8-2017

An Examination of the Workloads and the Effectiveness of an Athlete Monitoring Program in NCAA Division I Men's Soccer

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Recommended Citation

Sams, Matthew L., "An Examination of the Workloads and the Effectiveness of an Athlete Monitoring Program in NCAA Division I Men's Soccer" (2017). *Electronic Theses and Dissertations.* Paper 3275. https://dc.etsu.edu/etd/3275

An Examination of the Workloads and the Effectiveness of an Athlete Monitoring Program in NCAA Division I Men's Soccer

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A dissertation

presented to

the faculty of the Department of Sport, Exercise, Recreation, and Kinesiology

East Tennessee State University

In partial fulfillment

of the requirements for the degree

Doctor of Philosophy in Sport Physiology and Performance

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by

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August 2017

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Keywords: Vertical Jump, Athlete Monitoring, Athlete Fatigue

ABSTRACT

An Examination of the Workloads and the Effectiveness of an Athlete Monitoring Protocol in NCAA Division I Men's Soccer

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The purposes of this dissertation were to examine common athlete training and monitoring practices in men's collegiate soccer and to report the programming strategies and monitoring outcomes for an NCAA Division I men's collegiate soccer team whose coaching and sport science staff collaborated on a daily basis. The following are the major findings of the dissertation:

Study 1 – Coaches from all divisions of play responded to a custom survey. A majority of coaches developed an in-season training plan that varied both daily and weekly volume and intensity. One-third of the coaches performed no athlete monitoring, and a number of coaches performed purely subjective monitoring of training load and fatigue. Common athlete monitoring tools included sport performance, self-report questionnaires, and physical performance tests. Most coaches believed their athletes did not change or improved in all aspects of performance, while injuries were a mix of new and recurrent.

Study 2 – Statistical differences in training load were found between each phase of the season, and training load variation was found with respect to the number of days before a match. Phasic training loads were highest during the pre-season and non-conference portions of the season and decreased significantly during conference play and the post-season. The daily training load

values reflected the player groups' match involvement and therefore led to different loading strategies between the groups.

Study 3 – No statistically significant decreases in squat jump height occurred across the season, although a moderate practical decline occurred following the pre-season. The correlation between training load and squat jump height were statistically non-significant, while the cross-correlation was significant. The athlete monitoring program was successful in managing the athletes' neuromuscular fatigue across the season as evidenced by the maintenance of squat jump height and positive relationship between training load and changes in squat jump height.

Coach education on the importance of athlete training load and fatigue monitoring is imperative. Collaboration between coaching and sport science staffs in conjunction with an athlete monitoring program can ensure variation in training load and can help manage athlete fatigue across a competitive season.

DEDICATION

This work is dedicated to my family and friends who have supported me throughout this journey.

ACKNOWLEDGEMENTS

Dr. Kimi Sato, for your guidance throughout this process. Thank you for never saying "no."

Dr. Brad DeWeese, for introducing me to the world of sport science and athlete monitoring.

Dr. Adam Sayers, for keeping me focused on how to communicate with a coach.

Dr. Michael Stone and Meg Stone, for giving me the opportunity to complete both my master's and PhD at ETSU. My development as a coach and sport scientist wouldn't be the same without your guidance and the opportunities provided here.

The coaches and athletes, for their willingness to participate in our athlete monitoring program.

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CHAPTER 1

INTRODUCTION

Training for sport is a process that seeks to prepare an athlete technically, tactically, psychologically, physiologically, and physically for the highest possible levels of performance (Stone, Stone, & Sands, 2007). This process involves manipulation of human physiological responses to various forms of training—including strength training, sport-specific training, and cardiorespiratory training—in an effort to drive the athlete as close to their genetic limits of performance as possible (DeWeese, Hornsby, Stone, & Stone, 2015b). A properly designed training plan is carried out within the theoretical framework of training periodization. That is, the training plan involves periods of emphasis and de-emphasis of fitness characteristics specific to the sport (variation and specificity) and application of sufficient workloads and intensities to drive increases in these fitness characteristics (overload).

Importantly, a complex interplay exists between overload and variation of the training stimulus. While overloading fitness characteristics specific to the sport (e.g. maximal strength or aerobic endurance) is necessary to increase said fitness characteristics, this overload also produces fatigue. If not allowed to dissipate, overreaching (short-term) and overtraining (long-term) will result. While overreaching is often a planned part of training that can result in a "supercompensation" of performance (DeWeese et al., 2015b; Stone et al., 2007), nonfunctional overreaching (excessively high workloads that are carried out for extended periods of time) will result in a stagnation or decline in performance that will require several weeks of rest and decreased training to allow for performance restoration. If nonfunctional overreaching continues, the athlete will reach a point at which they are no longer able to recover with a few weeks of rest and/or reduced training. In such severe cases, the athlete is suffering from overtraining syndrome

(Meeusen et al., 2013). Thus, proper variation of the training volumes and intensities (“high” and “low” training days, recovery microcycles, etc.) in conjunction with variation of the fitness characteristic(s) emphasized in training are paramount in optimally preparing an athlete for competition while minimizing their fatigue.

In addition to the multifaceted demands of the sport, the scheduling for a men’s collegiate soccer season is exceptionally dense. Following a two-week pre-season period, teams may play up to three competitions in a week, with starters participating in a majority of the minutes played. This hectic schedule continues for approximately 12 to 14 weeks and may include as many as 24 regular season and conference tournament games and 5 national tournament games. Previous research has shown 3 or more days are required to return to precompetitive levels of fatigue and performance following a match (Andersson et al., 2008; Ascensao, Leite, Rebelo, Magalhaes, & Magalhaes, 2011; Cormack, Newston, McGuigan, & Cormie, 2008; Hoffman, Nusse, & Kang, 2003). So while the main focus of in-season training is often on maintenance of fitness characteristics and refinement of tactics and technique, the congested schedule can pose a serious problem from a fatigue management standpoint. As discussed above, poor fatigue management can result in stagnated or declining performance and increased risk of injury (Dupont et al., 2010; Meeusen et al., 2013; Taylor, 2012). Even a minor fatigue-related injury could result in an athlete missing multiple games and could negatively impact the team’s performance and conference standing. Thus, careful planning of the competitive season’s training foci (particularly at the daily, microcycle, and mesocycle levels), workloads, and session intensities are imperative. Further, an athlete monitoring program should be in place to assess athletes’ fatigue levels and make necessary adjustments to their training to minimize risk of injury and poor performance while maximizing competitive readiness.

A variety of tools are available to strength and conditioning professionals and sport scientists involved in soccer athlete monitoring. These tools can be categorized as load monitoring and load response monitoring. Common load monitoring tools include external measures of load such as GPS variables (total distance, total distance at certain velocities, acceleration loads, and the like) and internal measures of load such as session rating of perceived exertion (sRPE) and heart rate monitoring. Session rating of perceived exertion is perhaps the easiest tool to use and has been validated and found reliable as a global workload monitoring tool in team sport training (Alexiou & Coutts, 2008; Coutts, Murphy, Pine, Raeburn, & Impellizzeri, 2003; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Lockie, Murphy, Schultz, Knight, & Janse de Jonge, 2012; Wallace, Slattery, & Coutts, 2009) and resistance training (Day, McGuigan, Brice, & Foster, 2004; Singh, Foster, Tod, & McGuigan, 2007; Sweet, Foster, McGuigan, & Brice, 2004).

As for load response monitoring a survey by Taylor and colleagues (2012) found the second most commonly used tools were neuromuscular performance tests, with the most common neuromuscular test being the vertical jump. Of the follow-up respondents who performed vertical jump assessments, all used countermovement jumps (CMJ), one used an additional broad jump, and another employed concentric-only squat jumps (SJ) in addition to CMJ. Several studies have examined the influence of fatigue on vertical jump performance following short-term fatiguing training/competition periods and following one-off competitions. For instance, Ronglan and colleagues (2006) found a statistically significant decrease in vertical jump height across a 5-day handball training camp and during a 3-day international tournament. Likewise, a statistically significant decrease in vertical jump 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, vertical jump peak power (Hoffman et al., 2003) and vertical jump 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/flexion. Similarly, Sams (2014) found nearly perfect correlations between time-lagged sRPE-derived workload and changes in weighted SJ and CMJ height, suggesting changes in weighted vertical jump height may be a valid measure of accumulated fatigue.

Taken together, these tools allow sport scientists to understand both the training stresses being placed on their athletes and their tolerance to the stress. This “white box” approach to training plan design and athlete monitoring (DeWeese, Gray, Sams, Scruggs, & Serrano, 2013) affords the sport scientist greater control over the workloads prescribed to the athletes and allows them to modify the training plan (if necessary) to better target the desired fitness characteristics and manage the athletes’ fatigue.

Unfortunately, while theoretical papers outlining on-field programming strategies for soccer exist (Clemente, Martins, & Mendes, 2014), little in-depth analysis exists concerning the in-season programming, workloads, and athlete monitoring of soccer teams at any level of play. In the only available analysis of a full competitive season by Malone and colleagues (Malone et al., 2015a), no statistical differences in practice workloads were observed between preseason microcycles or between 6-week mesocycles during the competitive season for a professional soccer team. Further, when workloads were analyzed with respect to days before a match, only the day before a match (MD-1) displayed a statistically significant difference from the other pre-match days (MD-2 through MD-5). These findings suggest workloads were highly monotonous across the competitive season. It is impossible to determine the effect of this monotonous training without additional injury or performance data, but previous research has shown monotonous training can lead to “monotonous overtraining” through negative adaptations of the central nervous system (Stone, Keith, Kearney, & Triplett, 1991). Furthermore, a lack of training variation could lead to detraining of certain fitness characteristics and suboptimal fatigue management strategies, the latter having been associated with an increase in injury rates (Dupont et al., 2010) and illness (Foster, 1998).

Dissertation Purposes

1. To investigate the training and monitoring practices of NCAA Division I men’s soccer teams via a custom-designed questionnaire.
2. To quantify the programming strategies used by an NCAA Division I men’s soccer team with active collaboration between the coaching and sport science staffs.
3. To examine the effectiveness of the aforementioned men’s soccer team’s programming strategies in managing athlete fatigue via weighted vertical jump testing.

Operational Definitions

1. Acute-to-chronic workload ratio (A:C): a ratio created by dividing an athlete’s acute workload (a rolling average of the last 3 to 7 days) by their chronic workload (a rolling average of the last 21 to 42 days).
2. Countermovement jump (CMJ): a vertical jump involving a pre-jump countermovement, which takes advantage of the stretch reflex and stored elastic energy.
3. Fatigue: a reduction in the ability to produce force in a muscle or group of muscles.

4. Macrocycle: one training year; for the purpose of this dissertation, macrocycles begin and end the second week of August.
5. Mesocycle: a series of microcycles focused on the enhancement of a select few fitness characteristics.
6. Microcycle: one training week; for the purpose of this dissertation, microcycles begin on Monday and end on Sunday to be in line with the NCAA training calendar.
7. Session rating of perceived exertion (sRPE): a subjective measure of training session intensity.
8. Squat jump (SJ): a vertical jump with no pre-jump countermovement, which only tests an athlete’s concentric force production.
9. Session rating of perceived exertion-derived training load (TL): the product of sRPE and training duration.
10. Workload (also known as “training load” or “load”): the physiological stress imposed on athletes through training and competition.

CHAPTER 2

REVIEW OF THE LITERATURE

Training for sport is a process meant to drive athletes as close as possible to their genetic limits (Stone et al., 2007). Through the principles of physics, physiology, and psychology, athletes encounter training and competition stressors meant to disrupt their homeostasis and provoke an adaptive response (DeWeese et al., 2015b). To achieve positive adaptation, however, training cannot occur in a purely linear fashion; that is, athletes cannot continually provide ever-increasing disruptions to their homeostasis. Instead, training must involve a cyclical process of stimulus presentation and recovery to allow for positive adaptation to the training stimulus while subsequently preventing the over-accumulation of fatigue (DeWeese et al., 2015b). These ideas of homeostatic disruption and recovery, along with the fact that specific training will produce specific adaptations, form the key concepts of training periodization: overload, variation, and specificity. These three concepts are central to all periodization models found in the literature and ultimately drive the training implementation ("programming").

An extensive athlete monitoring program should be in place to ensure training is implemented optimally. Such a system—known as the "white box" approach to training (DeWeese et al., 2013)—provides insight into the loads imposed on the athletes, the athletes' acute responses to these loads, and the resultant adaptations (whether positive or negative) to these loads. Information gained from the athlete monitoring program allows coaches to make adjustments to the training prescription both in the short term and when planning for a season, training year, or quadrennial. Furthermore, an athlete monitoring program in which workloads, physiological responses, and psychological responses are monitored on a regular basis can identify athletes who are receiving inappropriate training prescriptions (either undertraining or overtraining) and lead to the adjustment of their training. Ultimately, the athlete monitoring program allows for finer control of the training process.

Programming for Soccer within the Framework of Periodization

While training periodization and programming have been studied extensively in individual sports such as weightlifting and track and field, implementation of periodized programming in team sports is a relatively unexplored area (Morgans, Orme, Anderson, & Drust, 2014). A review by Morgans and colleagues (2014) highlights the difficulty in implementation of "traditional" periodization and programming for team sports such as soccer—technical and tactical development must be balanced with the maintenance of the many physical qualities required for successful performance. Further, due to the heavy physiological demands of soccer match play (Stolen, Chamari, Castagna, & Wisloff, 2005), little time is available for dedicated physical training in season. This problem is compounded during congested fixture schedules, such as in NCAA Division I men's collegiate soccer where (at least for the author's team) athletes compete in a match every 3 – 4 days. Therefore, a majority of time is spent engaging in "recovery" training and low-intensity technical-tactical training between matches (Anderson et al., 2016; Moreira et al., 2015).

Although playing a match provides a potent physiological stimulus and can serve as conditioning, development and maintenance of the fitness qualities necessary to successful competitive performance cannot be neglected for the duration of the season. This is especially true for collegiate soccer: athletes return for a two-week preseason period following a three-month summer break in which the athletes are not allowed to communicate their training to the coaching staff. Given some of the athletes may complete minimal training, which will lead to detraining of the necessary fitness qualities (Mujika & Padilla, 2000), coaching and strength and conditioning staff must provide a training stimulus that builds “fitness” while avoiding workload application that induces fatigue-related maladaptation in the athletes. Therefore, careful planning and implementation of training is imperative in fitness development and performance optimization while minimizing fatigue and injury risk.

