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Comparison of Static and Countermovement Jump Variables in Relation to Estimated Training Load and Subjective Measures of Fatigue

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Comparison of Static and Countermovement Jump Variables in Relation to

Estimated Training Load and Subjective Measures of Fatigue

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ABSTRACT

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The purpose of this study was to compare changes in static and countermovement jump variables across a competitive season of collegiate soccer to estimated training load and subjective measures of fatigue. Monitoring data from 21 male collegiate soccer players were retrospectively examined. Nine vertical jump sessions occurred across the season in addition to daily training load assessment and daily mood-state assessment. Group average changes from the first testing session were calculated and compared to the group average training load for the 7 days preceding each vertical jump testing session for static and countermovement jump height and allometrically scaled peak power. Statistical analysis demonstrated strong relationships between changes in vertical jump height for both conditions, allometrically scaled peak power for static jumps, and estimated training load. The results indicate changes in static jump height and allometrically scaled peak power may be more useful athlete fatigue monitoring tools than countermovement jump variables.

DEDICATION

To my Family –

This thesis is dedicated to my mother Sonia for her love and support over the years and to my late father Charlie for instilling an unwavering work ethic and stubbornness in me that have kept me going all these years. I couldn't have accomplished what I have without everything you've done for me all these years. This is also dedicated to my niece and nephew, Callie and Nate, my biggest fans. Finally, I want to dedicate this work to my sister Sarah and brother-in-law Rusty for their swift kicks to the hind end when I've gotten off track.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

Statement of Problem

The purpose of this study was to compare changes in static and countermovement jump variables across a competitive season of collegiate soccer to estimated training load and subjective measures of fatigue. Static and countermovement vertical jump performances were measured via force plates, whereas estimated training load and fatigue were measured through assessment of perceived exertion and mood-state questionnaire distribution.

Hypothesis

It his hypothesized that changes in static vertical jump variables will more accurately reflect imposed training load and changes in mood state than changes in countermovement vertical jump variables.

Operational Definitions

1. Allometrically Scaled Peak Power (PPa): Peak power divided by the athlete's body mass raised to the 2/3 power

2. Countermovement Jump (CMJ): A vertical jump that assesses the athlete's ability to use a stretch-shortening cycle as well as the muscle plus connective tissues' ability to use elastic energy and generate a myototic (stretch) reflex. A bar is positioned across the trapezius to eliminate the contribution of arm swing to jump height.

3. Fatigue: A reduction in the force generating capabilities of a muscle or group of muscles.

4. Flight Time: The time in milliseconds (ms) an athlete has no contact with the force plates following a vertical jump.

5. Jump Height: The distance measured in centimeters (cm) the athlete jumps off the force plate as determined by flight time.

6. Peak Power: The highest instantaneous power value found over a range of motion under a given set of conditions.

7. Power: The product of force and velocity; a rate of doing work (P = force x distance/time).

8. Session Rating of Perceived Exertion (sRPE): A global measure of perceived intensity (difficulty) of a training or competitive session.

9. Static Jump: A vertical jump where the athlete is positioned at a 90 degree knee angle, which is held for ~3 seconds prior to jumping. The athlete uses the contractile elements of the muscle without the aid of a countermovement. This tests an athlete's concentric force production. Similar to a CMJ, a bar is positioned across the trapezius to eliminate the contribution of arm swing to jump height.

10. Stretch-Shortening Cycle: The increase in force production due to a rapid prestretch of a muscle immediately prior to concentric action of the same muscle.

11. Training Load (RPETL): The product of session rating of perceived exertion and the duration of the training activity.

Comprehensive Review of the Literature

The purpose of an athlete training plan is to optimally develop athletes physically, technically, and tactically so they may achieve the highest levels of performance of which they

are capable. Optimal training strategies involve overloading some component of an athlete's physiology, inducing a "valley of fatigue" (Taylor, 2012), followed by an unloading period in which volume and/or intensity are decreased to allow for recovery and supercompensation of performance (Stone, Stone, & Sands, 2007). During the competitive phase, however, the training process places emphasis on maintenance of developed physical qualities and fatigue management.

Competition induces high levels of fatigue in athletes. Numerous studies (Andersson et al., 2008; Ascensao, Leite, Rebelo, Magalhaes, & Magalhaes, 2011; Cormack, Newston, McGuigan, & Cormie, 2008b; Hoffman, Nusse, & Kang, 2003) suggest 3 or more days are required to return to precompetitive levels of fatigue and performance. In cases such as men's collegiate soccer, such lengthy recovery periods are impossible to achieve. Up to three competitions occur in a week, with starters participating in a majority of the minutes played. As a result in-season training focuses on maintenance of physiological characteristics, refinement of tactics and technique, and recovery from competition. When recovery is inadequate for prolonged periods, injury risk increases while performance stagnates or decreases (Meeusen et al., 2013; Stone et al., 2007; Taylor, 2012). With the increased professionalism in sport, an injury or poor performance could equal the loss of competitions and/or millions of dollars in revenue. Thus, the importance of athlete monitoring has increased in recent years.

This review of literature is an analysis of the most common means of quantifying training load (TL). Further, both objective and subjective measures of athletes' responses to TL are examined.

Methods of Quantifying Training Load

   Two broad categories of TL monitoring exist: external measures and internal measures (Table 1.1). While practitioners use various TL quantification methods, no gold standard has been suggested (Martin, 2014; Roos, Taube, Brandt, Heyer, & Wyss, 2013). Thus, practitioners often use a combination of internal and external measures to quantify training. The most commonly used methods of quantification are discussed below.

Table 1.1

Most Common Measures of Training Load

Measure	Category	Pros	Cons
Heart Rate	Internal	• Valid/reliable in steady state scenarios • Strong relationship to laboratory measures of intensity • Portable and noninvasive • Combination with other measures potentially useful monitoring tool	• Unit malfunctions lead to loss of data • Loss of accuracy in very-low/very-high intensity situations or intermittent training • Influenced by environmental (temperature, humidity, altitude) and physiological (hydration status, training status) factors
Motion Analysis Systems	External	• Valid/reliable measure of physical data (distance covered, distances covered at different velocities, etc.)	• Cost • Time-consuming analysis • Sampling rate influences reliability • Many systems purely examine physical data and do not account for accelerations/decelerations and changes of direction
Session Rating of Perceived Exertion	Internal	• Validated in a variety of activities and sports • Shown to be valid and reliable measure of intensity in steady-state and intermittent exercise • Strong relationship with physiological measures	• Subjective measure • Tends to reflect final activity of training session • Affected by duration • May be affected by length of time between activity and RPE acquisition

Heart Rate. Portable heart rate monitors (HRM) were first introduced as a means to monitor exercise intensity and TL in the 1980s (Achten & Jeukendrup, 2003). Typically the athlete wears an adjustable chest strap or wrist watch that measures heart rate (HR) on a beat-by-beat basis and reports either the instantaneous value or the average rate over a given time period. These monitors have been shown to be valid and reliable HR measurement tools and demonstrate accuracy similar to electrocardiography (ECG) (Achten & Jeukendrup, 2003; Strath et al., 2000).

Heart rate monitoring focuses on two areas: estimated energy expenditure (EE) and calculation of training impulse (TRIMP). At submaximal intensities oxygen uptake ($\dot{V}O_2$) and HR demonstrate a linear relationship (Astrand, Rodahl, Dahl, & Stromme, 2003). As such, HR can be used to estimate $\dot{V}O_2$. Researchers extrapolate this relationship to predict maximum oxygen uptake ($\dot{V}O_{2max}$) and $\dot{V}O_2$ and EE at a variety of submaximal intensities. These predictions involve several assumptions that introduce error: (a) the subject's HR-$\dot{V}O_2$ relationship is truly linear; (b) the subject's maximum heart rate is known or has been predicted accurately; (c) the subject's exercise economy is constant; (d) the subject's exercise heart rate is not influenced by day-to-day variability (Reuter & Hagerman, 2008). Due to these assumptions, predicted $\dot{V}O_{2max}$ values fall within 10%-20% of the subject's actual $\dot{V}O_{2max}$ (Reuter & Hagerman, 2008). To account for individual differences in the HR-$\dot{V}O_2$ relationship and to create the most accurate EE prediction curves, laboratory testing is required (Strath et al., 2000). This method, however, is time consuming, fatiguing, costly, and normally unfeasible in team sport settings. Thus, practitioners have placed increased focus on TRIMP.

Training impulse was devised as a means to quantify TL through heart rate responses to exercise. The initial calculation combined training volume (distance travelled) and an arbitrary intensity scalar (1 = warm-up intensity; 2 = low-intensity, long duration; 3 = high-intensity, short

duration) (Banister, Calvert, Savage, & Bach, 1975; Calvert, Banister, & Savage, 1976). With the advent of portable HRM, however, Morton, Fitz-Clarke, and Banister (1990) modified the TRIMP calculation to include training duration, average heart rate, heart rate reserve, and a weighting factor. The weighting factor mirrored the relationship between HR and the rise in blood lactate and, the researchers reasoned, corrected bias that would otherwise occur in long-duration, low intensity training.

One of the major drawbacks to Morton et al.'s (1990) method of TRIMP quantification is that it uses average heart rate across a session. While this method of quantification may be useful in steady-state scenarios, average heart rate does not reflect the variations that occur in more intermittent activities. In sports such as soccer, while the average HR for a match falls between 80% and 90% of maximum, periods of high intensity (near or at maximum heart rate) followed by recovery periods where HR is well below match average have been observed (Ascensao et al., 2008; Stolen, Chamari, Castagna, & Wisloff, 2005). Thus, average HR for a session may not be an appropriate indicator of TL in more intermittent-style sports.

To account for the intermittent nature of many sports, Edwards (1993) proposed the time-in-zone method. In this method arbitrary heart rate zones are identified and assigned an intensity value from 1-5 (Table 1.2). Time in each zone is multiplied by the respective intensity value. These products are summated to derive a total score. A great deal of criticism surrounds the quantification method. Zone assignment is arbitrary and weighted in a manner that has no physiological underpinning (Akubat, 2012). Further, each band typically encompasses ~10% of heart rate maximum, suggesting that the training "dose" and associated physiological responses are the same at every intensity within an intensity band (that is, 10 minutes of training at 81% of heart rate maximum would yield the same physiological load and adaptations as training for 10

minutes at 89% of heart rate maximum). Denadai and colleagues (2006), however, demonstrated that even small differences in training intensity could significantly alter training adaptations. The study results suggest broad, arbitrarily assigned categories such as those used in the time-in-zone TRIMP method may not be appropriate for accurately assessing TL.

