If you agree to contribute your data to the Sports Science Research Repository, the information from your previous monitoring results will be added to the repository. In addition, the information that will be obtained during future monitoring while you are an athlete at ETSU will be added to the Sports Science Research Repository. The types of data that may be added to the repository include:

a. Dates and times of monitoring tests
b. Results of your body size and composition tests, such as height, weight, skinfold measurements, muscle size (ultrasound or DEXA), bone density (DEXA) and other similar tests
c. Results of your hydration tests
d. Results of your vertical jump tests
e. Results of your isometric pull tests
f. Results of your blood work

APPROVED
By the ETSU IRB

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By ____ Chair/IRB Coordinator

ETSU IRB

g. Results of monitoring tests that are a specific part of your sport (for example, results of ball handling skill tests or sprints)

In the future, a researcher may wish to conduct research in the field of sports science that requires information (data) such as yours. That researcher would then ask the Sports Science Research Repository for information that includes your data, for a specific research study. The data will be used primarily by researchers at ETSU. However, there may also be collaborative efforts with other universities and private companies that use the data. Your information will be maintained by ETSU for such research purposes as long as allowed by the law or until Dr. Stone or ETSU decides to discontinue the Sports Science Research Repository.

What possible harms or discomforts might I experience if I take part in this research?

Because this study involves the use of your personal information, there is a possible risk of loss of confidentiality. Although, very unlikely, this means that someone may be able to piece together data such that your identity could be discovered. To lower that risk, the researchers will protect the data base by limiting access to the computer(s) in which access to the data is possible. Your data will not be provided to anyone without a sound research question (s) and without IRB approval or determination of non-human subject research.

What are the possible benefits I may experience form taking part in this research?

There is no direct benefit to the participant by permitting the investigators to add their performance information in the research repository. However, the results of future retrospective studies conducted using the data in this repository may contribute to the general knowledge of enhancing athletic performance, reducing the risks associated with over-training and aid in the prevention of injuries related to training or participation in collegiate athletic programs.

Do I have to participate in this study?

Your participation in adding your data to the repository is entirely voluntary. You should feel free to ask questions as they occur to you. Your questions should be answered clearly and to your satisfaction. You are free to withdraw at any time without fear of reprisal from the investigators and you will not lose any benefits to which you would otherwise be entitled. Your course grades also will not be impacted by your decision to participate or withdraw from the research repository. If you decide to withdraw your consent, you can have your data removed from the repository. To withdraw from this study, contact (Dr. Mike Stone), (423-439-5796) or Mark south (423-439-4655).

How will you keep the information you collect about me secure? How long will you keep it? Who will know that I took part in this research and learn personal information about me?

The information that will be entered in this Sports Science Research Repository is already used for non-research purposes as part of your athlete monitoring program. This document only applies to the information that becomes part of the repository for future research purposes.

The Sports Science Research Repository electronic records will be stored on computers/servers with password protection. A copy of the records from this study will be stored on the S drive at ETSU for at least 5 years after the end of this research repository. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the ETSU IRB, and personnel particular to this research in the Sports Science Department have access to the study records.

The Sports Science Research Repository will follow all legal requirements before releasing your information to others for research in the future. For example, future use of identifiable repository data for research would require review by the East Tennessee State University Institutional Review Board (IRB). The researcher would be required to submit the IRB's decision to the Coordinator of the Sports Science Research Repository in order to obtain release of your information for research.

<u>Who can I contact if I have questions?</u>

If you have any questions, problems or research-related problems at any time, you may call (Dr. Mike Stone) at (423-439-5796), or (Dr. Mike Ramsey) at (423-439-4375). You may call the Chair of the Institutional Review Board at 423/439-6054 for any questions you may have about your rights as a research subject. If you have any questions or concerns about the research and want to talk to someone independent of the research team or you can't reach the study staff, you may call an IRB Coordinator at 423/439-6055 or 423/439/6002.

By signing below, you confirm that you have read or had this document read to you, that you have been given the chance to ask questions and to discuss your participation with the person obtaining your consent, that you have decided to participate, and that a copy of this form has been given to you.

By signing this informed consent I verify that I am at least 18 years old.

SIGNATURE OF PARTICIPANT DATE

PRINTED NAME OF PARTICIPANT DATE

SIGNATURE OF INVESTIGATOR DATE

APPROVED
By the ETSU IRB
JUN 18 2015
By ____ Chair IRB/Coordinator

DOCUMENT VERSION EXPIRES
JUN 17 2016
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VITA

ANDREW A. PUSTINA

Education:	B.S. Physical Education. University of Wisconsin– Platteville, Platteville,WI, USA, 2008.
	M.S. Exercise and Sport Science. University of Wisconsin – La Crosse, La Crosse, WI, USA, 2010.
	Ph.D. Sport Physiology & Performance. East Tennessee State University, Johnson City, TN, USA, 2016.
Experience:	Sport Scientist/Strength and Conditioning Coach, East Tennessee State Unviersity Men's Soccer 2013-2016.
	Graduate Assistant/Teaching Fellow, East Tennessee State Unviersity, 2013-2016.
	Lecturer of Athletic Coaching Education, West Virginia University Institute of Technology, Montgomery, WV, USA, 2012-2013.
	Adjunct Lab Instructor, University of Wisconsin – La Crosse, La Crosse, WI, USA, 2011-2012.
	Adjunct Lecturer, Globe Unviersity, Onalaska, WI, USA, 2010-2012.
	Soccer Coach, 2004 – present
Publications:	Pustina, A. A., Sams, M. L., Liu, J., Sato, K., Mizuguchi, S. Relationship between subjective and objective indicators of training laod in division I men's soccer players during training sessions and competitive matches. Coaches College 2015.
	Sams, M., Pustina, A., Liu, J., Smith, J., Grazer, J., and Mizuguchi, S. The effect of position and team formation on the physical anctivity profiles of a division I men's soccer team. Coaches College 2015.
	Liu, J., Bazyler, C., Taber, C., Pustina, A. A., Mizuguchi, S., Application of pricipal component analysis in kinetics study for iso-squat. Coaches College 2015.
	Liu, J., Pustina, A. A., Uptmore, K., Santanna, H., Bingham, G., Taber, C., Harvey, E., Sams. M. L. A brief review of soccer performance analysis models. Coaches College 2014.

Wright, G. A., Pustina, A. A., Mikat, R.P., Kernozek, T. W. (2012). Predicting lower body power from vertical jump prediction equations for loaded jump squats at different intensities in men and women. Journal of Strength and Conditioning Research. 26, 648-655.