Several observations can be gleaned and applied to collegiate soccer from the available literature on in-season programming of professional soccer (Anderson et al., 2016; Delgado-Bordonau & Mendez-Villanueva, 2012; Jeong, Reilly, Morton, Bae, & Drust, 2011; Malone et al., 2015a; Thorpe et al., 2016), Australian rules football (Moreira et al., 2015; Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2016), and futsal (Miloski, de Freitas, & Bara-Filho, 2012; Miloski, De Freitas, Nakamura, De A Nogueira, & Bara-Filho, 2016). Foremost, a distinct difference exists between preseason and in-season training, with in-season training workloads significantly lower than preseason loads (Jeong et al., 2011; Ritchie et al., 2016). This decreased training load is necessary to compensate for the increased match loading (Moreira et al., 2015). Additionally, average training session intensity has been shown to be lower in-season compared to the preseason (Jeong et al., 2011; Ritchie et al., 2016), although overall session intensity distribution is similar between preseason and in-season (Moreira et al., 2015). Furthermore, the only in-depth analysis of a full competitive soccer season (Malone et al., 2015a) demonstrates weekly in-season training loads may be relatively stagnant, which can result in negative adaptations of the central nervous system (Stone et al., 1991). This lack of variation in workload is not necessarily unfounded—large increases in week-to-week workload and chronically high loads have been shown to increase injury risk when compared to smaller week-to-week increases in workload and more moderate cumulative workloads (Gabbett, 2016). Interestingly, high chronic workloads developed over a long period of time have been shown to provide a protective effect against injury, while low chronic workloads followed by a sudden jump in training also increase the risk of injury (Gabbett, 2016). Because of this observation, recent research has highlighted that it is the way workload is accumulated, not the total amount, which increases the risk for injury and maladaptation. This “U”-shaped relationship between acute-to-chronic workload accumulation and injury (Gabbett, 2016) demonstrates that athletes must receive adequate physical preparation to cope with the stress of competition while avoiding overstressing the athletes’ recovery abilities. Therefore, training should increase gradually and recovery periods should be included to ensure positive adaptations while minimizing injury risk (Bowen, Gross, Gimpel, & Li, 2016).

Unfortunately, the short preparatory period and congested competitive season in collegiate soccer pose difficult problems for physical development. As mentioned above, college soccer athletes engage in a two-week pre-season training period following a three-month summer break. Because of the extremely short preparatory period, fitness development must continue into the competitive season to avoid inducing maladaptation in the preseason from excessive workloads. Furthermore, advanced programming strategies such as functional overreaching (DeWeese et al., 2015b) during weeks with a light game load or weak opponent (Kelly & Coutts, 2007) can create mini-preparation periods that provide a re-establishment of fitness following phases containing necessarily low training loads. Similarly, short overreaching periods coupled with a taper prior to the most important competitions of the year (such as select opponents, the conference tournament, or the national tournament) may enhance match performance (Fessi et al., 2016). Importantly, such strategies should be carried out with the above discussion of training load increases in mind—monitoring should be in place to ensure athletes’ increases in weekly training loads and A:C are less than 10% and 1.5, respectively (Gabbett, 2016). Larger increases in training load have been shown to increase injury risk as well as incidence of illness, although individual tolerance and responses to workloads should not be discounted (Gabbett, 2016; Halson, 2014).

At the daily level, the concept of heavy and light training days (DeWeese, Hornsby, Stone, & Stone, 2015a) can be adapted to on-field training to ensure athletes receive adequate recovery following matches and fitness-oriented training sessions. While implementation differs between teams and based on the match schedule, the available training studies follow a similar loading pattern in which workload declines as a match approaches (Gastin, Meyer, & Robinson, 2013; Impellizzeri et al., 2004; Malone et al., 2015a; Thorpe et al., 2016). This decline in workload may occur across multiple days (Gastin et al., 2013; Impellizzeri et al., 2004; Thorpe et al., 2016) or only on the training day prior to a match (Malone et al., 2015a). Unfortunately, no literature has yet compared these differing microcycle tapering strategies in terms of fatigue reduction and resultant match performance. Regardless of the loading pattern employed, however, each is meant to facilitate the decay of accumulated fatigue (Akenhead, Harley, & Tweddle, 2016). In both professional Australian rules football (Gastin et al., 2013) and soccer (Thorpe et al., 2016) this load reduction strategy has been shown to improve perceived feelings of wellness in the days leading up to a match. A similar loading strategy in elite youth soccer athletes (Malone et al., 2015b) maintained and then led to a non-significant increase in CMJ height in the days leading up to a match. Although promising, further research is needed to examine the relationship between different training strategies, subjective measures of athletes' preparedness, and match outcomes. Moreover, additional research employing physical performance tests such as vertical jumping or sprinting should be included to examine the relationship between subjective and objective measures of fatigue.

Athlete Monitoring

In a men’s collegiate soccer injury report published by the National Collegiate Athletic Association (NCAA, 2012) injuries resulting in three to six days of time loss were the most common with acute non-contact injuries accounting for one-third of all reported injuries. With such a congested match schedule (matches played every 3 – 4 days), time lost to injuries can severely impact team performance (Eirale, Tol, Farooq, Smiley, & Chalabi, 2013; Hagglund et al., 2013) and conference and national rankings. Furthermore, because of the high physical demands of men’s collegiate soccer match play (Sams et al., 2015) and minimal training time available between games, return to play from even minor injuries that result in time loss is difficult in the context of the acute-to-chronic workload ratio and week-to-week variations in workload discussed above. Therefore, development of a comprehensive athlete monitoring system that assesses athletes’ workloads and responses to those workloads is vital in managing athlete fatigue and decreasing the likelihood of fatigue-related injuries. Furthermore, development of an athlete monitoring system allows for objective decision making during the return-to-play process in the event of an injury.

Quantifying Workload

Workload monitoring tools can be broadly classified based on what they measure: external load monitoring tools measure the physical work accomplished (distance traveled, weight lifted, number of collisions, etc.), whereas internal load monitoring tools measure the athletes’ responses to the external load (e.g. ratings of perceived exertion and heart rate monitoring) (Gabbett, 2016). Internal measurements allow practitioners to account for individual athlete characteristics, such as age, fitness level, fatigue level, and injury history (Impellizzeri, Rampinini, & Marcora, 2005). As such, workload monitoring should be carried out with both internal and external workload monitoring tools, and training decisions should occur on an individual or quasi-individual basis where possible. An overview of the most common workload monitoring tools in soccer follows.

Time-Motion Analysis. Different forms of time-motion analysis (TMA) are the most common external workload monitoring tools in soccer and can be split into three broad categories: (a) manual analysis of video, (b) computer-assisted analysis of video, and (c) integrated accelerometer and global positioning system (GPS) analysis. Because of the time-intensive nature of manual analysis (Carling, Bloomfield, Nelson, & Reilly, 2008; Gray & Jenkins, 2010) and the cost and lack of portability of computer-assisted analysis systems (Castellano, Alvarez-Pastor, & Bradley, 2014), the present discussion is limited to integrated accelerometer and GPS (A-GPS) systems.

Integrated accelerometer and GPS systems have exploded in popularity for practice and match quantification in recent years. Unlike other forms of TMA, A-GPS systems are portable and require minimal data manipulation prior to analysis. Furthermore, the on-board tri-axial accelerometers and gyroscopes present in A-GPS units are able to detect accelerations and decelerations, jumps, changes of direction, sideways and backwards running, and tackles (Carling et al., 2008; Gray & Jenkins, 2010; Varley, Fairweather, & Aughey, 2012), which ultimately provides practitioners a complete picture of the total load placed on the athletes (Casamichana, Castellano, Calleja-Gonzalez, Roman, & Castagna, 2013; Dalen, Ingebrigtsen, Ettema, Hjelde, & Wisloff, 2016).

Team sports such as soccer are intermittent in nature. Therefore, the variables reported by A-GPS systems go well beyond total distance traveled to avoid smoothing over the many sprints and other high-intensity activities inherent to the sport. The systems often use “velocity bands” to divide athletes’ movement profiles based on their intensity (walking, jogging, running, etc.) (Harley, Lovell, Barnes, Portas, & West, 2011). These movement profiles afford practitioners a better understanding of the demands of the sport and allow for differentiation of athletes based on position (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009), formation (Bradley et al., 2011), and level of play (Mohr, Krustrup, & Bangsbo, 2003). In addition to velocity metrics, modern A-GPS systems also report acceleration-based data in a similar fashion. Accelerations, decelerations, and composite scores based on accelerometer data (e.g. Catapult’s Player Load or GPSport’s Body Load) have received increasing interest as a measure of total stress placed on an athlete because they capture movements that would not necessarily register as high-intensity from a velocity perspective yet still contribute significantly to the total load placed on the athlete (Dalen et al., 2016).

In addition to descriptive analyses of training and match data, recent research has begun to couple A-GPS data with A:C analysis to better understand factors contributing to non-contact soft tissue injuries (Bowen et al., 2016; Colby, Dawson, Heasman, Rogalski, & Gabbett, 2014; Ehrmann, Duncan, Sindhusake, Franzsen, & Greene, 2016). Unsurprisingly, these studies found large increases in workload and/or intensity were associated with increases in injury risk, although the variable(s) contributing to the increased injury risk differed among the populations studied. Similarly, Hulin and colleagues (2016) observed over a two-year period that rugby league athletes who demonstrated greater chronic workloads (meters traveled) and an A:C between 1.0 and 1.2 were less likely to be injured during matches compared to athletes with lower chronic training load and greater A:C. Therefore, monitoring athletes’ A:C for A-GPS variables can provide practitioners with valuable information in identifying athletes who are at risk of injury and can be invaluable in preparing injured athletes for the rigors of competition during the return-to-play process. Unfortunately, research examining the most useful A-GPS-derived variables in monitoring soccer athletes' acute and chronic workloads is limited. Future research should seek to determine the most useful variables for workload monitoring in these athletes.

Importantly, while the data reported by A-GPS systems are useful, the values should be interpreted with some caution. Reliability and validity analyses of early A-GPS systems sampling at 1 Hz demonstrated acceptable reliability for total distance and peak velocity achieved, but estimates of distance covered at high velocities demonstrated poor coefficients of variation (Coutts, Quinn, Hocking, Castagna, & Rampinini, 2010). Likewise, A-GPS units sampling at 1 Hz were not valid or reliable for measuring distances traveled in change of direction tracks meant to simulate activities carried out in a match, especially for distances under 20 meters (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010). While an increase in GPS sampling rate to 5 Hz improved unit validity and reliability in measuring straight-line running distances (Castellano, Casamichana, Calleja-Gonzalez, Roman, & Ostojic, 2011; Jennings et al., 2010), 5 Hz A-GPS units were still unable to accurately or reliably measure distances traveled in "sport-specific" change of direction running tracks (Jennings et al., 2010). Similarly, while 10 Hz and 15 Hz units improved accuracy and reliability compared to 1 Hz and 5 Hz units in a relatively straight "team sport circuit" (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014) this improvement was not observed in change of direction drills meant to simulate on-court and on-field movement patterns (Vickery et al., 2014). Despite these limitations, the data obtained by these devices can still provide valuable insight into the external workloads experienced by athletes. Practitioners should understand the limitations and inherent error of their devices and make training decisions with respect to these limitations. Furthermore, these external workload measures should be obtained alongside internal workload measures such as heart rate data or sRPE data to provide strength and conditioning coaches and sport scientists with a clear understanding of the load the athletes are experiencing.

Heart Rate. Portable heart rate monitors have followed a similar trend to A-GPS systems in terms of adoption. First introduced as a means to monitor exercise intensity in the 1980s, advancements in technology have allowed for simultaneous monitoring of entire teams in real-time. This internal workload data can be analyzed on its own or coupled with external workload monitoring data (i.e. GPS data) to understand the cardiovascular stress experienced by the athletes during various training drills and games (Alexandre et al., 2012). Furthermore, data from heart rate monitoring studies have been used to generate training prescription guidelines for small-sided games based on the desired physiological target (Clemente et al., 2014).

Early heart rate monitoring research examined athletes' average heart rate during drills or across a match. For instance, Ogushi and colleagues (1993) reported average heart rate values of 161 beats per minute (bpm) for a friendly match. Likewise, Jeong and colleagues (2011) demonstrated average heart rates of 124 bpm during preseason training sessions and 112 bpm during in-season training sessions. Other researchers have expressed heart rate data as a percentage of heart rate maximum (HRM) or heart rate reserve in order to quantify relative intensity of training and match data (Alexandre et al., 2012). Much like GPS data, however, expressing heart rate data as a training or match average smooths over the intermittent nature of soccer. Therefore, expressing heart rate data as time spent in different heart rate zones (e.g. 20 minutes between 80% - 90% of HRM) can provide a more detailed picture of the intensity of match play and training and can be used to generate a session workload score.

The time-in-zone method of quantifying heart rate-based workload was first described by Edwards (1993). In this method intensity zones are based on percentage of HRM and have an arbitrarily defined intensity score (50% - 60% HRM = 1, 60% - 70% HRM = 2, etc.) that is multiplied by the total time spent in each zone to calculate a total workload score. A great deal of criticism exists for the time-in-zone method due to the arbitrary zone widths and the implication that training anywhere within a given zone will produce the same stimulus (Akubat, 2012). To the contrary, Denadai and colleagues (2006) demonstrated small differences in training intensity affected training adaptations. Researchers have, therefore, examined heart rate data in the context of physiological anchors such as the lactate threshold (Stagno, Thatcher, & van Someren, 2007) and athletes' individual heart rate-blood lactate curves (Akubat, Patel, Barrett, & Abt, 2012; Manzi, Iellamo, Impellizzeri, D'Ottavio, & Castagna, 2009) and have found strong relationships between the training impulses derived from these methods and changes in performance. As such, heart rate monitoring should be individualized when possible, although generic intensity zones can still prove useful if more individualized methods are unavailable.