Table 1.2

Edwards Heart Rate Zones and Weighting Factors

Intensity Zone (%HRM)	Weighting Factor
50%-60%	1
60%-70%	2
70%-80%	3
80%-90%	4
90%-100%	5

Adapted from Edwards, S. (1993). *Heart Rate Monitor Book*. Sacramento, CA: Fleet Feet Press

Despite its shortcomings, practitioners should not abandon HR measurement as a means to monitor training. As previously discussed, at submaximal intensities $\dot{V}O_2$ and HR demonstrate a linear relationship (Astrand et al., 2003). Thus, HRM are useful in gauging relative intensity in training situations other than weight training, plyometric training, and sprinting (Foster et al., 2001). As such, sport scientists and sport coaches can use HRM to determine relative intensities for various training and conditioning drills that may be useful in creating a training "menu." A training menu aids in the design of daily and weekly training plans based on relative intensities (Manolopoulos et al., 2012). Further, when HR data are combined with other measures (e.g. movement data, technical breakdowns, session RPE, and blood lactate), practitioners gain knowledge of the overall demands of the sport and/or position (Owen, Wong, McKenna, & Dellal, 2011). That is, they have a better understanding of the physiological, technical, and tactical requirements to compete effectively.

Time-Motion Analysis. Time-motion analysis (TMA) involves tracking the movements of athletes in one of three ways: (a) manual analysis of training/game film; (b) computer-assisted (CA) analysis of training and game film; (c) integrated accelerometry and global positioning system (GPS) analysis. Practitioners are able to calculate a number of physical performance variables, including distance covered, distance covered at various velocities, and number and magnitude of accelerations and decelerations. Initial TMA was a labor-intensive process and allowed researchers to quantify the movements of a limited number of athletes (Carling, Bloomfield, Nelson, & Reilly, 2008). Further, while validity and reliability of manual analysis were generally high, the subjective nature of human analysis introduces unwanted error into the system (Bloomfield, Polman, & O'Donoghue, 2007; Carling, Williams, & Reilly, 2005; Mohr, Krustrup, & Bangsbo, 2003). With the advent of CA and GPS analysis, manual analysis has fallen out of favor due to its time-intensive nature (Carling et al., 2008; Gray & Jenkins, 2010). Thus, the discussion focuses on CA and GPS analysis and their potential applicability to training load quantification.

The first CA analysis systems were those introduced in soccer in the late 1990s. Computer-assisted analysis systems use sophisticated video analysis software and mathematical algorithms to determine the positions and movements of each player on the field, allowing for whole-team and whole-match analysis as opposed to single-player, segmental match analysis offered by manual methods (Carling et al., 2008). Detailed descriptions of the methods used in CA analysis are available in Di Salvo, Collins, McNeill, and Cardinale (2006) and Barros et al. (2007).

More recently GPS and combined-GPS and accelerometer systems have become popular in training and match quantification. Unlike the majority of video analysis systems, GPS systems

are portable, very little data manipulation is required, and turnaround time (the time between collection of data to presentation of data to the coach) is expressed in hours instead of days. Further, because the athletes wear the units, data are not limited to distances covered and distances covered at different velocities. Onboard accelerometers and gyroscopes detect changes of direction, jumps, and tackles in sports such as soccer (Carling et al., 2008), Australian Rules Football (Gray & Jenkins, 2010), and rugby (Cunniffe, Proctor, Baker, & Davies, 2009). These data, and proposed component scores based on these data, may provide a more accurate depiction of the total load placed on athletes in both training and game settings.

Early TMA used estimation techniques in its calculations (Duthie, Pyne, & Hooper, 2005). Following the filming of games, selected athletes were videotaped performing activities ranging from walking to sprinting. These activities were used as calibration references when analyzing game film. Researchers recorded the duration of each activity and multiplied this value by the average velocity for the activity to obtain distance covered. Total time performing each activity, total training distance covered for each activity, and total distance for the game were all recorded (Carling et al., 2008; Duthie et al., 2005).

While total distance covered is a useful metric in steady state scenarios, team sports such as soccer are intermittent in nature. Total distance does not provide the full picture of the stresses placed on the athlete, as high-intensity movements are lumped together with low-intensity movements. More recently, increased focus has been placed on distances covered at high velocities (Cummins, Orr, O'Connor, & West, 2013). While the definition of high velocity often differs between researchers, recent research suggests the number of high-intensity activities performed (often lumped into the categories of high-intensity running, very high-intensity running, and sprinting), the time spent in each high-intensity zone, and the total distance covered

in each high-intensity zone are important metrics (Cummins et al., 2013). Running at high velocities places a great deal of stress on the body, both structurally and physiologically, and generates high amounts of fatigue. Thus, high-intensity running and sprint distance are potential training load monitoring tools.

Unfortunately, distances covered at various velocities may not provide the full picture of the stresses placed on the athlete. Team sports involve a high number of changes of direction and tackles in sports such as rugby and Australian Rules football. As such, only examining distances covered neglects the physiological stresses imposed through acceleration, deceleration, and impact forces (McLellan, Lovell, & Gass, 2011; Varley, Fairweather, & Aughey, 2012). Integrated GPS and accelerometer units have attempted to solve this problem. In addition to reporting distances traveled at various velocities and user-defined velocity bands (Cummins et al., 2013), these units report the total number of accelerations and decelerations the athlete experiences. These data also provide insight into the rate of acceleration and deceleration. In similar fashion to velocity bands, practitioners are able to set thresholds for low, medium, high, and very high accelerations and decelerations. When combined with gyroscopic data, some units are also able to detect the number and severity of tackles experienced by the athlete (Catapult Sports, 2013). Several GPS analysis companies have created algorithms that combine accelerometer data and gyroscopic data into a single value.

One such combined value is "Player Load." Player Load is derived from a mathematical formula that accounts for accelerations and decelerations in all three dimensions. Player Load has demonstrated a strong relationship to internal training load measures including heart rate and blood lactate levels (Casamichana, Castellano, Calleja-Gonzalez, Roman, & Castagna, 2013; Montgomery, Pyne, & Minahan, 2010; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013).

Further, Casamichana et al. (2013) and Scott et al. (2013) found a strong relationship between Player Load and session rating of perceived exertion, which researchers often consider a global quantification of training and competitive stress. Interestingly, in each case Player Load demonstrated stronger relationships to studied internal measures than other methods of quantifying external training stress, including distances covered at high velocities. These findings suggest acceleration-based measures of training load may be a better measure of training load than other often-cited external measures. Despite these findings, however, research examining the validity and reliability of Player Load as a measure of external load is limited in the number of participants and training activities studied (Casamichana et al., 2013; Montgomery et al., 2010). As such, future research should examine the validity, reliability, and sensitivity of Player Load and other acceleration-based measures of external load in a wide range of training and competitive scenarios. Further, Scanlan and colleagues (2014) suggest practitioners should use a combined method of external and internal load monitoring to most accurately quantify the stresses placed on an athlete.

Given recent trends in sport science, GPS analysis of athletic performance seems to have succeeded CA analysis. As previously mentioned, GPS units are portable, analysis takes hours instead of days, and the amount of information that can be gathered is much greater than what can be obtained through CA analysis (Carling et al., 2008). This analysis method is not without faults. Sampling rate of the technology influences the accuracy, reliability, and validity of data obtained. Early GPS units operated at 1 Hz. While this sampling frequency was deemed acceptable for measuring total distance and peak velocity achieved, estimates of distance covered at high velocity demonstrated poor coefficients of variation (high intensity running distance: 8.6 – 49.7%; very high intensity running distance: 11.5 – 46.4%) (Coutts & Duffield, 2010).

Newer GPS units sample at frequencies of 5 and 10 Hz. Studies that compared units operating at 5 Hz to older units operating at 1 Hz found that the increased sampling frequency increased the accuracy of measurements (Castellano, Casamichana, Calleja-Gonzalez, Roman, & Ostojic, 2011; Jennings, Cormack, Coutts, Boyd, & Aughey, 2010). Likewise, a study by Varley, Fairweather, and Aughey (2012) found that GPS units sampling at 10 Hz delivered superior accuracy to units sampling at 5 Hz when measuring instantaneous velocity, as compared to a laser-based criterion measure. Their findings, however, also suggest that units sampling at 10 Hz do not accurately measure extreme accelerations and decelerations, especially in the case of decelerations. Akenhead, French, Thompson, and Hayes (2013), who found coefficients of variation in excess of 30% for raw high-intensity acceleration data obtained from 10 Hz GPS units, agree with this finding. While data smoothing techniques improved reliability of the data, the researchers recommended caution when interpreting high-intensity acceleration and deceleration data. Varley et al. (2012) suggest that practitioners should only report the total number of accelerations and decelerations instead of attempting to quantify their magnitude.

The majority of the previously mentioned studies (Akenhead et al., 2013; Castellano et al., 2011; Varley et al., 2012) only examined straight-line running. Sport-specific movements, on the other hand, generally occur in multiple directions. Despite this, few studies have examined the validity and reliability of GPS units in assessing sport-specific movement patterns. Jennings et al. (2010) assessed GPS capabilities in straight line running, a change of direction track, and a running circuit meant to simulate activities carried out in a match. In all three scenarios, the 1 Hz and 5 Hz GPS units were not valid or reliable for measuring distances in short acceleration and deceleration activities or in short sprints. Specifically, the units were unable to accurately measure accelerations and sprints for distances under 20 meters. Given that the most common

sprint distance in team sport settings is between 10-20 meters (Spencer, Bishop, Dawson, & Goodman, 2005), using GPS to measure distance traveled at very high velocities may be inappropriate, especially if older units that sample at low frequencies are used for data collection.