Overall, heart rate monitoring provides a wealth of information regarding the cardiovascular stress experienced by soccer athletes during training and match play and may prove useful as a workload monitoring and injury prevention tool similar to GPS- and sRPE-based data (Owen et al., 2015). When combined with external measures of workload and other forms of athlete monitoring, heart rate data can provide deep insight into the conditioning status of the athletes and can be a useful tool in ensuring adequate exposure to the intensities required to drive cardiovascular adaptations. Importantly, practitioners should realize heart rate data may be affected by dehydration and ambient temperature and should, therefore, emphasize proper hydration and account for the environment when analyzing heart rate-based data (Gonzalez-

Alonso, Mora-Rodriguez, Below, & Coyle, 1997; Gonzalez-Alonso, Mora-Rodriguez, & Coyle, 2000).

Session Rating of Perceived Exertion. Session rating of perceived exertion (sRPE) is perhaps the easiest method of quantifying internal workload. Born from Borg's rating of perceived exertion (RPE) scale (Borg, 1970) and the modified Borg CR10 scale (Borg, 1982), Foster and colleagues (2001) developed the sRPE scale with common language verbal intensity anchors (e.g. "easy," "moderate," "hard"). Unlike other forms of RPE that have traditionally been used to measure instantaneous exercise intensity, sRPE is a single value collected post-training that is meant to act as a "global" measure of exercise intensity (Casamichana et al., 2013; Foster et al., 2001; Impellizzeri et al., 2004)—that is, the intensity ratings are meant to account for work rate, injury, illness, and psychological status (Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013). The intensity score reported by the athlete is then multiplied by the training or match duration to calculate a training load (TL).

Session RPE has been investigated in a variety of general (Day et al., 2004; Lockie, Murphy, Scott, & Janse de Jonge, 2012) and soccer-specific (Alexiou & Coutts, 2008; Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009; Impellizzeri et al., 2004) training contexts and has been found to be a valid and reliable measure of training intensity. Furthermore, the resultant TL score demonstrates strong correlations with a number of other variables including heart rate training impulse scores, blood lactate, distance traveled, and Catapult's Player Load (Casamichana et al., 2013; Coutts et al., 2003; Impellizzeri et al., 2004). These findings suggest sRPE and the resultant TL can be used as a stand-alone method of workload quantification if other external and internal measurements, such as A-GPS data and heart rate monitoring, are unavailable.

In addition to TL, sRPE data can be used to calculate training monotony and training strain scores (Foster, 1998). Training monotony is a measure of training variability throughout the week (average weekly TL divided by the standard deviation of the weekly TL) while training strain is a product of the TL and training monotony. Foster (1998) was the first to demonstrate a relationship between sRPE-derived variables and incidence of injury and illness. Since this seminal investigation, numerous studies have demonstrated a relationship between changes in TL, training monotony and strain, and incidence of injury and illness (Cross, Williams, Trewartha, Kemp, & Stokes, 2016; Gabbett, 2004; Gabbett & Domrow, 2007; Thornton et al., 2016). Importantly, many of these studies have examined these relationships from a group perspective, but individual characteristics and thresholds for training tolerance are important considerations within the context of athlete monitoring (Akenhead & Nassis, 2016; Foster, 1998).

Session RPE’s strength as a subjective measure of exercise intensity is also its greatest drawback. While sRPE can provide the sport scientist with valuable insight on an athlete’s current status—especially when combined with heart rate or GPS data—mood state can have an impact on said athlete’s response. This is especially true following matches as recent research has demonstrated sRPE responses tend to be higher following a loss or draw in high-level youth soccer athletes (Brito, Hertzog, & Nassis, 2016), although the researchers in the aforementioned study did not report any other measures of workload. Unfortunately, this lack of contextual data makes it impossible to determine how TL may have been influenced by other match-related variables. Future research should compare a combination of both internal and external workload variables to match outcome.

In a similar vein, initial work by Foster and colleagues (2001) suggested practitioners wait approximately 30 minutes before collecting sRPE scores from athletes to reduce the likelihood of the final training activity influencing their responses. Research investigating the veracity of this statement does not support this collection delay. For instance, Hornsby et al. (2013) found no difference in sRPE scores between subjects who performed a 5-minute, low-intensity cool-down and subjects who completed no cool-down following a steady-state treadmill run. Similarly, Fanchini and colleagues (2015) found no difference in sRPE scores taken immediately after or 30 minutes after 3 different small-sided games protocols in junior Swiss soccer athletes while Uchida et al. (2014) found no difference between sRPE scores taken 10 minutes or 30 minutes after 3 different boxing training protocols. Therefore, the initial guidelines of taking sRPE 30 minutes post-training may not be required for valid measurement of session intensity. Practitioners should, however, be aware of the potential influence of mood state discussed above. In emotionally charged situations, it may be prudent to delay sRPE collection until the athletes have had time to "cool off." Regardless of mood state's potential influence, sRPE is a powerful, no-cost workload quantification tool. If possible, more objective methods of workload quantification should be used in conjunction with sRPE to provide a clear picture of the stresses imposed on the athlete.

Quantifying Responses to Workload

Although measuring an athlete's workload is an integral part to an athlete monitoring program, these data are collected in a vacuum and are essentially meaningless if they are not related to changes in the athlete's status. Training and match play produce both positive (fitness) and negative (fatigue) responses that can be quantified to understand how the athlete is coping with the imposed workload. These data can then be used to modify the training program to ensure the goals of the training plan are met. In the context of a competitive season, these goals are maintenance of physical qualities important to the sport and careful control of athlete fatigue to minimize injury risk. The present discussion will be centered on methods of fatigue quantification.

Self-Report Questionnaires. In a survey of high performance coaches Taylor and colleagues (2012) found self-report questionnaires were the most common method of assessing athlete fatigue and recovery. Although subjective in nature, studies have repeatedly shown a relationship between changes in workload and changes in fatigue and mood profiles (Buchheit et al., 2013; Gastin et al., 2013; Saw, Main, & Gastin, 2016; Thorpe et al., 2015, 2016). Further, distinct changes in mood profiles have been found during overreaching and overtraining syndrome (Meeusen et al., 2013; Raglin & Morgan, 1994). Therefore, self-report questionnaires may provide the sport scientist with a simple, non-invasive assessment of athletes’ fatigue status.

A number of self-report questionnaires have been investigated in the literature including the Profile of Mood States (POMS) (McNair, Lorr, & Doppleman, 1971), Recovery-Stress Questionnaire (RESTQ-S) (Kellmann & Kallus, 2001), and the Daily Analysis of Life Demands for Athletes (DALDA) (Rushall, 1990). The POMS demonstrates a dose-response relationship between workload and changes in mood score (Raglin & Morgan, 1994; Zehsaz, Azarbaijani, Farhangimaleki, & Tiidus, 2011), and increases in the depression sub-score have been shown to coincide with overtraining syndrome (Meeusen et al., 2013; Raglin & Morgan, 1994). Similarly, responses on the more sport-oriented RESTQ-S and DALDA have been shown to be elevated in athletes who are at risk for or are already experiencing overreaching and overtraining syndrome

(Meeusen et al., 2013), and at least one study suggests a relationship exists between altered RESTQ-S scores, injury incidence, and occurrence of illness (Brink et al., 2010).

Despite the usefulness of standardized questionnaires in identifying athletes who are at risk for overreaching or injury, adoption of these questionnaires in high performance sport is poor (Taylor et al., 2012). In fact, Taylor et al. (2012) found 80% of high performance coaches who used self-report questionnaires created custom-designed questionnaires based on the needs of their team. These practitioners cited time requirements as a major concern, and rightfully so—each of the major standardized questionnaires contains over 50 questions. Therefore, frequent administration would be difficult. Low distribution frequency is problematic, however, as it would become difficult to identify overreaching and/or overtraining syndrome in a timely fashion. Therefore, most custom-designed questionnaires reported in the literature contain 3 to 9 questions meant to assess feelings of soreness, fatigue, sleep quality, and stress (Buchheit et al., 2013; Gallo, Cormack, Gabbett, & Lorenzen, 2016; Gastin et al., 2013; McLean, Coutts, Kelly, McGuigan, & Cormack, 2010; Thorpe et al., 2015, 2016).

Similar to the research on the standardized questionnaires, these custom questionnaires display a strong relationship between workload and changes in perceived feelings of fatigue and wellness. Moreover, Gallo et al. (2016) found an inverse relationship between pre-training wellness score and training intensity while Gastin et al. (2013) found wellness scores are moderated by individual athlete characteristics such as age, playing experience, and speed. The latter also demonstrated a weak but significant inverse relationship between pain in various lower body muscle groups and on-field performance. Further research is needed to examine the link between perceived wellness and on-field performance via both GPS-related variables and match play-related variables.

Self-report questionnaires, in conjunction with other objective and subjective measures of workload and fatigue, can provide sport science and strength and conditioning staff with valuable insight into an athlete's fatigue status. Importantly, practitioners should be wary of response distortion: athletes may a) exaggerate negative responses to gain time off; b) exaggerate positive responses to continue training through injury or illness; or c) answer at random (Meeusen et al., 2013). Each scenario has negative consequences for the athlete. Therefore, the athletes must be educated as to the goals of the questionnaire. Furthermore, compliance is critical in creating a baseline so that outlying values can be accurately identified. Finally, coach buy-in is paramount—if a coach or other individual involved in the training process is unwilling to modify or reduce training for at-risk athletes, collected data are worthless (Akenhead & Nassis, 2016).

Physical Performance Tests. While decreased performance within the context of the sport would be the most direct method of quantifying fatigue, maximal sport performance is fatiguing in itself. Therefore, practitioners turn to various physical performance tests that purportedly test the athlete's status without adding to their fatigue state. A survey by Taylor et al. (2012) found the most common physical performance tests in elite level sport are vertical jump (VJ) tests. These VJ tests included countermovement jumps (CMJ), squat jumps (SJ), and drop jumps (DJ). Due to the comparably lower frequency of other physical performance tests (Taylor et al., 2012), the present discussion will be limited to VJ testing. Furthermore, due to technique being a factor in DJ performance (both CMJ and SJ are often controlled by holding the hands on the hips or a bar placed across the shoulders) and the lack of familiarity of team sport athletes with DJ (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015b) the discussion will focus on CMJ and SJ.

Fatigue and muscle damage have been shown to impair neuromuscular function (Enoka & Duchateau, 2008). As such, using physical performance tests, such as VJ, is a logical method of quantifying athlete fatigue. Compared to other physical performance tests VJ are simple, quick, generate little fatigue, and require little familiarization (Moir, Button, Glaister, & Stone, 2004; Moir, Sanders, Button, & Glaister, 2005). Furthermore, a number of studies have investigated acute changes in VJ variables in response to fatiguing stimuli, which has allowed practitioners to map the recovery process and establish the minimum time required to return to baseline following competition and fatiguing training (Andersson et al., 2008; Byrne & Eston, 2002; Cormack et al., 2008; Gathercole, Sporer, Stellingwerff, & Sleivert, 2015a; Gathercole et al., 2015b).

Countermovement jumps are the most commonly assessed VJ in athlete monitoring programs (Taylor et al., 2012). The CMJ is reliant on the stretch-shortening cycle (SSC), an eccentric-concentric coupling that enhances the concentric phase of the CMJ through neural and mechanical factors (Stone et al., 2007). Several studies have suggested fatigue impairs SSC function through both central and peripheral mechanisms, which ultimately impairs CMJ performance (Gathercole et al., 2015b; Ross, Leveritt, & Riek, 2001; Skurvydas et al., 2007). Interestingly, the time course and magnitude of performance decrement is variable-dependent (Gathercole et al., 2015a; Gathercole et al., 2015b; Gathercole, Stellingwerff, & Sporer, 2015c). As such, the literature has yet to reach a consensus on which variables are most important from a monitoring perspective and instead suggests a multivariate approach to athlete fatigue monitoring. Of note is the observation that unweighted CMJ jump height calculated from flight time (JH-FT) may be less sensitive to fatigue status than other variables that measure the movement strategy (e.g. concentric and eccentric duration) (Gathercole et al., 2015a; Gathercole et al., 2015b; Gathercole et al., 2015c). These studies and others (Hoffman et al., 2002; Robineau, Jouaux, Lacroix, & Babault, 2012) have highlighted athletes are able to maintain CMJ

JH-FT by altering their mechanics in a manner that overcomes the decrement in SSC function. Therefore, in-depth analysis of CMJ kinetics and/or analysis of SJ performance may provide a better understanding of athlete fatigue status.

Unlike CMJ, SJ are performed in a way that minimizes or removes the effects of the SSC. The athletes are often required to squat to a predetermined depth (e.g. 90-degree knee angle) and hold the position for several seconds prior to jumping. This protocol allows the practitioner to examine the athlete’s performance without influence from the alterations in technique described above. In the few available studies comparing SJ and CMJ variables’ responses to fatiguing protocols, SJ JH-FT displayed superior sensitivity to CMJ JH-FT (Gathercole et al., 2015b; Hoffman et al., 2002; Hortobagyi, Lambert, & Kroll, 1991; Robineau et al., 2012). Interestingly, Gathercole and colleagues (2015b) demonstrated this reduction in SJ performance did not extend to force-time-related variables, whereas a number of CMJ variables were still impaired 72 hours after a repeated sprint protocol meant to induce neuromuscular fatigue. Therefore, while SJ JH-FT may prove more useful as an athlete fatigue monitoring tool compared to CMJ JH-FT, further research is required to investigate the relationship between fatigue and changes in mechanistic VJ variables.

Few long-term (microcycle or longer) studies investigating the relationship between neuromuscular fatigue and changes in VJ performance exist. Furthermore, the findings of these studies have been mixed. For instance, Malone and colleagues (2015b) found no significant difference in CMJ JH-FT across a microcycle in elite junior soccer athletes. Furthermore, the researchers found no relationship between sRPE-derived TL and CMJ performance. Conversely, McLean and colleagues (2010) found CMJ JH-FT was lowest following a match and improved four days, six days, and eight days post-match in rugby league athletes. These conflicting findings may have been a result of the testing protocols. In both cases the researchers used the athletes' best jump for analysis as opposed to using the mean of their trials. A recent meta-analysis (Claudino et al., 2016) highlighted CMJ JH-FT may be more sensitive to changes in athlete fatigue status when average values are calculated instead of taking the best trial. This may be because fatigue status influences CMJ variability (Taylor, Hopkins, Chapman, & Cronin, 2016). Therefore, merely using the highest jump for analysis may mask decrements in performance an average value may highlight.

Only two season-long investigations examining changes in VJ performance exist to the author's knowledge. Cormack and colleagues (2008) found the ratio between flight time and contraction time in CMJ was decreased in 60% of mid-week VJ testing sessions across a 22-week season. Unfortunately, the researchers did not include a measure of workload so it is impossible to discern the cause of the reduction. In contrast, Sams (2014) examined changes in SJ and CMJ JH-FT and allometrically scaled peak power (PPa) in relation to sRPE TL and found large to nearly perfect correlations between time-lagged TL (i.e. TL accumulated approximately two weeks prior to testing, a proxy measure of accumulated fatigue) and changes in JH-FT. Further, while not statistically greater, SJ JH-FT displayed a trend toward a stronger relationship with time-lagged TL than CMJ JH-FT with time-lagged TL. These latter findings agree with several studies that have demonstrated greater fatigue sensitivity for SJ JH-FT in comparison to CMJ JH-FT (Hoffman et al., 2002; Hortobagyi et al., 1991; Robineau et al., 2012). Due to the shortage of long-term monitoring studies and the different variables assessed, however, further research is needed to examine the relationship between workload and changes in VJ characteristics. Furthermore, additional study is needed comparing fatigue-related changes in CMJ and SJ variables.

Summary

In summary, quantification of workload and responses to said workload are vital in an athlete monitoring program. Several methods of workload quantification have been discussed, including external measures such as A-GPS and internal measures such as heart rate monitoring and sRPE. Of these, sRPE is perhaps the most well-studied method of workload quantification and was the primary tool for workload quantification in this dissertation. Similarly, while self-report questionnaires and VJ testing are the most common methods of response monitoring, the strong relationship between workload and changes in VJ performance previously established in the athletes monitored in this dissertation (Sams, 2014) served as the basis for weighted SJ JH-FT as the primary fatigue monitoring tool.

Little is known about the athlete training and monitoring practices in men's collegiate soccer. Therefore, one purpose of this dissertation was to investigate the training and monitoring practices carried out in men's collegiate soccer. Additionally, while numerous studies have investigated in-season programming in soccer athletes, this research has been carried out without researcher intervention in the training program. A novel aspect of this dissertation is that the coaching staff and sport science staff collaborated on a daily basis to ensure on-field programming aligned with the team's annual plan and to ensure athlete fatigue was closely monitored and managed. Therefore, the additional purposes of this dissertation were to examine the in-season workload programming strategies employed by the team and to examine the effectiveness of this collaborative strategy in managing athlete fatigue via measurement of weighted SJ throughout the in-season period.

CHAPTER 3

ATHLETE TRAINING AND MONITORING IN MEN'S COLLEGIATE SOCCER: A SURVEY OF CURRENT TRENDS

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Prepared for submission to *Journal of Strength and Conditioning Research*

Abstract

The purpose of this study was to provide insight into common athlete training and monitoring practices in men's collegiate soccer. One hundred nineteen of 1264 (9.4%) men's collegiate soccer coaching staffs responded. The survey examined background information, training design, athlete monitoring (optional based on whether they indicated they performed athlete monitoring), and training responses. All divisions of play responded: NCAA Division I (*n* = 10), NCAA Division II (*n* = 16), NCAA Division III (*n* = 44), NAIA (*n* = 19), and NJCAA (*n* = 30). Coaches most often had 10-20 years (44%) of coaching experience. One hundred four coaches (87%) developed an in-season training plan that varied both daily (94.1%) and weekly (86.6%) volume and intensity. Seventy-five (63%) coaches monitored their athletes, although several coaches performed purely subjective monitoring of training load (4%) and fatigue (16%). Common athlete monitoring tools included sport performance (46.7%), self-report questionnaires (38.7%), and physical performance tests (30.7%). Most coaches believed their athletes did not change or improved in all aspects of performance, while injuries were a mix of new and recurrent (56.3%). Strength and conditioning and sport science professionals working in men's collegiate soccer are encouraged to review these responses and others described in this survey and identify targetable deficiencies in current athlete training and monitoring programs.

INTRODUCTION

Soccer is the world’s most popular sport. A number of papers have described the physiology of the sport (19), the physical demands at different levels of play (2, 15), and the theoretical on-field programming strategies meant to maximize match performance (4). Unfortunately, studies describing the real-world programming strategies for soccer athletes are rare. To the authors’ knowledge, only Malone and Colleagues (12) have published an in-depth season-long evaluation of a professional soccer club’s on-field programming. While their investigation provides valuable insight into on-field programming for a professional team, the generalizability of their findings to lower levels of play is limited. Therefore, observational studies and surveys are needed to better comprehend the programming strategies of understudied levels of play.

The United States’ men’s collegiate soccer system is one such understudied area. Limited research on one National Collegiate Athletic Association (NCAA) Division I men’s soccer team has described the physical demands of match play (18) and the team’s on-field programming strategies (in press); however, no other data are available to the authors’ knowledge. This lack of information is troubling, as men’s college soccer possesses one of the highest injury rates per 1,000 exposure hours for men’s collegiate sports (11). Furthermore, the majority of these injuries are non-contact in nature and result in 3 to 6 days of time loss from participation (16). Because player availability has been identified as an important component in competitive success (7, 9), such injuries can negatively impact a team’s conference and national rankings.

While it is impossible to completely eliminate injuries, non-contact soft-tissue injuries are often viewed as a result of misapplied training load (8). That is, athletes’ injury risk increases when they experience training loads exceeding their tolerance (see Gabbett [8] for a discussion on what qualifies as excessive). Therefore, monitoring athletes' training loads and their responses to those loads may lead to a reduction in non-contact soft-tissue injuries.

A number of training load and response monitoring tools exist. Common training load monitoring tools include external measures such as GPS variables (total distance, total distance at different velocities, number of accelerations, etc.) and internal measures such as heart rate load or session rating of perceived exertion (sRPE or session RPE). Likewise, professional-level coaches employ a variety of monitoring tools to understand their athletes' responses to imposed training loads, although no consensus exists on the most effective monitoring tools (1, 20).

Given the lack of information on men's collegiate soccer and the wide array of monitoring tools employed at the professional level, the purpose of this study was to provide insight into the athlete training and monitoring practices of men's collegiate soccer teams. This study aimed to provide strength and conditioning coaches and sport science practitioners working in men's collegiate soccer an understanding of how they may target deficiencies in current athlete training and monitoring programs.

METHODS

Experimental Approach to the Problem

The survey titled "Athlete Monitoring in Men's Collegiate Soccer" was adapted from a questionnaire by Taylor and colleagues (20) and another by Akenhead and Nassis (1). The questionnaire was designed to provide an understanding of common athlete training and monitoring practices in men's collegiate soccer. The survey contained 4 sections: background information, training design, athlete monitoring (optional based on whether they indicated they performed athlete monitoring), and training responses (supplemental material). The adapted questionnaire was pilot tested with 10 graduate students who served as the head sport scientists for their respective collegiate and national-level teams. Following pilot testing, the survey was slightly modified to clarify the wording of certain questions. The survey was distributed to all coaching staffs working in men's collegiate soccer in the United States.

Subjects

To be included in this study, respondents were required to be members of the coaching staff over the age of 18 and to have an active email address posted on the school's athletics website. Of the 1314 men's collegiate soccer teams in the United States, 1264 coaching staffs met those criteria (50 email addresses were not active, presumably due to coaching changes), and 119 staff members responded. No coach or team names were associated with the responses to protect the confidentiality of the coaches. This study was approved by the East Tennessee State University institutional review board.

Procedures

An introductory letter describing the project was emailed to all coaching staffs in the sample. The introductory letter described the survey, the expected time commitment, and the confidentiality of the information. A follow-up email was sent approximately one week after the first mailing. Data were collected for the first 3 weeks of January 2017. After completion of data collection and analysis, a report of survey findings was emailed to the 1264 active email addresses.

Statistical Analyses

Frequency analysis for each question was conducted with results presented as absolute frequency counts or percentages. Three questions employed a Likert scale, where respondents rated average in-season and average pre-game training intensity on a 10-point scale (1 = very easy, 10 = maximal) and where respondents rated how effective they felt their athlete monitoring program was on a 5-point scale (1 = minimally effective, 5 = extremely effective). In addition to frequency analysis, the mean response ± SD is presented for these questions.

RESULTS

Background information

Nearly all participants served as the head or assistant coach (96.6%), while one respondent served as the head strength and conditioning coach and another served as the team high performance manger. Approximately 26% of coaches were in the profession for more than 20 years, 44% had coached for 10-20 years, 18% had coached for 5-10 years, and 12% had coached for 1-5 years. One coach had worked in a coaching capacity for less than a year. Responses were spread across all divisions of play: NCAA Division I (*n* = 10), NCAA Division II (*n* = 16), NCAA Division III (*n* = 44), NAIA (*n* = 19), and NJCAA (*n* = 30).

Training design

Approximately 87% of respondents indicated they developed and followed an in-season training plan. A majority varied daily and weekly training volume and intensity (daily: 94.1%, weekly: 86.6%), whereas variation in intensity only (daily: 3.4%, weekly: 4.2%) or volume only (daily: 0.8%, weekly: 1.7%) was less common. Two participants (1.7%) did not vary daily training intensity or volume, while nine participants (7.6%) reported no variation in weekly training intensity or volume. Weekly training frequency was almost equally split between 2-4 practices per week (46.2%) and 4-6 practices per week (49.6%), with an additional 2.5% completing more than 6 practices per week and 1.7% completing 1-2 practices per week. A majority (63.9%) reported average practice duration between 60 and 90 minutes, while 33.6% reported an average practice duration greater than 90 minutes. Three participants (2.5%) reported an average practice duration of 30-60 minutes. With respect to practice intensity, 37% indicated an average intensity of 7, and 36.1% indicated an average intensity of 8 (mean: 7.2 ± 1.1) (Figure 1). Pre-game practice intensity was lower than average practice intensity, with 31.1% rating their pre-game practice as a 3 (mean: 4.2 ± 1.8).

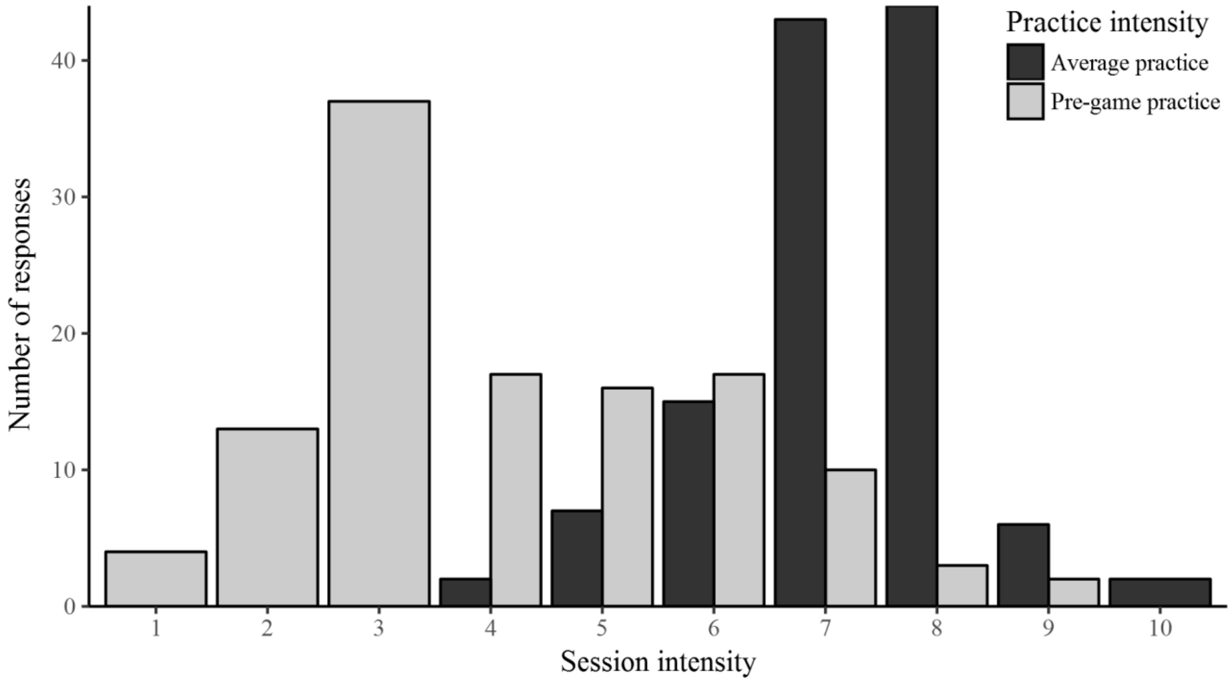

Figure 1. Intensities for average practices and pre-game practices

Athlete monitoring

Seventy-five (63%) coaches implemented athlete training load and/or fatigue monitoring. Those who monitored their athletes completed follow-up questions concerning their reasons for monitoring, the tools they used for monitoring training load and athlete fatigue, and how frequently they used each tool in their monitoring program. Of those who monitored their athletes, 88% were attempting to reduce injuries, 78.7% sought to maintain performance, 74.7% sought to prevent overtraining, and 44% were monitoring the effectiveness of their training plan. On average, respondents felt their athlete monitoring programs were moderately effective (mean: 3.4 ± 0.7). Over half (57.3%) monitored their athletes' fatigue and recovery, while 38.7% monitored both training load and fatigue. Only 4% quantified training load exclusively. Thirty-three participants (46.4%) collected and analyzed training load and fatigue data with pen and paper, 32.4% used a spreadsheet-based program, 11.3% used specially designed software, and 2.8% used a web-based interface. Five respondents (7.1%) selected they used "other" methods to understand their athletes' training load and fatigue. Follow-up analysis of their responses suggested they spoke with their athletes but did not quantify their responses or retain them for monitoring purposes.