To the researcher's knowledge, no studies examining sport-specific movement patterns with newer 10 Hz GPS units exists. Despite this, time motion analysis via GPS units is still a popular method of quantifying external training and match demands. Although high-intensity and very high-intensity running distances should be examined with caution, other methods of external load quantification are possible. These methods include measuring relative work rate in meters per minute, total distance traveled, the total number of accelerations and decelerations completed, and the total number of tackles encountered in contact sports. Further, metrics such as Player Load may be useful for quantification of external load. While no studies have yet assessed the metric's reliability and validity, its strong correlations with other measures of training load quantification provide some evidence for it being a useful monitoring tool. More work is needed to assess the validity and reliability of newer GPS units in team sport settings and movement patterns, including sport-specific running tracks and small-sided games. Likewise, future research investigating Player Load and other acceleration-based metrics is required to establish them as valid and reliable monitoring tools in a variety of competitive settings.

Session Rating of Perceived Exertion. Session rating of perceived exertion (sRPE) is a modified form of the Borg CR-10 scale (Borg, 1982), introduced by Foster et al. (1995) as a means to describe exercise intensity. The scale ranges from 0-10 and uses verbal anchors to describe each value on the scale (Table 1.3).

Table 1.3

Session Rating of Perceived Exertion Scale and Verbal Anchors

Rating	Verbal anchor
0	Rest
1	Very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal

Adapted from Foster et al. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research, 15*(1), 109-115.

Unlike other variants of rating of perceived exertion (RPE) measurement that traditionally measure instantaneous exercise intensity, sRPE is a single value that acts as a global measure of exercise intensity (Casamichana et al., 2013; Foster et al., 2001; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Athletes rate the session as a whole in effort to describe the total internal stress imposed by the training or competitive bout. This rating theoretically accounts for factors such as work rate, injury, illness, and psychological status (Impellizzeri et al., 2004; Scott et al., 2013).

Initial research by Foster et al. (1995) compared sRPE to HR responses and blood lactate responses in 30 minutes of steady-state training. A follow-up study (Foster et al., 2001) examined sRPE in relation to HR and blood lactate in both steady-state and intermittent training bouts. In each case strong relationships were observed between the physiological measures and the reported sRPE. The researchers further calculated a training load score (RPETL) by multiplying the reported sRPE by the duration of the training bout. When compared to the time-

in-zone TRIMP calculation method, RPETL values demonstrated a stronger relationship. Foster and colleagues (2001) argued that these results suggested RPETL could be a useful quantification method for all types of training including aerobic exercise, high-intensity intermittent exercise, weight training, and plyometric training.

Session rating of perceived exertion and RPETL have been investigated in endurance sports (Foster et al., 2001; Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster, 2012) and in team sports such as soccer, basketball, rugby, and ARF (Alexiou & Coutts, 2008; Casamichana et al., 2013; Coutts, Murphy, Pine, Raeburn, & Impellizzeri, 2003; Impellizzeri et al., 2004; Lockie, Murphy, Schultz, Knight, & Janse de Jonge, 2012; Wallace, Slattery, & Coutts, 2009). These studies found sRPE to be a valid and reliable measure of internal TL when compared to objective measures including HR, blood lactate, total distance covered, and Player Load. Research has also examined the usefulness of sRPE in quantifying weight training. Day, McGuigan, Brice, and Foster (2004) compared sRPE values to the average RPE that followed each working set of a session. The researchers found no statistically significant difference between sRPE and average RPE, a measure previously shown to be a valid quantification method of resistance training (Gearhart et al., 2001; Lagally et al., 2001). Their findings agree with Sweet, Foster, McGuigan, and Brice (2004) and Egan, Winchester, Foster, and McGuigan (2006), who found similar relationships between sRPE and average RPE during resistance training. Of note is the observation that relative intensity (percentage of one repetition maximum) of the weights is a more important factor than volume of work performed. That is, heavier loads performed for fewer repetitions elicit a higher RPE and sRPE response than lower loads performed for more repetitions. Day et al. (2004) argue this observation may be due to increased high-threshold motor unit recruitment and increased sensorimotor cortex activity with increased intensity,

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factors that also underlie aerobic- and anaerobic-based training. Taken together these findings suggest sRPE is a valid tool in quantifying the internal TL an athlete experiences from separate training modalities.

A major limitation of sRPE is that it is a subjective measure of internal load. As such, RPETL may under- or overestimate the true TL of a session if the athlete perceives the final activity of the session as low intensity or high intensity, respectively. Foster and colleagues (2001) attempted to avoid this phenomenon by measuring sRPE 30 minutes posttraining. Uchida et al. (2014) suggest practitioners may only need to wait 10 minutes before collecting sRPE. This finding contrasts with Singh, Foster, Tod, and McGuigan (2007) who found that measurements taken at 5 and 10 minutes following a resistance training protocol were statistically significantly different from measurements taken 30 minutes posttraining. These differences in findings may be due to methodology. Uchida et al. (2014) examined sRPE following three submaximal boxing training sessions, whereas Singh et al. (2007) examined sRPE following performance of a one repetition maximum (1RM) protocol for five exercises. While sRPE has been validated as a marker of perceived intensity for weight training (Day et al., 2004; Egan et al., 2006; Sweet et al., 2004), previous research has not examined sRPE in relation to maximal weight training. As such, performing multiple 1RMs may have distorted the values the researchers received immediately following the protocol, but further research is needed to examine the potential effects of maximal weight training on sRPE. Given these conflicting results and overall lack of research, collection of sRPE prior to 30 minutes posttraining is ill-advised. In practice, however, practitioners may not be able to wait 30 minutes. In such cases sRPE measurement should occur as far removed from training as is practical.

Interestingly, the relationship between sRPE and HR breaks down during very high-intensity intermittent training (Alexiou & Coutts, 2008; Impellizzeri et al., 2004; Scott et al., 2013). As discussed by Achten and Jeukendrup (2003), HR responds slowly to rapid changes in intensity. This slow HR response to rapid changes in intensity could explain the weak relationship between HR and sRPE at very high intensities. When HR responses and blood lactate responses are combined, the relationship with sRPE is strengthened (Coutts, Slattery, & Wallace, 2007b). These findings support the notion that sRPE is a global variable influenced by multiple internal and external factors.

Similarly, sRPE demonstrates a weak relationship to the distance covered at high velocities during soccer training (Casamichana et al., 2013; Scott et al., 2013). The problem is twofold in this scenario. As discussed in the section on TMA, the integrated GPS and accelerometer units employed in Scott et al. (2013) and Casamichana et al. (2013) lose accuracy and reliability at high velocities. Also, soccer is an intermittent sport. As such, bursts of high intensity are followed by long recovery periods that may depress the athlete's perception of the difficulty of the training bout. Taken together these factors help explain the weak relationship between distances covered at high velocities and sRPE responses. Casamichana et al. (2013) did find a strong relationship between sRPE and Player Load, an acceleration-based metric that may be a useful external load quantification tool. More research is required to elucidate the relationship between sRPE and external measures such as Player Load.

Despite its drawbacks, RPETL is a useful training quantification method. Its underlying component, sRPE, is valid and reliable in comparison to internal measures of TL (Coutts et al., 2007b; Foster et al., 2001; Impellizzeri et al., 2004) and external measures of TL (Casamichana et al., 2013; Scott et al., 2013). Session RPE is a subjective measure, however, so careful

acquisition is necessary. Ideally, sRPE measurement should occur 30 minutes posttraining. If 30 minutes is not practical, however, a standardized time should be set. If possible, more objective methods of TL quantification should be used in conjunction with sRPE. This combined method allows for greater understanding of the training stresses imposed upon the athlete. If other methods are not available, however, the global nature of sRPE allows RPETL to act as a standalone measure of TL.

Measuring Responses to Training Load

A recent survey describes the most common monitoring tools used by coaches in high performance settings (Taylor, Chapman, Cronin, Newton, & Gill, 2012). The survey results indicate athlete monitoring is extremely important in high performance settings and carried out in effort to reduce the likelihood of injury, monitor training effectiveness, maintain performance, and prevent overtraining. Further, the responses indicate monitoring is relatively noninvasive, the tests require little time to perform, and fast turn-around of results to the coaches is paramount. Taylor et al. (2012) further describe the most common methods of athlete assessment. The two most common, mood-state questionnaires and vertical jump tests, are described below.

Mood-State Questionnaires. The most common athlete monitoring tool is the mood-state questionnaire (Taylor et al., 2012). The purpose of mood-state questionnaires is to assess the overall well-being of the athlete. Research shows increases in TL often coincide with mood disturbances, feelings of fatigue, and decreases in performance (Halson et al., 2002; Kellmann & Gunther, 2000; Meeusen et al., 2013; Morgan, Brown, Raglin, O'Connor, & Ellickson, 1987). Further, individuals experiencing overreaching and overtraining syndrome often exhibit altered mood profiles (Raglin & Morgan, 1994). Various questionnaires have been designed in effort to

understand the relationship between TL disturbances, changes in physiological and psychological well-being, and overreaching and overtraining syndrome. Practitioners use the results of these questionnaires to alter an athlete's training plan.

One such mood-state questionnaire is the Profile of Mood States (POMS). The POMS detects changes in both negative mood (tension, depression, anger, fatigue, and confusion) and positive mood (vigor) and provides a mood score. Published research reveals a relationship between increased TL and an increased mood score (Raglin & Morgan, 1994; Zehsaz, Azarbaijani, Farhangimaleki, & Tiidus, 2011). Training load and mood score changes seem to follow a dose-response relationship (Raglin & Wilson, 2000). More important, however, is the change in select subscores of the POMS. Raglin and Morgan (1994) observed different mood profile changes between healthy athletes and athletes suffering from overtraining syndrome during the competitive training season. Both groups demonstrated an increase in total score with large shifts occurring with fatigue and vigor. The athletes deemed to be suffering from overtraining syndrome also demonstrated a sharp rise in the depression subscore with many of the athletes demonstrating signs of clinical depression (Meeusen et al., 2013). Thus, a mood-state questionnaire such as the POMS could be useful in detecting athletes who are at risk for overtraining syndrome or who are already suffering from the condition.