Of the methods identified for monitoring training load, training duration was the most common method (41.3%). Session RPE was the second most common (25.3%), followed by heart rate-based monitoring (14.7%), sport-specific devices (5.3%), and GPS analysis (4%). Three respondents (4%) indicated they used the "eyeball test" and "common sense." Twenty-seven respondents (36%) did not monitor training load. Fatigue and recovery were most often quantified through tracking performance in the sport (46.7%), self-report questionnaires (38.7%), and physical performance tests (e.g. vertical jumps or sprints) (30.7%). Twelve coaches (16%)

subjectively assessed their athletes' fatigue through the "eyeball test," conversations with the athletes, and "having sense." Monitoring frequency was dependent on the tool (Figure 2). For example, physical performance tests were most frequently carried out monthly (*n* = 23) while sport performance was most frequently measured on a session-by-session (*n* = 12) or daily (*n* = 14) basis.

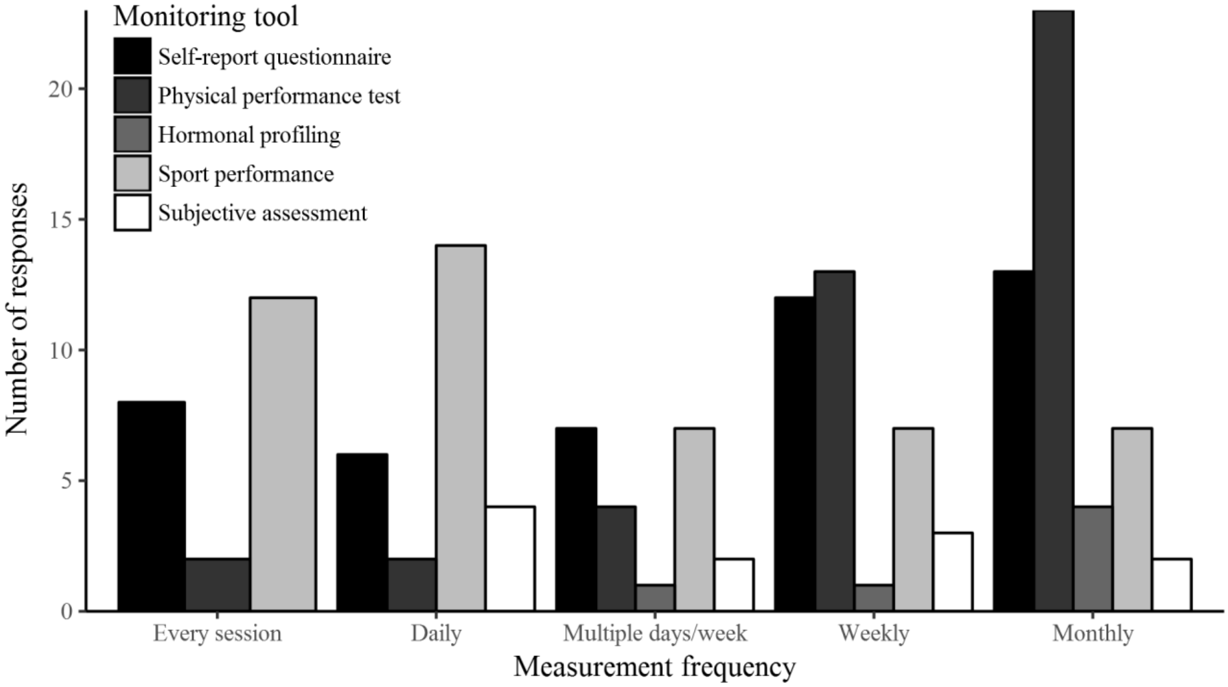

Figure 2. Measurement frequencies for various fatigue monitoring tools

Self-report questionnaires were primarily custom-designed (91.7%). Two respondents used the REST-Q, and one coach held interviews. Sport-specific testing was the most frequent method of physical assessment (73.1%) followed by sprint testing (38.5%), strength testing (28.8%), jump testing (21.2%), and sub-maximal running/cycling (19.2%). The majority of coaches who performed athlete monitoring (93.3%) modified training based on a mixture of individual and team trends observed from their monitoring program. Three coaches (4%) modified training based only on individual trends, and two coaches (2.7%) examined team trends only. When the athletes or team were identified as overly fatigued, training modification occurred through a combination of "recovery" sessions (68%), decreased training frequency (64%), and modified training duration (52%).

Training responses

In general, most coaches believed their athletes did not change or improved in all aspects of performance (Figure 3). Injuries resulting in athletes missing one day of training were most frequent, while injuries resulting in multiple weeks lost or the athletes being out for the season were very uncommon to uncommon (Figure 4). Injuries were primarily a mix of new and recurrent injuries (56.3%) or new injuries (26.9%). Mostly recurrent injuries were less frequent (9.2%), while 7.6% of coaches were unsure.

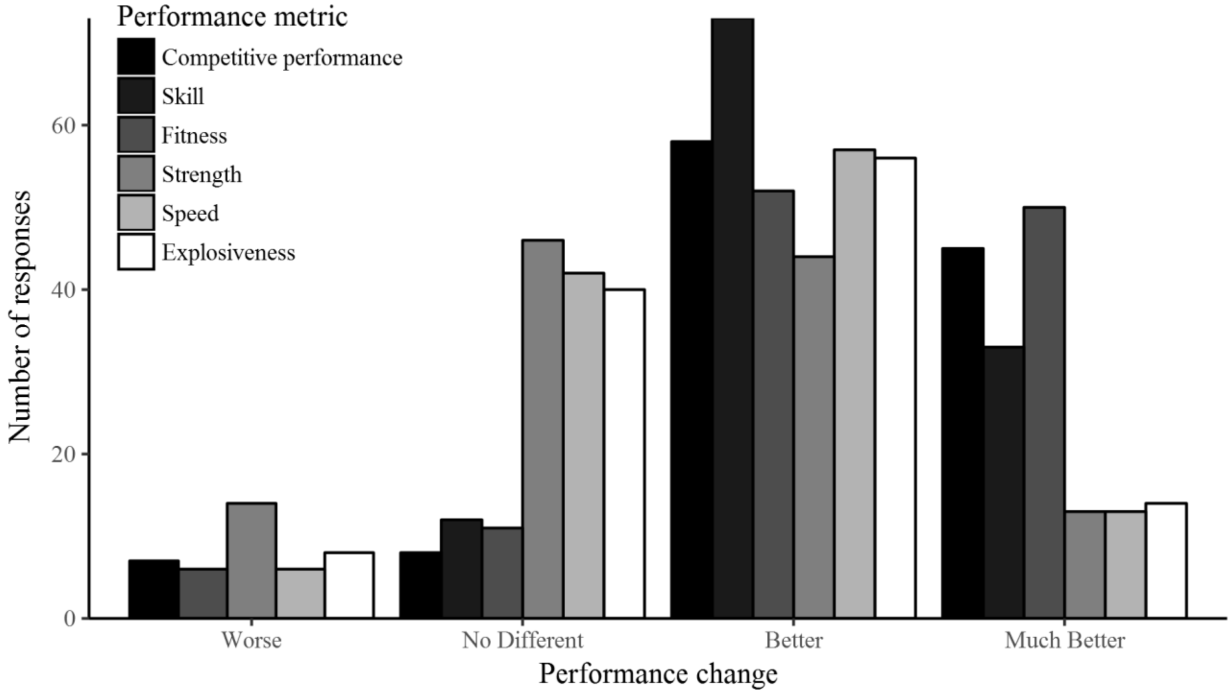

Figure 3. Changes in performance metrics across the competitive season

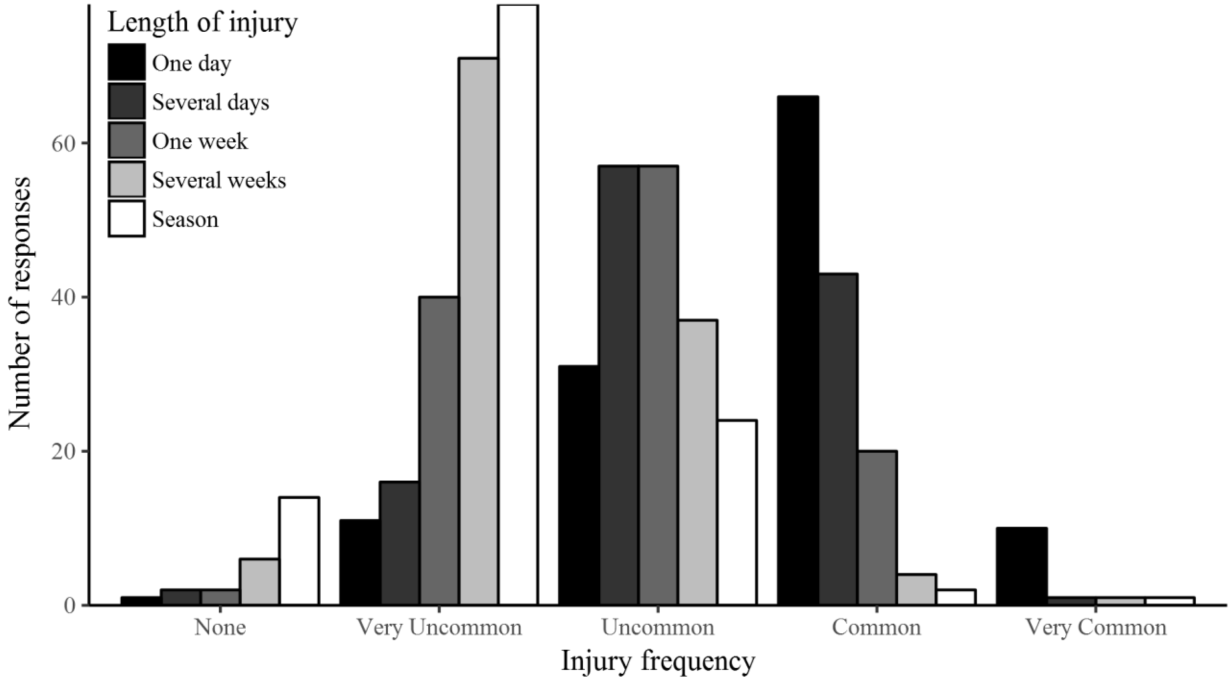

Figure 4. Frequency of different-length injuries

DISCUSSION

The purpose of this study was to provide insight into the athlete training and monitoring practices of men's collegiate soccer teams. One hundred nineteen coaches responded, yielding a response rate of approximately 9.4%. While lower than previous surveys of professional soccer clubs (1) and elite Australian coaches in various sports (20), a relatively low response rate was to be expected for an email-based survey—research indicates email-based survey response rates range between 3% and 30% (17, 23). In contrast to the aforementioned studies, however, we sought to survey the entire population of collegiate men's soccer coaching staffs. Therefore, because responses were split across all divisions of play, data presented in this study likely reflect common collegiate men's soccer training and athlete monitoring practices.

An important first step in the training process is development of an annual plan. The annual plan serves as a blueprint for the training program, listing competition dates, travel and testing schedules, and a general framework of the on-field and weight room programming (6). Most coaches indicated they developed and followed a training plan that employed variation in training volume and intensity at both the daily and weekly level. Training variation is an integral component in managing athletes' fatigue, preventing nonfunctional overreaching and overtraining syndrome, and decreasing the likelihood of fatigue-related injuries (14). Differences in intensities between average practices and pre-game practices (intensities of 7.2 ± 1.1 and 4.2 ± 1.8, respectively) highlight this reported training variation and emphasize commonalities with the training strategies employed in professional soccer athletes (10, 22).

In addition to the development of an annual plan, an athlete monitoring program should be in place to understand the athletes' responses to the training program and to ensure training is optimally implemented. Information gained from an athlete monitoring program allows for short-term adjustment of the training program, aids in the identification of athletes who need training modification, and aids in the development of subsequent annual plans. Unfortunately, one-third of the surveyed coaches performed no athlete monitoring, and a number of coaches indicated they used purely subjective measures of training load and fatigue with no means of quantification or tracking over time. This method of training has previously been described as the “black box” approach (5), as no data exist tying training to performance and injury outcomes. While it is unclear why many coaches do not monitor their athletes or monitor by “feeling,” education on the importance of evidence-based athlete monitoring and access to low- or no-cost tools that require minimal time for collection and analysis are vital.

The tools used to monitor athletes’ training loads and fatigue status and their frequency of use are similar to reports by Akenhead and Nassis (1) and Taylor et al. (20). Training duration was the most popular method of quantifying training load. Monitoring duration alone, however, does not account for the intermittent nature of the sport. Therefore, increased use of sRPE, which attempts to account for both training intensity and training duration, can serve as an alternative for training load assessment.

Custom-designed self-report questionnaires served as the second most popular method for quantifying athletes’ fatigue and recovery. A number of studies have highlighted the relationship between training load and mood-state (3, 21, 22), suggesting self-report questionnaires can provide low-cost, non-invasive assessment of athletes’ fatigue status. Therefore, a combined monitoring approach using sRPE and self-report questionnaires can act as the first step in developing an athlete monitoring program. Readers are referred to McFarland and Bird (13) for an example of how these data can be married together in the form of a spreadsheet-based athlete monitoring dashboard.

Injuries were generally a mix of new and recurrent. While injuries resulting in one lost training day were the most commonly reported, 63 coaches reported it was “common” for injuries to result in a loss of athlete availability for several days to a week. In NCAA Division I soccer, a match occurs every 3 – 4 days. Losing an athlete for one or more games during the season can prove detrimental to team performance because athlete availability has been identified as one of the most important factors in team success across a season (7, 9). As a result, reducing injury risk and chance of re-injury are important training considerations. Recent research has highlighted the way training load is accumulated most affects injury risk. That is, gradual increases in training load can confer a protective effect against injury, while sudden sharp increases (such as the start of the pre-season, returning to play from injury, or transitioning from single- to multi-game weeks) increase athletes’ injury risk (8). Therefore, creating an athlete monitoring program that monitors athletes’ acute and chronic training loads can afford coaches finer control over training load application for both healthy and injured athletes and decrease the risk of fatigue-related injuries.