Similar to the POMS are the Recovery Stress Questionnaire for Athletes (RESTQ-Sport) and the Daily Analysis of Life Demands (DALDA). Both mood-state questionnaires are more sport-oriented and more focused on the most likely psychological responses that occur in athletes who are experiencing nonfunctional overreaching and overtraining syndrome (Meeusen et al., 2013). The RESTQ-Sport assesses both stress and recovery-related metrics, whereas the DALDA examines general and sport-related stress over the previous 24 hours. The RESTQ-

Sport may prove useful in detecting nonfunctional overreaching and overtraining syndrome well before physical symptoms (e.g. staleness, loss of performance, irritability, and apathy) develop (Meeusen et al., 2013). Further, some evidence suggests a relationship between altered RESTQ-Sport scores, injury incidence, and occurrence of illness (Brink et al., 2010). The DALDA acts similarly to the POMS in that it is useful in detecting signs and symptoms of overreaching and overtraining syndrome once they have begun to manifest themselves (Meeusen et al., 2013; Taylor, 2012).

Despite these published mood-state questionnaires and the creation of other potentially useful questionnaires, practitioners often create their own. In fact, Taylor et al. (2012) found that 80% of the high performance coaches who used mood-state questionnaires created their own. Cited reasoning for creating their own questionnaires included time requirements for both athlete completion and coach analysis. Each of the major published questionnaires contains more than 50 questions. In time-constrained settings, the time to completion prohibits administration on a frequent basis. Low administration frequency may, however, miss signs and symptoms of overreaching and/or overtraining syndrome that a more time-efficient custom questionnaire may catch (Taylor, 2012).

The major cause for concern when administering mood-state questionnaires regularly is that of response distortion. Athletes may distort responses in one of three ways: a) exaggerating negative responses to gain time off; b) exaggerating positive responses to continue training despite illness or injury; or c) answering at random. Each scenario can negatively affect the athlete's training. Thus, Meeusen et al. (2013) suggest one member of the sport science staff have a background in psychology and questionnaire administration. If no such team member

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exists, the questionnaire administrator must stress confidentiality and the reasoning for the questionnaire.

Despite the dose-response relationship observed between TL increases and changes in the POMS, RESTQ-Sport, and DALDA, the relationship between mood-state alteration and sport performance is less clear. While a relationship between changes in mood-state and performance in triathlon (Coutts et al., 2007b) and cycling (Halson et al., 2002) was observed during overreaching protocols, no threshold change in DALDA scores was identified. Instead, Halson et al. (2002) relied on the criterion of the DALDA score being elevated for more than 4 consecutive days. While this criterion may be useful, it could also represent normal acute responses to imposed training (Taylor, 2012). Thus, while mood-state questionnaires may be useful in identifying athletes who are already suffering from overreaching or overtraining syndrome, their use as standalone monitoring tools is questionable. If anything, mood state questionnaires act as a supplement to other monitoring tools.

Vertical Jump Assessment. Fatigue and muscle damage have been shown to disrupt muscle function (Enoka & Duchateau, 2008; Ross, Leveritt, & Riek, 2001; Ross, Middleton, Shave, George, & Nowicky, 2007), although the mechanisms are not completely understood (Stone et al., 2007). Muscular performance tests are a popular method of fatigue assessment. Vertical jump assessment is the most common form of muscular performance assessment and athlete monitoring (Taylor et al., 2012). It is a useful test of lower-body explosiveness, as it is simple and quick, generates little fatigue in comparison to other assessment methods, and requires little familiarization (Moir, Button, Glaister, & Stone, 2004; Moir, Sanders, Button, & Glaister, 2005). Vertical jump variables have been shown to respond acutely to fatigue (Andersson et al., 2008; Byrne & Eston, 2002; Hoffman et al., 2003; Skurvydas et al., 2007).

Further, vertical jumping has been used as a neuromuscular performance test to map the recovery process and establish the minimum time required to repeat maximal performance following fatiguing training protocols and competitions (Cormack et al., 2008b; Kraemer et al., 2001; Nindl et al., 2002; Ronglan, Raastad, & Borgesen, 2006).

Two common forms of vertical jump assessment are the static jump (SJ) and the countermovement jump (CMJ). Static jumps are concentric-only in nature, whereas an eccentric stretch precedes the concentric component of a CMJ. This eccentric-concentric coupling leverages the effect of the stretch-shortening cycle (SSC), which enhances the concentric portion of the CMJ.

Countermovement jumps are the most commonly assessed vertical jump in athlete monitoring programs (Taylor et al., 2012). Ross et al. (2001) suggest central and peripheral neuromuscular factors negatively affect SSC function. Similarly, Fowles (2006), Raastad and Hallen (2000), and Skurvydas et al. (2007) suggest impaired excitation-contraction coupling may impair SSC function. Impairment of SSC function negatively affects CMJ performance and its underlying force-time variables, providing support for using CMJ as a monitoring tool.

Currently, no consensus exists as to the most appropriate vertical jump variable(s) to monitor. In a survey by Taylor et al. (2012), sport coaches reported they were unsure what vertical jump variables were most important for monitoring purposes. Similarly, while some research has found vertical jump height to be a useful fatigue monitoring tool (Andersson et al., 2008; Hoffman et al., 2003; Nindl et al., 2002; Ronglan et al., 2006), at least one study demonstrates no statistically significant change in jump height following 6 weeks of intensified training (Coutts, Raeburn, Piva, & Rowsell, 2007a). Similarly, Cormack, Newston, and McGuigan (2008a) observed vertical jump height was not sensitive enough a measure to warrant

use as a monitoring tool. In fact, the researchers observed only 6 of the 18 measured vertical jump variables demonstrated statistically significant decreases. Even then, the variables returned to baseline at different rates, making it difficult to determine the best tools for monitoring athlete fatigue. Thus, future research is needed to determine the most important vertical jump variables for athlete monitoring.

While CMJ has received quite a bit of attention in vertical jump research, SJ has received comparatively little, although SJ variables respond similarly to CMJ variables (Byrne & Eston, 2002; Hortobagyi, Lambert, & Kroll, 1991; Robineau, Jouaux, Lacroix, & Babault, 2012). Decreases in SJ height have been observed in conjunction with decreased torque generation of the lower limbs (Raastad & Hallen, 2000) and with decrements in maximum voluntary contraction (MVC) (Byrne & Eston, 2002; Gee et al., 2011).

Some evidence suggests SJ variables may be more sensitive to fatigue than CMJ variables. Byrne and Eston (2002) examined the relationship between eccentric exercise-induced muscle damage and changes in SJ, CMJ, and depth jump (DJ) performance. The researchers found SJ performance was affected to a greater degree than CMJ or DJ performance. Byrne and Eston (2002) hypothesized the difference may have been due to the lack of SSC in SJ. Their hypothesis is in agreement with Hortobagyi et al. (1991), who examined the effects of 50 depth jumps on CMJ, SJ, and DJ performance. They observed a reduction in SJ height while CMJ and DJ heights were unaffected. Countermovement jump height and DJ height were maintained by lengthening the eccentric phase of the movement, thereby potentiating the effect of the SSC. Similar observations occurred during an American football game (Hoffman et al., 2002) and following a 90-minute mock soccer match (Robineau et al., 2012). These studies suggest that the decrease in force generating capabilities is more pronounced in SJ due to the lack of SSC

involvement or other strategies meant to cope with fatigue and eccentric exercise-induced muscle damage. Further research investigating the differences between CMJ and SJ variables is warranted.

Summary

Multiple methods of quantifying athlete TL exist. Each method possesses strengths and weaknesses, though combined methods of TL quantification are preferred. Perhaps the most studied method of quantification of those discussed is the session RPE method. Despite the subjective nature of sRPE, the resultant RPETL is a valid and reliable measure of TL in a variety of training and competitive settings.

Mood-state questionnaires and vertical jump assessments are the two most common forms of monitoring athletes' responses to imposed TL. Mood-state questionnaires are useful when paired with other monitoring tools, but their efficacy as a stand-alone is questionable. Vertical jump assessment, however, has demonstrated a strong link to imposed fatigue from training and competition. While vertical jump assessment is a useful monitoring tool, research has not yet determined the most useful vertical jump variables. Further, little research has investigated the differences between SJ and CMJ with respect to fatigue, although several studies suggest SJ variables may possess a stronger relationship to fatigue. Thus, the purpose of the present thesis was to compare changes in CMJ and SJ variables to RPETL and athlete mood-state across a competitive season.

CHAPTER 2

COMPARISON OF STATIC AND COUNTERMOVEMENT JUMP VARIABLES

IN RELATION TO ESTIMATED TRAINING LOAD

AND SUBJECTIVE MEASURES OF FATIGUE

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Abstract

The present study examines the relationship between changes in vertical jump variables, estimated training load, and subjective measures of fatigue across a competitive season of Division I collegiate men's soccer. **PURPOSE:** The purpose of this research was to examine changes in static and countermovement jump variables across a competitive season of collegiate soccer in relation to estimated training load and subjective measures of fatigue. **METHODS:** A total of twenty-one male Division I collegiate soccer players participated. Each athlete completed a daily mood-state questionnaire prior to the first training session and provided a session rating of perceived exertion value after each training and competitive bout. Further, nine vertical jump sessions were carried out across the competitive season following a day off. Pearson correlation coefficients were calculated to perform cross-correlation between training load for the seven days preceding each vertical jump session, changes in vertical jump height and allometrically scaled peak power, and mood and sleep-related component scores for the seven days preceding each vertical jump session. **RESULTS:** Statistically significant relationships were found between training load with a lag of 1, changes in static jump height ($r = -0.96$) and allometrically scaled peak power ($r = -0.78$), and changes in countermovement jump height ($r = -0.89$). **CONCLUSION:** The results of this study indicate changes in static jump height and allometrically scaled peak power may be more useful in monitoring athlete fatigue from the previous two weeks of training than countermovement jump variables. Allometrically scaled countermovement jump peak power may be a useful tool for prescribing alterations in an athlete's training plan immediately following acute periods of heavy loading. **PRACTICAL APPLICATION:** Changes in static jump height and allometrically scaled peak power serve as useful athlete monitoring tools.

Introduction

  With the increased professionalism of sports and often grueling competitive schedules,

athlete monitoring has become increasingly important in recent years. Training induces fatigue in

athletes that requires between 24 and 72 hours to dissipate on average (Kentta & Hassmen,

1998), though fatigue from competitive bouts may require even longer recovery times to

dissipate (Andersson et al., 2008; Ascensao et al., 2011; Cormack et al., 2008a). Due to training

and competitive schedules, however, complete restoration between sessions appears difficult. If

proper fatigue management protocols are not followed, nonfunctional overreaching (short-term)

and overtraining syndrome (long-term) may result (Meeusen et al., 2013). Both conditions lead

to a stagnation or decline in performance that will require rest and decreased training to allow for

performance restoration. In an effort to prevent nonfunctional overreaching and overtraining,

strength and conditioning professionals and sport scientists can employ a variety of monitoring

tools to assess their athletes' training responses, including training load quantification, self-report

questionnaires, and practical tests of neuromuscular performance (Taylor et al., 2012).

  Foster's session rating of perceived exertion (sRPE) (Foster et al., 1995) is one method of

quantifying training load (TL). Adapted from Borg's CR-10 scale (Borg, 1982), athletes provide

a number between 1 and 10, which corresponds to a plain-language rating of the perceived

intensity of the session. The response is multiplied by the duration of the session to calculate the

estimated training load (RPETL). Session rating of perceived exertion demonstrates a strong

relationship to exercise intensity and the physiological responses occurring during training

(Foster et al., 2001; Impellizzeri et al., 2004) and is considered valid for quantifying training load

in endurance sports, team sports, and resistance training (Alexiou & Coutts, 2008; Coutts et al.,

2003; Day et al., 2004; Rodriguez-Marroyo et al., 2012; Sweet et al., 2004). Thus, sRPE and the

resultant RPETL act as global measures of exercise intensity and the total training and competitive stress imposed upon the athlete.

As reported in a study by Taylor et al. (2012) mood-state questionnaires are the most common tool to assess athletes' responses to training load. Maetsu and colleagues (2005) suggest athlete mood-state reflects the clinical state of the athlete and is related to their performance. During periods of heavy training, negative responses tend to increase, whereas positive responses tend to decrease (Meeusen et al., 2013; Raglin & Morgan, 1994; Zehsaz et al., 2011). Several popular mood-state questionnaires are commercially available, including the Profile of Mood States (POMS), the Recovery-Stress Questionnaire for Athletes (REST-Q), and the Daily Analysis of Life Demands (DALDA). Athletes suffering from overtraining syndrome demonstrate high values in negative response scores for the POMS, including signs of clinical depression (Meeusen et al., 2013). Similarly, Brink and colleagues (2010) demonstrate a correlation between increased REST-Q scores and illness in athletes. Despite these available mood-state questionnaires, practitioners most often use custom-designed questionnaires tailored to their situation (Taylor et al., 2012).

Taylor et al. (2012) identified vertical jumping as the most common neuromuscular performance test. Of the follow-up respondents contacted, all used countermovement jumps (CMJ), one used a broad jump, and another employed concentric-only static jumps (SJ) in addition to CMJ. Several studies have examined the influence of fatigue on vertical jump performance following short-term fatiguing training and competition periods and following one-off competitions. For instance, Ronglan and colleagues (2006) found a statistically significant decrease in CMJ height across a 5-day handball training camp and during a 3-day international tournament. Likewise, a statistically significant decrease in CMJ performance occurred

following a 3-day fatigue-inducing military training operation (Nindl et al., 2002) and following a strength training session meant to induce fatigue and soreness in rowers (Gee et al., 2011). Following one-off soccer matches, SJ and CMJ peak power (Hoffman et al., 2002) and CMJ height (Andersson et al., 2008; Ascensao et al., 2011) have been shown to fall in conjunction with increases in muscle damage markers and concomitant decreases in maximal voluntary contraction, sprint performance, and isometric leg extension and flexion.

While short-term data are available concerning the relationship between fatigue and vertical jump performance, only one long-term training study exists (Cormack et al., 2008b). Further, no consensus exists as to what practical vertical jump variables are most useful in fatigue monitoring (Cormack et al., 2008a; Coutts et al., 2007a; Coutts et al., 2007b; Taylor et al., 2012). While vertical jump testing is a common monitoring tool, little research has examined the effects of neuromuscular fatigue on SJ performance, though a few published studies seem to suggest SJ variables may be more sensitive to fatigue than CMJ variables (Byrne & Eston, 2002; Hoffman et al., 2002; Hortobagyi et al., 1991; Robineau et al., 2012). Thus, the aim of the present study was to track changes in a number of CMJ and SJ variables across a season of collegiate men's soccer and compare them to estimated training load and subjective measures of fatigue.

Methods

Vertical jump testing, mood-state questionnaire assessment, and training load calculation took place as a normal part of the East Tennessee State athlete monitoring program. The East Tennessee State Institutional Review Board (IRB) approved retrospective analysis of athlete monitoring data.

Experimental Approach to the Problem

The study sought to examine the relationship between estimated training load, athlete mood-state, and changes in vertical jump performance across a season of men's collegiate soccer. Estimated training load was calculated daily along with daily assessment of mood-state questionnaires. Vertical jump testing sessions occurred approximately once per week (9.0 ± 2.9 days) following an NCAA-mandated day off.

Athletes

A total of twenty-one NCAA Division I collegiate male soccer players (age: 19.9 ± 1.7 years, weight: 79.3 ± 9.1 kg, height: 181.1 ± 6.7 cm) participated in the study. The group was composed of 16 field players (12 starters and substitutes and 4 red shirts) and 5 goalkeepers (1 starter and 4 backups). Athletes took part in the team's normal athlete monitoring program during a fall competitive season. A typical week consisted of 3-5 field sessions (ranging from 60-120 minutes), 1-2 weight training sessions, and 1-3 competitive matches. All athletes were not available for some sessions due to injuries or scheduling conflicts. As a result, the number of athletes for testing sessions ranged from 14-18.

Training Load Calculation

Assessment of session rating of perceived exertion occurred following each training session and competitive match. The assessment occurred at least 10 minutes following each training session. While Foster et al. (2001) suggest sRPE assessment should occur a minimum of 30 minutes following the conclusion of training, athlete availability and schedules did not permit this method of sRPE collection. Foster et al.'s (1995) modified version of the Borg CR10-scale

was used. Estimated training load in arbitrary units (AU) was calculated as the product of sRPE and training duration in minutes.

Daily estimated training load was calculated for each athlete as the sum of all training and competitive bouts for a given day. Group daily estimated training load was calculated as the average of the individuals' training loads. Total training load for the group (RPETL) was calculated as the sum of the group daily training loads for the seven days preceding each vertical jump testing session. Seven days were selected because they were deemed reasonable given the NCAA employs a seven-day cycle (i.e. a week).

Mood-State Assessment

Assessment of a sleep and mood-state questionnaire occurred each day prior to the first training activity. Subjects completed an electronic copy of the questionnaire (Figure 2.1a). If time constraints prevented them from completing the electronic version, a paper version (Figure 2.1b) was also available. Similar to sRPE assessment, timing of questionnaire assessment was not standardized due to differing class and training schedules.

Sleep and mood-state responses were scored from 0-4 and combined to generate the following variables:

$$Sleep\ Score = \frac{\sum Sleep\ Response\ Scores}{Hours\ of\ Sleep},$$

$$Mood\ Score = \frac{(Cheerful + Athletic) - (Fatigue + Nervous + Helpless)}{\sum Mood\ Response\ Scores},$$

$$Preparedness = \frac{Mood\ Score}{Sleep\ Score}.$$

Group averages were calculated for all variables for the seven days prior to each vertical jump session. Absolute changes in the averages from the initial seven day period prior to the first vertical jump session were calculated for each subsequent session.

Figure 2.1a - Electronic version of the sleep and mood-state questionnaire

Figure 2.1b - Paper version of the sleep and mood-state questionnaire

Adapted from Stone, M. H., Stone, M., and Sands, B. (2007). *Principles and Practice of Resistance Training*. Champaign, IL: Human Kinetics Publishers.

Vertical jump assessment began in the first week of the competitive season and continued for 11 weeks until the end of the postseason. Testing sessions occurred prior to any physical activity once per week on the first training day following a complete day off (normally an NCAA-mandated day off). Due to travel and training conflicts, no vertical jump data collection occurred in the fifth or tenth week of the regular season.

Vertical jumps were assessed via two 2-axis force platforms (PS-2142; PASCO, Roseville, CA), each measuring at 1,000 Hz. The plates were positioned in a custom wooden frame to prevent slippage. The tops of the force platforms were flush with the frame.

Subjects completed a standardized dynamic warm-up protocol (Table 2.1) prior to vertical jump testing. Following the warm-up, they performed a series of warm-up jumps: two 0 kg SJ (PVC pipe placed across the shoulders), one 11 kg SJ, and one 20 kg SJ.

Table 2.1 – Dynamic warm-up protocol

Exercise	Repetitions or Distance
Jog	300 m
Leg swings (each leg)	12
Hip rotation (each direction)	10
Knee hug (each leg)	10
Squat to toe touch	10
Quad stretch to kick (each leg)	10
Walking lunge (each leg)	5
Lunge – elbow to opposite knee (each leg)	5
Jockey – forward	20 m
Jockey – backward	20 m
A-skip	20 m
Squat jump	5

For each 20 kg SJ trial, subjects stepped onto the force platforms and assumed "ready position," which consisted of the subjects squatting down until a 90° knee angle was achieved as measured by handheld goniometer. Subjects were given the command "3, 2, 1, jump" to jump from the static position in an effort to remove the involvement of the stretch-shortening cycle (Haff et al., 1997). Two trials were competed with 30 s of rest between each trial. If the athlete or investigator deemed a trial to be a bad jump (countermovement prior to jumping, submaximal effort, lifting the legs prior to landing, or jumping to one side), a third trial was completed. The average of the two trials was retained for statistical analysis. Subjects rested for 60 s before completing two 20kg CMJ trials.

For each 20 kg CMJ trial, CMJ depth was self-selected with no pause occurring between the eccentric and concentric phases. Subjects stood upright on the force platforms and were given the command "3, 2, 1, jump." Two trials were completed with 30 s of rest between each trial. If the athlete or investigator deemed a trial to be a bad jump (submaximal effort, lifting the legs prior to landing, or jumping to one side), a third trial was completed. The average of the two trials was retained for statistical analysis.