PRACTICAL APPLICATIONS

This study sheds light on common athlete training and monitoring practices in collegiate men’s soccer. While coaches generally develop and follow an in-season training plan, coach education concerning the development and implementation of athlete monitoring programs that assess athletes’ training loads and fatigue states should be a primary concern. A number of low- or no-cost monitoring tools, such as sRPE and self-report questionnaires, can provide insight into athletes’ training and fatigue states. These data can be acted upon in the short-term and can be used as a part of the planning process for subsequent seasons.

ACKNOWLEDGEMENTS

The authors would like to thank the coaches who participated in this study.

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CHAPTER 4

EXAMINATION OF THE TRAINING LOADS IN A DIVISION I MEN'S COLLEGIATE SOCCER TEAM

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Prepared for submission to *Journal of Strength and Conditioning Research*

Abstract

The purpose of this study was to examine the training load (TL) programming of a Division I men’s collegiate soccer team across a season when the coaching and sport science staff were collaborating. Twenty Division I men’s collegiate soccer players provided session rating of perceived exertion values after each field training session during the pre-season, in-season, and post-season. The athletes were subdivided into three groups based on minutes played (starters, substitutes, and redshirts). Linear mixed modeling was used to compare average weekly TL for the pre-season, non-conference and conference portions of the in-season, and the post-season and to compare average daily TL for four microcycles with similar training schedules. Statistical differences were found between each phase of the season, and TL variation was found with respect to the number of days before a match. Phasic TL were highest during the pre-season and non-conference portions of the season and decreased significantly during conference play and the post-season. The daily TL values reflected the player groups’ match involvement and therefore led to different loading strategies between the groups. Future studies are needed to evaluate the programming strategies discussed in this study with respect to athlete preparedness, performance, and injury incidence.

Keywords: periodization, team sport, session RPE, athlete monitoring, soccer training

INTRODUCTION

While training periodization and programming have been studied extensively in individual sports such as weightlifting and track and field, periodized programming in team sports is relatively unexplored (13). The dense competitive schedule makes programming for team sports such as soccer difficult (13). In collegiate soccer, for instance, matches occur every 3 – 4 days for 10 or more weeks. The athletes are forced to spend a majority of time engaging in "recovery" training and low-intensity technical-tactical sessions between matches. This training pattern produces stagnant training loads (TL) that can create negative adaptations of the central nervous system (17) and leave athletes unprepared for sudden increases in training and match volume (e.g. moving from single- to multi-game weeks or tournaments).

Gabbett (7) reviews the relationship between TL and injury risk. Low chronic TL followed by a sudden increase in acute TL increases injury risk. Similarly, low acute and chronic TL (such as following an injury) leave athletes underprepared for the rigors of competition, again increasing their injury risk. Therefore, high chronic TL developed over a long period of time can confer a protective effect against injury. Unfortunately, the collegiate pre-season limits the implementation of physical training. The two-week collegiate pre-season follows a three-month summer break in which the athletes are barred from communicating with the coaching staff. Anecdotal experience suggests many athletes complete minimal summer training, resulting in a loss of competition-specific fitness (14). Therefore, fitness development must continue into the early season to avoid inducing maladaptation from excessive TL.

Daily variation in on-field training, such as heavy and light days (6), can ensure athletes receive adequate recovery following matches and fitness-oriented training sessions. The available training studies on professional soccer athletes show this heavy-light strategy involves a mid-week TL peak with a taper into the weekend match (8, 10, 18). The decay of accumulated fatigue is the intent of this tapering strategy (1), with several studies demonstrating improved perceived feelings of wellness in the days leading into a match (8, 18).

To the authors' knowledge, only one examination of professional-level TL across a season exists (12), and no research has examined the TL of men's collegiate soccer athletes. Further, Malone et al. (12) was observational in nature, with no intervention to ensure the on-field programming occurred within the framework of periodization. This lack of intervention led to relatively stagnant TL across the season.

Therefore, the purpose of this study was to examine the TL of a Division I men's collegiate soccer team across a season. This study aimed to examine the effect of collaboration between the coaching and sport science staffs on TL programming at the phasic and daily level.

METHODS

Experimental Approach to the Problem

This study was designed to examine the effects of collaboration between a coaching and sport science staff on phasic and daily TL programming across a season of NCAA Division I men's collegiate soccer. Data were collected as a part of the day-to-day athlete monitoring program for the team. Session rating of perceived exertion values were collected from athletes following all field training sessions during a fall competitive season. Athletes who transferred mid-season or received a season-ending injury were excluded from analysis. Athletes were split into three groups based on percentage of total possible minutes played during the season: starters (>60% possible minutes, $n = 7$), substitutes (10% - 40% possible minutes, $n = 6$), and redshirts (<5% possible minutes, $n = 7$).

Subjects

Twenty outfield NCAA Division I male collegiate soccer athletes (20 ± 1 years, 179 ± 6cm, 75.9 ± 6.4kg) participated in this study. Goalkeepers were excluded from data analysis. Retrospective analysis of training load data was approved by the East Tennessee State University Institutional Review Board.

Procedures

Training load data were collected over a 14-week period spanning the pre-season (2 weeks), in-season (10 weeks), and post-season (2 weeks). The team participated in 21 matches across the season, with 2 pre-season exhibition games 3 days apart, 6 non-conference games every 5 ± 1 days, 10 conference games every 4 ± 1 days, and 3 post-season games (the first game was 7 days after the final conference game and the last two games were 6 and 8 days after the first post-season game). For the purposes of this study, only full team field training sessions where all players trained together were considered. Therefore, games, rehabilitation sessions, weight training sessions, and individual "skill" sessions were excluded.

Throughout the data collection period, all players provided a session rating of perceived exertion (sRPE) value post-training. A total of 1130 individual training observations were collected during the season, with an average of 57 observations per player (range: 51 – 61). The coaching and sport science staff met on a daily basis to plan the training sessions and adjust training based on the available athlete monitoring data. The training program's intent was to provide variation in TL at the phasic and daily level and to individualize the athletes' TL based on their playing group—starters, substitutes, and redshirts.

Statistical analyses

TL data were broken down into two time categories for analysis of the competitive season (Figure 1). The season consisted of the pre-season (PRE, 2 weeks), non-conference (NC, 5 weeks), conference (C, 5 weeks), and post-season (POST, 2 weeks). The average weekly TL for each phase was analyzed for phasic difference in TL. Four microcycles following the same training structure (weeks 3, 6, 7, and 9) were analyzed in relation to the number of days away from the match (i.e. match day minus, [MD-]) for daily differences in TL. Each of these weeks involved four consecutive field training sessions following a day off (MD-4 through MD-1).

The statistical software R (version 3.3.2) and the packages nlme (version 3.1-128), lsmeans (version 2.23-5), and compute.es (0.2-4) were used to create a series of linear mixed models (LMM), perform post hoc comparisons, and calculate effect sizes, respectively. Linear mixed models were chosen in lieu of repeated-measures ANOVA because LMM can cope with unbalanced designs (5)—as the data were collected in a collegiate setting, class and work obligations forced athletes to miss training sessions. Time period (phase and day) and player group (starter, substitute, and redshirt) were treated as fixed effects, whereas the athletes were treated as random effects. A stepwise procedure was used to select the model of best fit for each time period. Significance was set at $p < .05$. When one or more fixed effects were statistically significant in the selected model, Tukey post hoc pairwise comparisons were performed to compare between pairs of the significant factor(s). Cohen's *d* effect sizes (ES) were calculated from the *t* ratios of statistically significant comparisons to determine the magnitude of the effects (15). Descriptions of effect size magnitudes follow Hopkins (9): <0.2 = trivial, 0.2 – 0.6 = small, 0.6 – 1.2 = moderate, 1.2 – 2.0 = large, 2.0 – 4.0 = very large, and >4.0 = nearly perfect. Data are presented as the model-derived means and 95% confidence intervals (CI) in arbitrary units (au). Pairwise comparisons and ES are presented as the estimate and corresponding 95% CI.

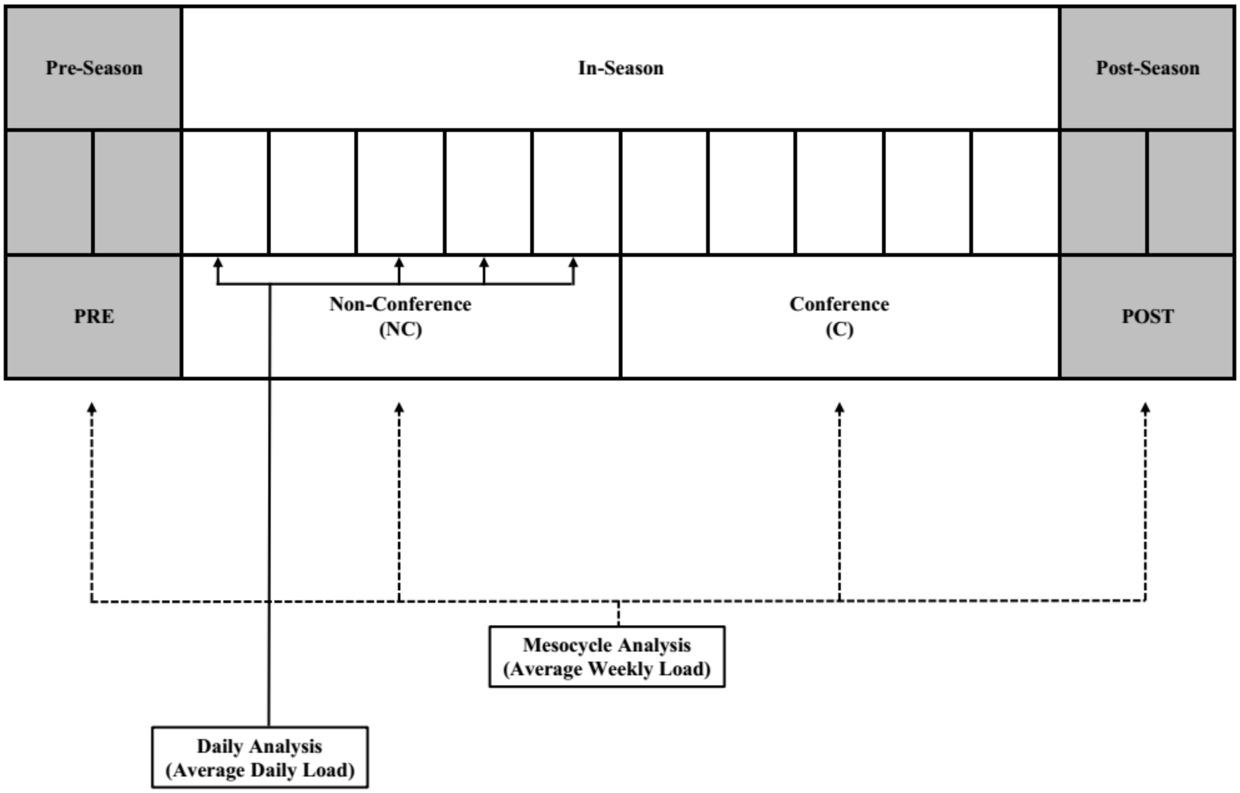

Figure 1. Outline of the experimental design.

RESULTS

Phasic analysis

No statistically significant differences in TL were observed between player groups during PRE, NC, and POST ($p > .05$; Table 1; Figure 2). Similarly, no difference in TL was observed between substitutes and redshirts during C or between starters and substitutes during C. Redshirts' TL values were significantly greater than starters' values during C (463 [147 – 779] au, ES = 2.93 [1.26 – 4.61], very large).

Starters displayed significantly greater TL during PRE compared to other phases of the season (PRE – NC: 628 [293 – 962] au, ES = 3.31 [1.52 – 5.10], very large; PRE – C: 1224 [890 – 1559] au, ES = 6.46 [3.55 – 9.36], nearly perfect; PRE – POST: 1003 [603 – 1402] au, ES = 4.43 [2.26 – 6.59], nearly perfect). Similarly, starters' NC TL values were significantly greater than both their C (597 [344 – 849] au, ES = 4.16 [2.09 – 6.24], nearly perfect) and POST (375 [41 – 710] au, ES = 1.98 [0.56 – 3.4], large). Substitutes displayed significantly greater PRE TL values compared to C (774 [412 – 1135] au, ES = 3.93 [1.84 – 6.03], very large) and POST (686 [254 – 1117], ES = 3.03 [1.14 – 4.91], very large), and their NC TL values were significantly greater compared to C (443 [170 – 716] au, ES = 3.09 [1.18 – 4.99], very large). Redshirts followed a similar trend to starters in that their PRE TL values were significantly greater than all other phases of the season (PRE – NC: 471 [116 – 826] au, ES = 2.44 [0.82 – 4.05], very large; PRE – C: 869 [515 – 1224] au, ES = 4.50 [2.20 – 6.80], nearly perfect; PRE – POST: 973 [556 – 1390] au, ES = 4.28 [2.07 – 6.50], nearly perfect) and that their NC TL values were significantly greater than C (399 [146 – 651] au, 2.78 [1.15 – 4.41], very large) and POST (502 [168 – 836] au, ES = 2.65 [1.05 – 4.25], very large). No statistically significant differences were observed between C and POST for any of the player groups, and no differences existed between PRE and NC for substitutes.