All jump trials were recorded using PASCO's proprietary DataStudio software (version 1.9.8r10, Roseville, CA) and analyzed with a custom-designed program (LabView 11.0 software, National Instruments Co., Austin, TX). Vertical jump height calculated from flight time (JH-FT) (Linthorne, 2001) and allometrically scaled peak power (PPa) were used in analysis. Peak power was determined by multiplying the force-time and velocity-time curves (Linthorne, 2001) to obtain a power-time curve. The highest instantaneous power value observed prior to take-off was measured as peak power (Zaras et al., 2014). Allometrically scaled peak power was determined via the following equation:

$$PPa = \frac{Peak\ Power}{Body\ Mass^{0.67}}$$

These variables were chosen for their practicality, as vertical jump height can be determined from common equipment including switch mats and jump-and-reach vanes while peak power can be estimated from jump height (Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999). Allometric scaling of peak power was used to control for differences in athletes' body sizes (Jacobson, Thompson, Conchola, & Glass, 2013).

Group average values were calculated for each vertical jump variable. For each testing session, the absolute change from the first testing session was calculated for each variable.

Statistical Analysis

Principal component analysis with varimax rotation was performed on questionnaire variables to condense them into principal components. Regression analysis of the component values was used to generate individual players' component scores.

Pearson product-moment correlation coefficients were used to perform cross-correlation to determine the relationships between RPETL, the average absolute change in component scores, and the average absolute change in vertical jump variables. Cross-correlation involved shifting (lagging) the RPETL values preceding the testing sessions down by one in relation to the changes in component scores and vertical jump variables. Initially, eight sessions, each representing a data point, were available for analysis (0 lag). With each subsequent lag, the available sessions for examination were reduced by one. Each lag represented approximately nine days, the average time between testing sessions. Hopkins' (2002) descriptors of correlational strength were used to describe the correlation coefficients obtained from cross-correlation.

Correlation coefficients for each lag were compared with a correlation test (Lee & Preacher, 2013) to determine if a statistically significant difference exists between the static and countermovement jumps. The correlation test converted the CMJ and SJ correlation coefficients for a given variable to z-scores via Fisher's r-to-z transformation. Inclusion of the correlation coefficient between the CMJ and SJ as well as the number of data points available for the given lag allowed for calculation of an asymptotic z-test. The p-value of the resultant z-score was used for analysis. The critical alpha level was set at $p \leq 0.05$. Statistical analysis was performed with SPSS version 20.0 (SPSS, Chicago, IL) and Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA).

Results

Training Load Calculation

High RPETL values occurred during the beginning and middle of the season (Figure 2.2a). The first testing session was preceded by an RPETL of 2397.15 ± 290.95 AU. The following three sessions were preceded by 1926.11 ± 300.45, 1691.86 ± 317.26, and 1748.33 ± 287.32 AU, respectively. The largest RPETL, 2606.18 ± 399.44 AU, preceded the fifth testing session before falling prior to the next four testing sessions with values of 1604.25 ± 245.24, 1215.97 ± 245.74, 1225.55 ± 172.42, and 1605.58 ± 240.55 AU, respectively.

Mood-State Assessment

Principal component analysis yielded two components with Eigenvalues greater than 1. These two components, termed General Mood and Sleep Disturbances, accounted for 66.3% of the variance in the data. Questionnaire mood-state responses (fatigued, cheerful, athletic, mood

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score, and preparedness) loaded on General Mood, whereas difficulty to sleep, restless sleep, premature awakening, and sleep score loaded on Sleep Disturbances. An increase in General Mood signaled a positive change in the athlete's overall mood-state, whereas an increase in Sleep Disturbances signaled a decrease in restful sleep.

The means and standard deviations of General Mood scores preceding sessions 1 through 9 were 2.60 ± 0.76, 2.93 ± 0.67, 2.45 ± 0.70, 2.77 ± 0.64, 2.87 ± 0.60, 2.95 ± 0.78, 2.44 ± 0.81, 2.87 ± 0.62, and 2.66 ± 0.52 AU, respectively. Similarly, the means and standard deviations of Sleep Disturbances scores preceding sessions 1 through 9 were 1.10 ± 0.44, 1.13 ± 0.59, 1.28 ± 0.83, 1.11 ± 0.39, 1.05 ± 0.28, 1.09 ± 0.55, 1.45 ± 0.93, 1.00 ± 0.20, and 1.22 ± 0.82 AU, respectively.

When compared to estimated training load, changes in General Mood displayed trivial to large relationships at lags of 0 ($r = 0.37$, $p = 0.37$), 1 ($r = 0.22$, $p = 0.63$), 2 ($r = -0.58$, $p = 0.23$), 3 ($r = 0.36$, $p = 0.55$), and 4 ($r = -0.003$, $p = 0.99$). At a lag of 5 ($r = -0.97$, $p = 0.03$), estimated training load and changes in General Mood displayed a nearly perfect correlation, although only 3 data points were available for analysis and the result should be interpreted with caution.

Changes in Sleep Disturbances behaved similarly. Lags of 0 ($r = -0.39$, $p = 0.34$), 1 ($r = -0.04$, $p = 0.93$), 2 ($r = 0.64$, $p = 0.17$), 3 ($r = -0.56$, $p = 0.33$), and 4 ($r = -0.03$, $p = 0.97$) demonstrated trivial to large correlations between changes in Sleep Disturbances and estimated training load. A lag of 5 ($r = 0.96$, $p = 0.04$) demonstrated a nearly perfect correlation. As with General Mood, only 3 data points were available for a lag of 5.

<u>Vertical Jump Measures</u>

The means and standard deviations for the measured vertical jump variables and their absolute changes from the first testing session are presented in Table 2.2. The lowest values occurred for all four vertical jump measures during the sixth testing session (CMJ JH-FT: 25.3 $\pm$ 4.1 cm; SJ JH-FT: 22.5 $\pm$ 3.5 cm; CMJ PPa: 213.8 $\pm$ 21.3 W·kg$^{-0.67}$; SJ PPa: 200.9 $\pm$ 21.3 W·kg$^{-0.67}$). Similarly, this session presented the largest decrease from the first testing session for all four measures (CMJ JH-FT: -2.6 cm; SJ JH-FT: -3.9 cm; CMJ PPa -7.4 W·kg$^{-0.67}$; SJ PPa -5.9 W·kg$^{-0.67}$).

Table 2.2 – Means, standard deviations, and absolute changes for vertical jump measures

Session	CMJ JH-FT (cm)			SJ JH-FT (cm)			CMJ PPa (W·kg$^{-0.67}$)			SJ PPa (W·kg$^{-0.67}$)		
	Mean ± SD		Abs Chng	Mean ± SD		Abs Chng	Mean ± SD		Abs Chng	Mean ± SD		Abs Chng
1	27.85	3.30		26.43	3.98		221.20	18.54		206.76	15.25	
2	27.67	3.62	-0.19	25.33	2.94	-1.10	217.80	21.08	-3.40	209.81	15.72	3.05
3	26.25	3.23	-1.61	24.13	2.61	-2.30	219.57	22.94	-1.62	208.83	18.06	2.06
4	27.34	3.18	-0.51	25.16	2.82	-1.27	216.00	23.92	-5.20	206.26	23.48	-0.50
5	26.86	2.96	-1.00	24.05	2.83	-2.38	215.16	16.97	-6.04	205.81	22.02	-0.95
6	25.27	4.14	-2.58	22.49	3.48	-3.94	213.77	21.27	-7.42	200.90	21.31	-5.86
7	27.72	4.06	-0.14	24.72	3.35	-1.71	224.41	19.54	3.21	214.94	20.38	8.18
8	28.10	4.04	0.24	25.68	3.74	-0.75	220.47	22.13	-0.73	218.36	22.23	11.60
9	27.14	3.22	-0.72	25.37	3.22	-1.06	220.09	23.56	-1.11	209.65	25.05	2.89

Note: **CMJ JH-FT**, countermovement jump height calculated from flight time; **SJ JH-FT**, static jump height calculated from flight time; **CMJ PPa**, allometrically scaled peak power in the countermovement jump; **SJ PPa**, allometrically scaled peak power in the static jump

Large to nearly perfect correlations were observed between 1 lag RPETL and change in CMJ JH-FT (r = -0.89, p = 0.008), SJ JH-FT (r = -0.96, p < 0.001), CMJ PPa (r = -0.61, p = 0.14), and SJ PPa (r = -0.78, p = 0.04). Changes in PPa demonstrated large correlations with 0 lag RPETL for both CMJ (r = -0.65, p = 0.09) and SJ (r = -0.57, p = 0.14). Table 2.3a presents a

summary of the Pearson product-moment correlation coefficients between RPETL and changes

in vertical jump variables obtained through cross-correlation.

Very large correlations were observed between changes in General Mood and changes in

CMJ JH-FT ($r = 0.73$, $p = 0.16$) and SJ JH-FT ($r = 0.81$, $p = 0.09$) at a lag of 3. Similarly, at a

lag of 3, changes in Sleep Disturbances displayed very large to nearly perfect relationships with

changes in CMJ JH-FT ($r = -0.95$, $p = .01$), SJ JH-FT ($r = -0.98$, $p = 0.004$), CMJ PPa ($r = -0.70$,

$p = 0.19$), and SJ PPa ($r = -0.87$, $p = 0.05$). Table 2.3b presents a summary of the Pearson-

product moment correlation coefficients between changes in General Mood, changes in Sleep

Disturbances, and changes in vertical jump variables obtained through cross-correlation.

Graphical examples of 0 lag and 1 lag data are presented in Figures 2.2a and 2.2b, respectively,

for visualization of the lag process.

Table 2.3a – Training load and vertical jump correlation coefficients

	Lag	CMJ JH-FT	SJ JH-FT	CMJ PPa	SJ PPa
	0	-0.25	-0.24	-0.64	-0.57
	1	-0.89†	-0.96‡	-0.62	-0.78†
TL7	2	0.22	-0.11	0.40	0.20
	3	0.54	0.46	0.13	0.63
	4	-0.19	0.16	-0.18	-0.32
	5	-0.02	-0.99	0.95	-0.11

Note: **CMJ JH-FT**, countermovement jump height calculated from flight time; **SJ JH-FT**, static jump height calculated from flight time; **CMJ PPa**, allometrically scaled peak power in the countermovement jump; **SJ PPa**, allometrically scaled peak power in the static jump; **TL7**, estimated training load

†, statistically significant at the $p \leq 0.05$ level; ‡, statistically significant at the $p \leq 0.001$ level

Table 2.3b – Correlations between General Mood, Sleep Disturbances, and vertical jump variables

Component	Lag	CMJ JH-FT	SJ JH-FT	CMJ PPa	SJ PPa
GM	0	-0.10	-0.12	-0.72	-0.33
S		0.07	0.02	0.70	0.22
GM	1	-0.49	-0.50	0.22	-0.25
S		0.56	0.51	0.08	0.54
GM	2	0.30	0.15	0.22	0.36
S		-0.11	0.17	-0.14	-0.22
GM	3	0.73	0.81	0.41	0.53
S		-0.95†	-0.98†	-0.70	-0.87†
GM	4	-0.63	-0.34	-0.86	-0.62
S		0.21	-0.15	0.50	0.24
GM	5	-0.48	-0.93	0.70	-0.56
S		0.82	0.68	-0.32	0.86

Note: **CMJ JH-FT**, countermovement jump height calculated from flight time; **SJ JH-FT**, static jump height calculated from flight time; **CMJ PPa**, allometrically scaled peak power in the countermovement jump; **SJ PPa**, allometrically scaled peak power in the static jump; **TL7**, estimated training load; **GM**, General Mood component score; **S**, Sleep Disturbances component score

†, statistically significant at the $p \leq 0.05$ level

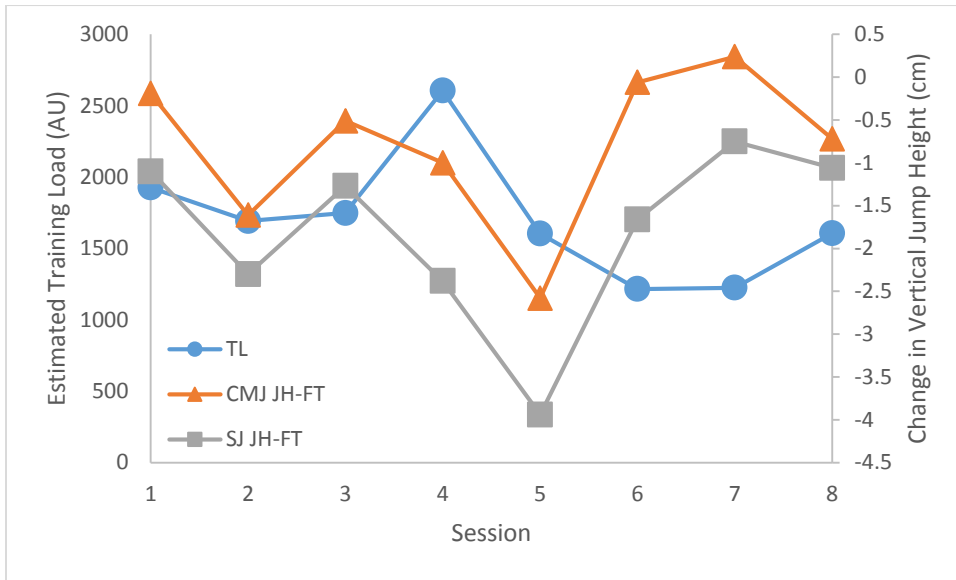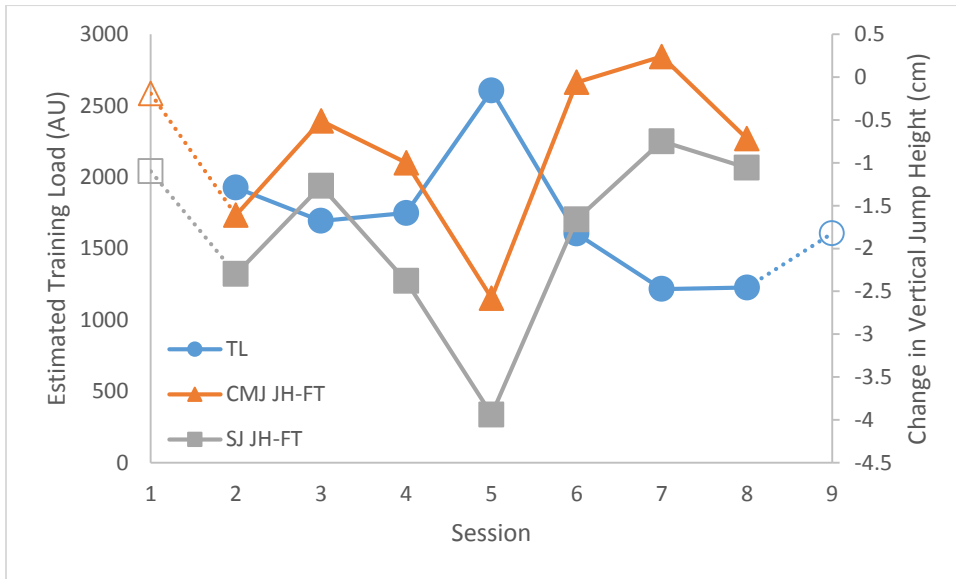Figure 2.2a – 0 lag training load and changes in jump height calculated from flight time

Figure 2.2b – 1 lag training load and changes in jump height calculated from flight time

Comparisons of Correlation Coefficients

The correlation test identified no statistical differences between coefficients with changes in CMJ and SJ variables and RPETL at all lags ($p > 0.05$). Statistically significant differences

were observed between coefficients with changes in CMJ and SJ PPa and changes in General Mood ($z = -2.16$, $p = 0.03$) and Sleep Disturbances ($z = 2.55$, $p = 0.01$) at lag of 0. No statistical differences were observed between coefficients with CMJ and SJ JH-FT and changes in General Mood and Sleep Disturbances at all lags ($p > 0.05$). Similarly, no statistical differences were observed with changes in CMJ and SJ PPa at lags greater than 0 ($p > 0.05$).

Discussion

The purpose of this study was to examine associations between changes in SJ and CMJ variables and RPETL and athlete mood-state across a season of collegiate men's soccer. Changes in JH-FT and PPa demonstrated large to nearly perfect correlations with 1 lag RPETL (CMJ JH-FT: $r = -0.89$; SJ JH-FT: $r = -0.96$; CMJ PPa: $r = -0.61$; SJ PPa: $r = -0.78$), whereas traditional 0 lag correlations demonstrated small to large correlations (CMJ JH-FT: $r = -0.25$; SJ JH-FT: $r = -0.24$; CMJ PPa: $r = -0.64$; SJ PPa: $r = -0.57$). While not statistically significant, differences were found between correlation coefficients, with a trend of the stronger relationships being between changes in SJ JH-FT and SJ PPa and RPETL at a lag of 1. These findings agree with other studies (Byrne & Eston, 2002; Hoffman et al., 2002; Hortobagyi et al., 1991; Robineau et al., 2012) that have demonstrated larger decreases in SJ performance when the athletes were fatigued. While no laboratory measurements of fatigue or muscle damage were performed during the course of this study, RPETL acts as a valid measurement of the internal stresses imposed on athletes through training and competition (Casamichana et al., 2013; Impellizzeri et al., 2004). Thus, the RPETL in the days leading up to a testing session acts as a proxy measurement of the athletes' fatigue state. That is, increases in training load generally reflect an athlete's increased fatigue state, whereas decreases in training load reflect an athlete's decreased fatigue state.

Of interest was the lack of statistical correlations between RPETL and changes in vertical jump height at a lag of 0. Changes in JH-FT displayed small negative correlations (CMJ JH-FT: $r = -0.25$; SJ JH-FT: $r = -0.24$) to RPETL at a lag of 0. This could suggest that fatigue does not immediately manifest itself in vertical jump height performance outside of extreme training bouts (Byrne & Eston, 2002; Nindl et al., 2002) and following competition (Cormack et al., 2008a; Kraemer et al., 2001; Ronglan et al., 2006). This suggestion is bolstered by the observation that JH-FT responded almost identically for both SJ and CMJ. It has been previously reported that athletes will adopt coping strategies to maintain SSC function in states of fatigue, thereby preserving countermovement jump height (Rodacki, Fowler, & Bennett, 2002). When properly executed, SJ do not involve the SSC, are more reflective of lower body concentric muscle function, and may be more susceptible to losses in muscle function that have been observed in a fatigue state (Byrne & Eston, 2002; Gee et al., 2011; Raastad & Hallen, 2000). As such, one would assume SJ height would demonstrate a stronger relationship to RPETL at a lag of 0 if manifestation of fatigue was immediate.

Allometrically scaled peak power, on the other hand, demonstrated large, though statistically nonsignificant, negative relationships to 0 lag RPETL (CMJ PPa: $r = -0.64$; SJ PPa: $r = -0.57$). Stone, Stone and Sands (2007) suggest fatigue affects different aspects of performance at different rates. Similarly, Cormack et al. (2008a) demonstrated varying recovery profiles for each of the vertical jump variables measured. Power is dependent on rate of force development, which is in turn dependent upon neuromuscular system function. Fatigue and muscle damage depress rate coding and disrupt excitation-contraction coupling (Ross et al., 2001), which may more severely affect rate of force development acutely.

Estimated training load demonstrated very large and nearly perfect correlations with changes in CMJ JH-FT ($r = -0.89$) and SJ JH-FT($r = -0.96$) at a lag of 1, respectively. Given the above discussion on different rates of fatigue manifestation, vertical jump height may respond more slowly to imposed training load. Static jump PPa's relationship to RPETL behaved in a similar manner to JH-FT (lag of 0: $r = -0.57$; lag of 1: $r = -0.78$), whereas CMJ PPa's relationship remained relatively constant (lag of 0: $r = -0.64$; lag of 1: $r = -0.62$). While a large, statistically nonsignificant correlation coefficient was observed between RPETL and SJ PPa at a lag of 0, a very large, statistically significant correlation coefficient was observed between RPETL and SJ PPa at a lag of 1. This suggests changes in CMJ PPa may reflect short-term effects (e.g. a week) of fatigue more strongly, whereas SJ PPa may reflect the long-term effects (e.g. two weeks) of fatigue.