Table 1. Phasic mean weekly training loads

Group	Training Phase	Mean (95% CI), au	Grouped Difference*
Starters	PRE	1575 (1387 – 1763)	AB
	NC	948 (822 – 1073)	DEF
	C	351 (225 – 477)	H
	POST	573 (384 – 761)	GH
Substitutes	PRE	1397 (1195 – 1598)	ABC
	NC	1066 (931 – 1200)	CDE
	C	623 (489 – 758)	FGH
	POST	711 (509 – 912)	EFGH
Redshirts	PRE	1683 (1480 – 1886)	A
	NC	1212 (1087 – 1338)	BCD
	C	814 (688 – 939)	EFG
	POST	710 (522 – 898)	EFGH

PRE, Preseason; NC, Non-conference; C, Conference; POST, Postseason; au, arbitrary units
*Variables sharing the same letter are not statistically different at *a* = .05

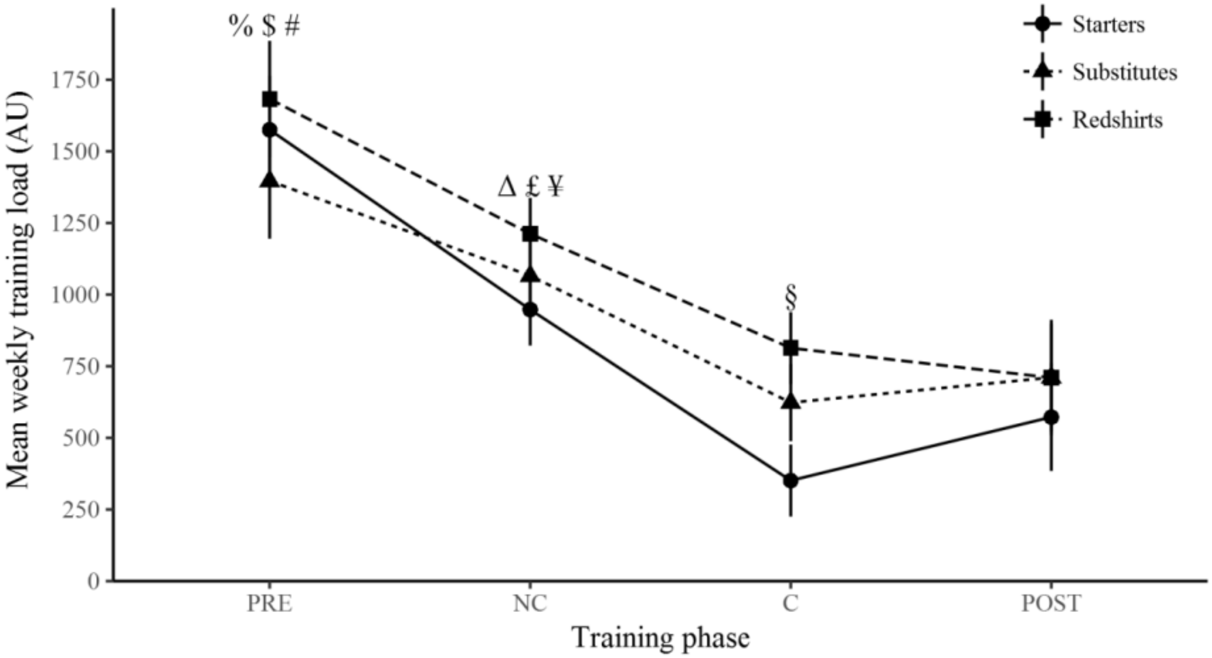

Figure 2. Phasic changes in mean weekly training load by group, mean ± 95% CI. Abbreviations: PRE, pre-season; NC, non-conference; C, conference; POST, post-season; au, arbitrary units; § significant difference starter versus redshirt; % significant difference starter PRE versus NC, C, and POST; $ significant difference substitute PRE versus C and POST; # significant difference redshirt PRE versus NC, C, and POST; Δ significant difference starter NC versus C and POST; £ significant difference substitute NC versus C; ¥ significant difference redshirt NC versus C and POST.

Daily analysis

No differences in TL were found between groups for MD-3, MD-2, or MD-1 (Table 2; Figure 3). Both substitutes (124 [29 – 219] au, ES = 2.73 [1.03 – 4.43], very large) and redshirts (173 [88 – 258] au, ES = 4.07 [2.03 – 6.11], nearly perfect) displayed significantly greater TL on MD-4 compared to starters.

Starters demonstrated significantly greater TL on MD-3 compared to other training days (MD-3 – MD-4: 214 [148 – 279] au, ES = 5.76 [3.12 – 8.41], nearly perfect; MD-3 – MD-2: 132 [72 – 192] au, ES = 3.90 [1.91 – 5.88], very large; MD-3 – MD-1: 175 [115 – 235] au, ES = 5.15 [2.73 – 7.57], nearly perfect). Substitutes demonstrated significantly greater TL on MD-4 compared to MD-1 (101 [27 – 174] au, ES = 2.62 [0.86 – 4.37], very large), MD-3 compared to MD-2 and MD-1 (MD-3 – MD-2: 81 [12 – 150] au, ES = 2.24 [0.60 – 3.88], very large; MD-3 – MD-1: 161 [91 – 230] au, ES = 4.39 [2.01 – 6.76], nearly perfect), and MD-2 compared to MD-1 (79 [13 – 145] au, ES = 2.29 [0.64 – 3.95], very large). Redshirts demonstrated significantly greater TL on MD-4 compared to MD-2 and MD-1 (MD-4 – MD-2: 73 [10 – 135] au, ES = 2.05 [0.61 – 3.49], very large; MD-4 – MD-1: 124 [62 – 186] au, ES = 3.54 [1.67 – 5.40], very large) and on MD-3 compared to MD-2 and MD-1 (MD-3 – MD-2: 66 [1 – 132] au, ES = 1.79 [0.41 – 3.17], large; MD-3 – MD-1: 117 [53 – 182] au, ES = 3.20 [1.44 – 4.96], very large). No statistically significant differences were found between MD-2 and MD-1 for starters and redshirts. Similarly, starters demonstrated no statistical difference between MD-4 and MD-1. No significant differences were found between MD-4 and MD-3 for substitutes or redshirts, while substitutes also displayed no difference between MD-4 and MD-2.

Table 2. Mean daily training loads

Player Group	Training Day$^+$	Mean (95% CI), au	Grouped Difference*
Starters	MD-4	115 (79 – 151)	F
	MD-3	329 (262 – 336)	A
	MD-2	196 (165 – 228)	DE
	MD-1	154 (122 – 185)	DEF
Substitutes	MD-4	239 (200 – 279)	ABCD
	MD-3	299 (262 – 336)	AC
	MD-2	218 (184 – 252)	BD
	MD-1	138 (104 – 173)	EF
Redshirts	MD-4	288 (256 – 320)	AB
	MD-3	281 (247 – 316)	AB
	MD-2	215 (182 – 248)	CDE
	MD-1	164 (131 – 196)	DEF

au, arbitrary units

$^+$represents number of days before a match; ex, MD-4 = 4 days before match

*Variables sharing the same letter are not statistically different at *a* = .05

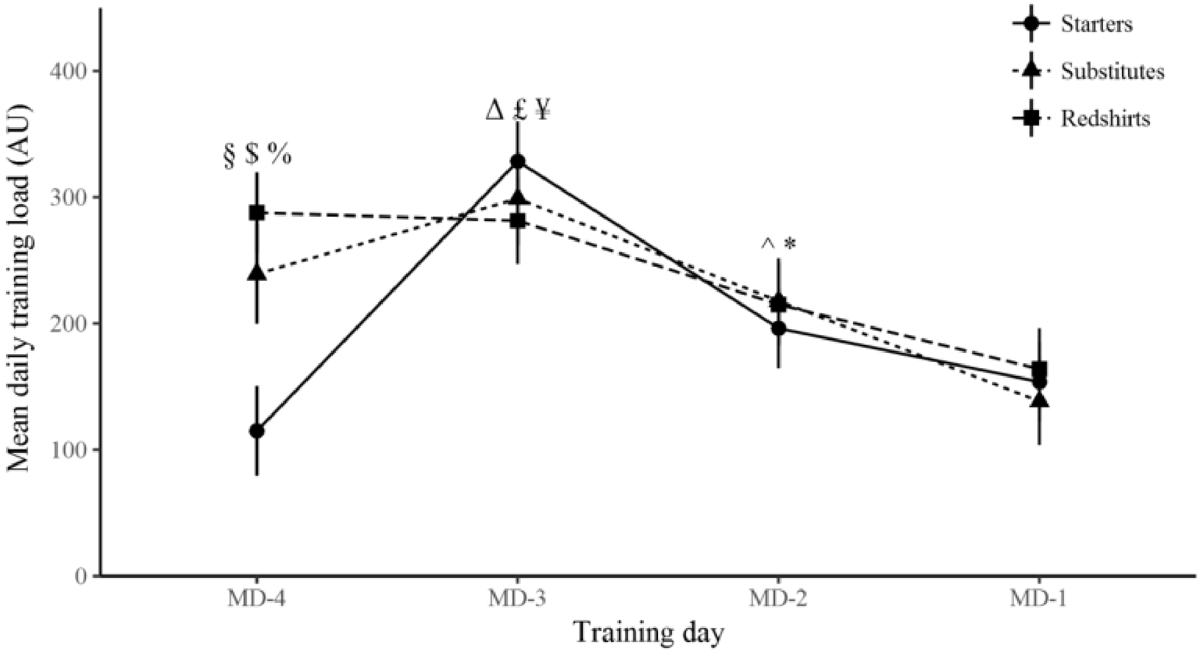

Figure 3. Daily changes in training load by group, mean ± 95% CI. Days before a match are represented in the MD-minus format: e.g., MD-4 = 4 days before the next match. Abbreviations: au, arbitrary units; § significant difference substitutes and redshirts versus starters; $ significant difference substitute MD-4 versus MD-1; % significant difference redshirt MD-4 versus MD-2 and MD-1; Δ significant difference starter MD-3 versus all other sessions; £ significant difference substitute MD-3 versus MD-2 and MD-1; ¥ significant difference redshirt MD-3 versus MD-2 and MD-1; ^ significant difference starter MD-2 versus MD-4; * significant difference substitute MD-2 versus MD-1.

DISCUSSION

The purpose of this study was to examine the TL programming of a Division I men's collegiate soccer team across a season when the coaching staff were collaborating with the sport science staff. The study revealed variation in TL at the phasic and daily level for all three player groups.

The pre-season period emphasizes rebuilding soccer-specific fitness parameters that may decrease during the off-season period. Rebuilding fitness is especially important for collegiate soccer, as athletes have limited or no contact with the strength and conditioning staff and coaching staff for the better part of three months. While some athletes participate in summer competitive leagues, anecdotal experience suggests many other athletes complete varying amounts of training over the summer period and are often unprepared for the fall season. Therefore, the statistically greater TL during PRE compared to other phases of the season is unsurprising. In comparison with other studies on professional and semi-professional soccer teams, the present pre-season TL values are lower. For instance, Jeong et al. (11) reported weekly TL of 4343 ± 329 au in Korean soccer athletes, and Algroy et al. (2) reported weekly TL of 3577 ± 920 au in professional Norwegian soccer athletes. The substantial difference in TL is likely threefold: 1) both included all field training sessions, and Algroy et al. (2) further included strength training in the TL analysis; 2) the level of athletes involved in the analyses; and 3) the shortened pre-season in the collegiate setting. With respect to the second point, previous analysis has shown that fitness characteristics and competitive demands generally increase as the competitive level increases (3). Therefore, the athletes in the present study may not have been physically developed enough to tolerate professional-level TL. Furthermore, the structure of the pre-season, in which the athletes trained approximately two weeks before the first competitive match, is at odds with the pre-season lengths reported at the professional level—see Malone et al. (12) as an example—and limits training that can be carried out without risk of non-functional overreaching and overtraining.

During C and POST, the training emphasis shifts to maintenance of physical qualities and technical/tactical refinement. Therefore, the early in-season must continue PRE's physical development because of the short pre-season and variable summer preparation described above. This changing emphasis is reflected in the phasic analysis, in which TL values during the NC portion of the season were statistically greater than during C and POST for starters and redshirts and C for substitutes. Interestingly, the substitutes did not display a statistically significant difference between PRE and NC TL values. The lack of significant decline in substitutes' TL may stem from their decreased game involvement; that is, their lack of match involvement (compared to starters) led to an additional TL stimulus to continue soccer-specific fitness development. This trend did not hold for redshirts, however, due to different emphases in training. While not covered in the present study, these athletes were freshmen and not expected to contribute meaningfully to the team in matches. Their training emphasized strength and power development while de-emphasizing soccer-specific fitness development.

The TL differences between starters and redshirts during C reflect the shift in the competitive schedule described previously (one match every 5 ± 1 days in NC vs. every 4 ± 1 days in C). Because starters contributed a majority of the minutes played during C and because of the physical demands of the collegiate game (16), starters spent a majority of the week performing recovery-based training and low-intensity match preparation sessions. Redshirts continued normal training, although their statistically significant decline in TL during C likely resulted from a reduced training schedule to accommodate the increased number of games per week. Substitutes represented an amalgam of the other two groups—while they were not as involved in matches as the starters, they played a moderate percentage of the total weekly minutes. Therefore, the strength of the opposition and their match involvement dictated whether they performed recovery-based training or soccer-specific fitness development.

The above discussion of phasic variations in training load highlights the differences in athletes' TL as a means of managing fatigue. Examining TL at the daily level further reinforces this idea of varied TL application based on match involvement. In each of the weeks included in the daily analysis, MD-4 followed a match and a complete day off from training. Starters were limited to playing as outside-the-grid neutrals for small-sided games and participating in very low-intensity technical/tactical aspects of training to prevent exacerbation of lingering match fatigue. The remainder of the week for the starters followed a "single peak" strategy similar to the theoretical TL programming outlined by Clemente et al. (4) The decline in TL on MD-2 and MD-1 was intended to minimize accumulated fatigue from the match and MD-3 to maximize preparedness for the next match (1). The substitutes followed a similar strategy, although their MD-4 TL was statistically greater than the starters'. This greater loading on MD-4 is related to the above discussion on player group-based phasic variations in TL. As each of the weeks contained in the daily analysis occurred during the NC phase, substitutes' match loads were lower compared to the starters (unpublished observation). Therefore, elevated training loads were generally employed on MD-4 in effort to increase substitutes' weekly TL to values similar to those of the starters. Because of this larger early-week loading, substitutes' MD-1 TL was significantly reduced compared to their other training days. The redshirts followed a unique loading pattern compared to the starters and substitutes. Similar to the substitutes the redshirts completed two accumulation sessions on MD-4 and MD-3. Unlike the substitutes, though, the redshirts were not expected to play in any of the matches. Therefore, while the redshirts' MD-2 and MD-1 followed a tapering strategy into the match in the off chance the athletes were needed, no significant difference existed between MD-2 and MD-1. Unfortunately, no measures of fatigue were taken as a part of the present study so the effects of these differing loading strategies on athletes' fatigue (both perceived and objective) is unclear. Future analyses including self-report questionnaires and physical performance tests are needed to discern the differences—if any—in how these loading strategies affect athlete fatigue and preparedness.