Changes in General Mood and Sleep Disturbances demonstrated poor relationships with RPETL at lags of 0, 1, and 4. While moderate to large relationships were observed at lags of 2 (General Mood: $r = -0.58$; Sleep Disturbances: $r = 0.64$) and 3 (General Mood: $r = 0.36$; Sleep Disturbances: $r = -0.56$), the directions of the correlations are conflicting. The variables' relationships with 2 lag RPETL follow the "expected" pattern (i.e. a rise in RPETL causing a decrease in General Mood and increase in Sleep Disturbances) observed in studies that have examined overreaching and overtraining syndrome (Meeusen et al., 2013), whereas the inverse relationships observed at 3 lag may be caused by a combination of the lag process and the varying athlete pool used in the study. While the correlations between RPETL, General Mood, and Sleep Disturbances are nearly perfect at a lag of 5, these results are likely an artifact of the lag process.

Similar conflicting relationships exist when examining associations between changes in General Mood and Sleep Disturbances and changes in vertical jump variables. Lags of 0, 1, 4, and 5 demonstrated trivial to nearly perfect relationships with inverse directions to those expected, while lags of 2 and 3 demonstrated the expected directions (i.e. a positive relationship between changes in General Mood and changes in vertical jump variables and a negative relationship between changes in Sleep Disturbances and changes in vertical jump variables). The training process employed during the competitive season may explain these conflicting correlations. Unlike research examining deliberate increases in training load and/or volume that have demonstrated concomitant changes in mood-state and performance (Coutts et al., 2007b; Halson et al., 2002), the current study examined data taken from a competitive season. Sport science staff were actively involved in the planning process and specifically sought to minimize accumulated fatigue through periodized training and use of recovery protocols. As such, the fatigue management strategies employed may be the reason the current study demonstrates no clear relationship between RPETL and changes in measures of mood state or changes in measures of mood state and changes in vertical jump variables.

Further, the present study sought to distill a fatigued mood-state to overarching components, which may also contribute to the lack of observed relationship. Previous research has shown certain subcomponents of athlete mood-state are more responsive to fatigue, with severe elevations in depression and anger scores in athletes suffering from overtraining syndrome (Raglin & Morgan, 1994). As such, use of principal component analysis may have masked changes in subcomponents measured on the custom questionnaire from the current study. Future research examining these subcomponents in relation to RPETL and changes in vertical jump variables is warranted.

No statistical differences in correlation coefficients were observed between CMJ and SJ when compared to RPETL, although a trend toward larger correlation coefficients in SJ JH-FT and PPa was observed at a lag of 1. These findings are in agreement with previous research (Byrne & Eston, 2002; Hoffman et al., 2002; Hortobagyi et al., 1991; Robineau et al., 2012) that has demonstrated greater decrements in SJ performance during a fatigued state. These studies, however, examined acute responses to extreme training bouts and/or competition. To the authors' knowledge, only one other long-term study examining performance changes during a competitive season exists (Cormack et al., 2008b), but the researchers examined changes in the CMJ flight time-contraction time ratio against changes in resting cortisol and the testosterone-cortisol ratio. Further, Cormack and colleagues (2008b) did not take a measure of training load. Thus, comparison between the current findings and previous research is difficult. Future long-term studies examining the relationship between RPETL and neuromuscular performance changes during the competitive phase are needed. Due to the aforementioned conflicting results, the statistical differences between CMJ and SJ correlation coefficients in relation to General Mood and Sleep Disturbances do not appear to be able to be explained.

In summary, the relationships between RPETL and changes in the vertical jump measures differed depending on the time frame considered. Changes in CMJ PPa demonstrated a large negative relationship with RPETL at a lag of 0 ($r = -0.64$), whereas CMJ JH-FT ($r = -0.89$), SJ JH-FT ($r = -0.96$), and SJ PPa ($r = -0.78$) demonstrated very large and nearly perfect correlations at a lag of 1. A lag of 0 represented the RPETL in the 7 days preceding a vertical jump testing session, and a lag of 1 represented the RPETL accumulated over two weeks prior to the vertical jump testing session. As such, these findings suggest CMJ PPa may be useful in examining athlete's fatigue state acutely (e.g., weekly) following heavy loading periods while SJ JH-FT and

PPa may be more useful in examining the long-term (e.g., two weeks) effects of heavy loading periods on athlete's fatigue state. Changes in General Mood and Sleep Disturbances presented conflicting results when compared to RPETL and changes in vertical jump measures. The causes for these conflicting results were not immediately apparent, although the authors speculate examination of principal components as opposed to examination of individual subcomponents may have masked important changes in the subcomponents.

While the methods used in this study were sound, several limitations exist. Vertical jump assessment occurred only 9 times across the competitive season, limiting the number of data points available for analysis. The small number of data points can likely affect the relationships observed during cross-correlation as the lag increases, especially at lags of 4 and 5. A longer observational period beginning during the preseason and ending following the postseason, which would have allowed for up to 16 vertical jump assessments, would have been ideal. Further, the athlete pool varied at each testing session. The varied athlete pool may have influenced the averages observed. As such, future long-term observation with a more consistent athlete pool is needed. Finally, while principal component analysis was useful in reducing the number of variables, future studies should consider examination of original variables.

Practical Applications

Changes in CMJ and SJ JH-FT reflect the effects of fatigue induced from RPETL as much as two weeks prior. Similarly, changes in CMJ PPa reflect acute effects of RPETL, while changes in SJ PPa may respond similarly to SJ JH-FT. The relationships observed suggest SJ measurements may more strongly reflect the long-term effects of RPETL and, as such, may serve as preferred long-term athlete monitoring tools. Countermovement jump PPa, however, may

have practical application for prescribing alterations in an athlete's training plan immediately following heavy periods of loading. The lack of a statistically significant correlation for CMJ PPa warrants further investigation with a larger data set.

Acknowledgements

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Zaras, N., Stasinaki, A., Krase, A., Methenitis, S., Karampatsos, G., Georgiadis, G., . . . Terzis, G. (2014). Effects of tapering with light vs. heavy loads on track and field throwing performance. *Journal of Strength and Conditioning Research,* (Advance online publication). doi: 10.1519/JSC.0000000000000566

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APPENDIX

ETSU Institutional Review Board Approval

ETSU

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

February 26, 2014

Matt Sams

Re: Comparison of static and countermovement jump variables in relation to estimated training load and subjective measures of fatigue
IRB#:c0214.9sw
ORSPA #:

The following items were reviewed and approved by an expedited process:
- xform new protocol submission, CV of PI

On **February 21, 2014**, a final approval was granted for a period not to exceed 12 months and will expire on **February 20, 2015**. The expedited approval of the study will be reported to the convened board on the next agenda.

Study has been granted a Waiver or Alteration of Informed Consent by the ETSU IRB Vice-Chair under category 45 CFR 46.116(d):

The research involves no more than minimal risk to the participants as the study involves data analysis only. The waiver or alteration will not adversely affect the rights and welfare of the subjects as the study involves data analysis only. The research could not practicably be carried out without the waiver or alteration as the study involves data analysis of existing data collected at a previous time and could not be done given students have already graduated. Providing participants additional pertinent information after participation is not appropriate as participants will not be contacted ; some students have already graduated; and the purpose of the study is merely data analysis.

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.

Full AAHRPP Accreditation

Accredited Since December 2005

VITA

MATTHEW LANDON SAMS

Education:	M.A. Kinesiology and Sport Studies
	East Tennessee State University, Johnson City, TN, 2014
	B.S. Physical Education, Exercise Science
	East Tennessee State University, Johnson City, TN, 2011
	Hampton High School, Hampton, TN, 2008
Professional Experience:	Graduate Research Assistant
	East Tennessee State University, 2012-2014
	Graduate Strength & Conditioning Coach
	East Tennessee State University, 2012-2014
	Push Track Project Manager, U.S. Olympic Training Center
	Lake Placid, NY, Summer 2012
	Sport Performance Intern, U.S. Olympic Training Center
	Lake Placid, NY, 2011-2012
	Personal Trainer, ETSU Recreation Department
	Johnson City, TN, 2009-2014
Professional Certifications:	ACSM Certified Personal Trainer (CPT), 2009
	American Heart Association CPR/AED, 2012
Abstracts:	C.J. MacDonald, R.P. Alexander, A.L. Sayers, H.S. Gray, C.R. Carter, J.A. Gentles, A. Casey, **M.L. Sams**, H.S. Lamont, M.W. Ramsey, and M.H. Stone (2011). *Changes in Measures of Power in NCAA Division I Female Soccer Athletes through Competitive Seasons*. ETSU Coaches & Sport Science College, December 2011.
Peer Reviewed Publications:	
	DeWeese, B.H., Serrano, A.J., Scruggs, S.K., and **Sams, M.L.** (2012a). The pull to knee—proper biomechanics for a weightlifting movement derivative. *Strength & Conditioning Journal, 34*(4), 73-75.

DeWeese, B.H., Serrano, A.J., Scruggs, S.K., and **Sams, M.L.** (2012b). The clean pull and snatch pull: Proper technique for weightlifting movement derivatives. *Strength & Conditioning Journal, 34*(6), 82-86.

Non Peer Reviewed Publications:

B.H. DeWeese, H.S. Gray, **M.L. Sams**, S.K. Scruggs, and A.J. Serrano (2013). Revising the definition of periodization: Merging historical principles with modern concern. *Olympic Coach Magazine*, *24*(1), 5-19.

In Press Publications: DeWeese, B.H., **Sams, M.L.**, and Serrano, A.J. (In Press). Sliding toward Sochi: A review of the programming tactics used during the 2010-2014 quadrennial part 1.

DeWeese, B.H., **Sams, M.L.**, and Serrano, A.J. (In Press). Sliding toward Sochi: A review of the programming tactics used during the 2010-2014 quadrennial part 2.

Honors and Awards: ETSU Outstanding Graduate Student Award, EXSS Department, 2014

ETSU Summa Cum Laude, 2012

ETSU Dean's List for Academic Achievement, 2008-2012

Professional Conferences Attended:

ETSU Coaches and Sport Science College, December 2013
ETSU Coaches and Sport Science College, December 2012

Courses Taught: PHED 1130 Wellness for Life, ETSU 2013-2014
PHED 1140 Strength Conditioning, ETSU, Spring 2013
PHED 2225 Bowling, ETSU, Spring 2013
PHED 2553 Backpacking, ETSU, Fall 2012