PRACTICAL APPLICATIONS

This study is the first to highlight the potential benefits of collaboration between a sport science staff and coaching staff in planning a season of Division I men's collegiate soccer. Unlike Malone et al. (12) who observed limited TL variation, we observed TL variation at both the phasic and daily level for the three athlete groups. Training variation serves to prevent monotony of training and limits the unnecessary accumulation of fatigue. Our findings suggest periodized programming can occur in a team sport setting, although further research is needed to determine how such programming strategies influence athletes' fatigue and on-field performance.

Some limitations can arise from the study process. Namely, several athletes were missing data points due to class and work obligations. Linear mixed modeling was employed to combat the unbalanced nature of the analysis, although we cannot rule out influence on the results. Training load not accumulated during team training was excluded to emphasize the team's training strategies. Inclusion of this data is paramount in creating a link between TL, an athlete's preparedness, and changes in physical and match performance and injury risk. Future research examining the effects of the programming strategies discussed in this paper on performance and injury risk are needed. Further, comparison of weekly mini-tapering strategies would enhance our understanding of maximizing athletes’ preparedness.

ACKNOWLEDGEMENTS

The authors would like to thank the team’s coaches and players for their willingness to participate in the athlete monitoring program.

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CHAPTER 5

QUANTIFYING CHANGES IN SQUAT JUMP HEIGHT ACROSS A SEASON OF MEN'S COLLEGIATE SOCCER

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Prepared for submission to *Journal of Strength and Conditioning Research*

Abstract

The purposes of this study were to examine the effectiveness of an athlete monitoring program in managing athlete neuromuscular fatigue across a men's collegiate soccer season as measured by changes in squat jump (SJ) height and to compare possible changes with session rating of perceived exertion (sRPE) training load (TL). Eighteen outfield Division I men's college soccer players performed SJ testing prior to each game of the fall season in addition to a baseline measurement at the start of pre-season. The athletes provided sRPE values after all training sessions, weight training, and games. Linear mixed modeling was used to compare changes in SJ height across the season with the baseline, and a correlation coefficient and single-lag cross-correlation coefficient were calculated between TL and changes in SJ height. No statistically significant decreases in SJ height occurred across the season, although a moderate practical decline occurred following the pre-season (-1.6 cm, ES = -0.70). The correlation between TL and changes in SJ height was statistically non-significant, while the cross-correlation was significant ($r = 0.18$, $p = .48$ and $r = 0.55$, $p = 0.02$, respectively). The athlete monitoring program was successful in managing the athletes' neuromuscular fatigue across the season as evidenced by the maintenance of SJ height and positive relationship between TL and changes in SJ height. Thus, SJ monitoring may serve as a useful fatigue monitoring tool for collegiate soccer athletes. Future study is needed relating changes in vertical jump performance to other markers of athlete preparedness and performance.

Keywords: athlete monitoring, fatigue, vertical jump

INTRODUCTION

In an injury report published by the NCAA in 2012 (36), it was found that the most common injuries in men's college soccer resulted in three to six days of lost time per injury. With such a congested fixture schedule (matches played every 3 – 4 days), time lost to injury can severely affect team performance. Previous research has identified player availability and low injury rates as some of the most important factors in team success (15, 23). Therefore, development and implementation of a comprehensive athlete monitoring program that assesses athletes' workloads and responses to those workloads is vital in managing athlete fatigue and decreasing the risk of fatigue-related injuries. This "white box" approach (14) affords the coaching staff finer control over the workloads prescribed and allows for modification of the training plan (if necessary) to manage the athletes' fatigue.

Session rating of perceived exertion (sRPE or session RPE) is perhaps the easiest method of quantifying athlete workload. Born from Borg's rating of perceived exertion scales (4, 5), Foster and colleagues (18) developed the sRPE scale with common-language verbal intensity anchors (e.g. "easy," "moderate," and "hard"). Unlike other forms of RPE that have traditionally been used to measure instantaneous exercise intensity, sRPE is a single value collected post-training that is meant to act as a "global" measure of exercise intensity (7, 18, 28)—that is, the intensity ratings are meant to account for work rate, injury, illness, and psychological status (40). The intensity score reported by the athlete is multiplied by the training or match duration to calculate a training load (TL) score.

Session RPE has been investigated in a variety of general (13, 30) and soccer-specific (1, 12, 28) training contexts and has been found to be a valid measure of training intensity. Furthermore, the resultant TL score demonstrates strong correlations with a number of other variables including heart rate training impulse scores, blood lactate, distance traveled, and Catapult's Player Load (7, 11, 28). These findings suggest sRPE and the resultant TL can be used as a stand-alone method of workload quantification if other tools are unavailable.

For an athlete monitoring program to be effective, athletes' responses to imposed TL must also be quantified to understand the athletes' fatigue status. Fatigue and muscle damage have been shown to impair neuromuscular function (16). A direct method of quantifying neuromuscular fatigue-related performance decrements would be to assess performance within the sport. Unfortunately, maximal sport performance is fatiguing and would be a poor monitoring tool in sports with dense competitive schedules. Men's collegiate soccer falls into this category as matches occur every 3 – 4 days for 10 or more weeks. Therefore, various proxy measures of neuromuscular fatigue have been investigated in the literature.

The most commonly used tool to monitor neuromuscular fatigue is the vertical jump (42). Vertical jumps are relatively quick to assess, generate little fatigue, and require little familiarization (33, 34). Furthermore, a number of studies have used various vertical jump tests to map the recovery process and establish the minimum time required to return to baseline following competition and fatiguing training (3, 6, 22). Countermovement jumps (CMJ) are the most commonly assessed vertical jump in practice (42), although several studies have observed that CMJ height calculated from flight time may be less sensitive to fatigue status than variables that measure the movement strategy (20-22). This lack of sensitivity may be due to altered mechanical alterations that maintain CMJ height.

An alternative to CMJ measurement may be squat jump (SJ) measurement. Unlike CMJ, SJ are performed in a way that minimizes the influence of the stretch-shortening cycle and removes the influence of mechanical changes observed in CMJ studies (24, 37). In the few available studies comparing changes in SJ and CMJ variables to fatiguing protocols, SJ height displayed superior sensitivity compared to CMJ height (21, 24, 27). Unfortunately, studies relating SJ performance changes to fatigue is limited. Therefore, further research is needed examining this relationship.

To the authors' knowledge, only two season-long investigations of changes in vertical jump performance have been published. Cormack and colleagues (10) found the flight time-contraction time ratio for CMJ was decreased in 60% of mid-week testing sessions across a 22-week Australian Rules football season, although the authors did not include a measure of workload. Sams (39) investigated the relationship between sRPE-derived TL and changes in weighted CMJ and SJ performance and found large to nearly perfect correlations between time-lagged TL and changes in CMJ and SJ height. Further, changes in SJ height displayed a trend toward a stronger relationship with TL compared to changes in CMJ height. Given these findings and the lack of available long-term athlete monitoring studies in the collegiate setting or otherwise, the purpose of this study was to examine the effectiveness of an athlete monitoring program in managing athlete neuromuscular fatigue as measured by weighted SJ height. A secondary purpose of this research was to examine the relationship between TL and changes in SJ height. It was hypothesized the athlete monitoring program, which was focused on fatigue management, would lead to no change or an increase in SJ height across the season. We also hypothesized that a strong relationship would exist between accumulated TL and changes in SJ height because of previous research on these athletes (39).

METHODS

Experimental Approach to the Problem

This retrospective study was designed to examine changes in weighted SJ height across a season of men's collegiate soccer and to relate these changes to TL. Weighted SJ were selected as the measurement tool because of previous research relating changes in SJ height to accumulated TL in the current athletes (39). The absolute change in SJ height from baseline was determined for 18 pre-game testing sessions across a 14-week season of Division I men's collegiate soccer. Training load in the 7 days preceding each testing session was correlated and cross-correlated to changes in SJ performance. All field training sessions, weight training, and games were included in the TL quantification.

Subjects

Eighteen outfield NCAA Division I male collegiate soccer athletes (20 ± 1 years, 179 ± 6cm, 75.6 ± 6.6kg) participated in this study; goalkeepers and athletes who sustained season-ending injuries at any point during the season were excluded from this analysis. Goalkeepers were excluded from this analysis because they followed different weight and field training schedules from the rest of the team. The East Tennessee State University Institutional Review Board approved retrospective analysis of training load and vertical jump data.

Procedures

Squat jump testing. Baseline testing was performed on the first day of pre-season practice. Further testing sessions were carried out approximately 4 hours before 18 of the season's 21 matches. This timing window was chosen to not interfere with class schedules or team pre-game activities. No measurements were taken prior to matches 11, 14, and 17 due to travel constraints.

Prior to each testing session, the athletes completed a standardized dynamic warm-up followed by warm-up jumps with 0 kg (a PVC pipe held across the shoulders; 2 repetitions), 11 kg (1 repetition), and 20 kg (1 repetition). The athletes then completed two maximal SJ attempts on a switch mat (Just Jump, PROBOTICS, Huntsville, AL) with a 20 kg bar held across their shoulders. Flight time data were reported to the hundredth of a second. If the trials differed by more than 0.01 s, a third trial was performed. Jump height was calculated from the time in air method described in Moir (35). The average of the two trials (or average of the two closest trials in the event of a third jump) was retained for analysis.

When performing the SJ, the athletes were instructed to squat down to a knee angle of 90° (visually confirmed by the researchers). The athletes were given the command “3, 2, 1, jump” at which point they jumped from the static start position in effort to remove the involvement of the stretch-shortening cycle and to dampen the influence of mechanical alterations that have been shown to preserve jump height in CMJ (24, 37). The athletes were verbally encouraged to jump as high as possible prior to each trial. A total of 325 observations (mean sessions per athlete: 18; range: 16 – 19) were recorded.

Training load quantification. Athletes’ sRPE values were collected approximately 10 minutes after each training session and game. While sRPE collection 30 minutes post-training is often cited as ideal, recent research has suggested this delay in collection may not be necessary (17, 26, 43). For training and games, the researchers approached the athletes individually and asked them how difficult they felt the session was in accordance with Foster et al.’s (18) sRPE scale.

For weight training, each athlete's training sheet displayed the sRPE scale at the bottom. The athletes wrote their selected sRPE score in a box next to the training session. All responses were uploaded to the team's athlete monitoring database. Each sRPE value was multiplied by the session duration to generate a TL value. These individual TL values were summed to calculate a total TL score for the day. A total of 1150 athlete training days (mean training days per athlete: 64; range: 52 – 72) were recorded. The total TL in the seven days preceding each testing session was calculated to examine the relationship between TL and changes in SJ performance.

Training design and modifications. During the pre-season and non-conference portions of the season (first 7 weeks), matches were held every 5 ± 1 days. On-field training was implemented in a similar fashion to the proposed microcycle pattern in Clemente et al. (8). Matches were followed by a day off and then a 30-minute recovery-oriented session where the athletes engaged in foam rolling, stretching in a pool, and cold-water immersion. Depending on the time between matches, two to three 75-minute field training sessions and one to two 60-minute weight training sessions were carried out prior to the next match. During conference play and the post-season, however, matches were held every 4 ± 1 days. As a result, high-minute players performed two 30-minute recovery sessions per week, two 60-minute pre-game training sessions per week, and one 45-minute weight training session each week. Instead of the recovery sessions, low-minute players performed two 45-minute field training sessions. Otherwise, their training did not differ from high-minute players.

The content of field training sessions was determined through a joint effort by the coaching and sport science staffs. The two staffs met daily to adjust training as necessary based on the available athlete monitoring data. The goal of the athlete monitoring program was to minimize athlete fatigue while maximizing performance. Therefore, TL and SJ height were monitored closely for each athlete. Athletes who deviated too far from their norms, as measured by statistical process control analysis (41), were flagged for reductions in training volume, extra recovery-oriented training, and/or reduced minutes in game.

Statistical analyses

The statistical software R (version 3.3.2) and the packages lme4 (1.1-12), lsmeans (version 2.23-5), and compute.es (0.2-4) were used to create a linear mixed model (LMM) of SJ data, perform comparisons, and calculate effect sizes, respectively. Linear mixed modeling was chosen in lieu of repeated-measures ANOVA because LMM are able to cope with unbalanced designs (9)—due to class, work, and travel schedules athletes missed some testing sessions. The testing sessions (time) were treated as the fixed effect, whereas the athletes were treated as random effects. Dunnett's test was used to compare each of the SJ testing sessions with the baseline measurement. Significance was set at $p < .05$. To describe the magnitude of the differences, Cohen's *d* effect sizes (ES) with 95% confidence intervals (CI) were calculated from the resultant *t* ratios (38). Descriptions of effect size magnitudes follow Hopkins (25): <0.2 = trivial, 0.2 – 0.6 = small, and 0.6 – 1.2 = moderate.

To assess the relationship between TL and absolute changes in SJ height, a zero-order Pearson product-moment correlation coefficient and a single-lag cross-correlation coefficient were calculated between the team's model-derived average jump height values and average TL values for testing sessions 2 through 18. Testing session 1 was omitted from the correlation analyses because it acted as a significantly influential outlier. Single-lag cross-correlation was included as previous research in these athletes identified a strong relationship between single-lag

TL and changes in SJ height (39). Squat jump data are presented as the model-derived mean and 95% confidence interval (CI) in centimeters. Training load data are presented as the mean ± SD in arbitrary units (au). Comparisons and ES are presented as the estimate and corresponding 95% CI.

RESULTS

Changes in jump height

Testing sessions occurred every 5 ± 2 days. Testing session 8 represented the only statistically significant increase in SJ height from the baseline measurement (2.3 [0.1 – 4.5] cm, ES = 1.01 [0.29 – 1.72], moderate; Figure 1). All other testing sessions did not statistically differ from the baseline measurement (*p* > .05 for all comparisons; Table 1).

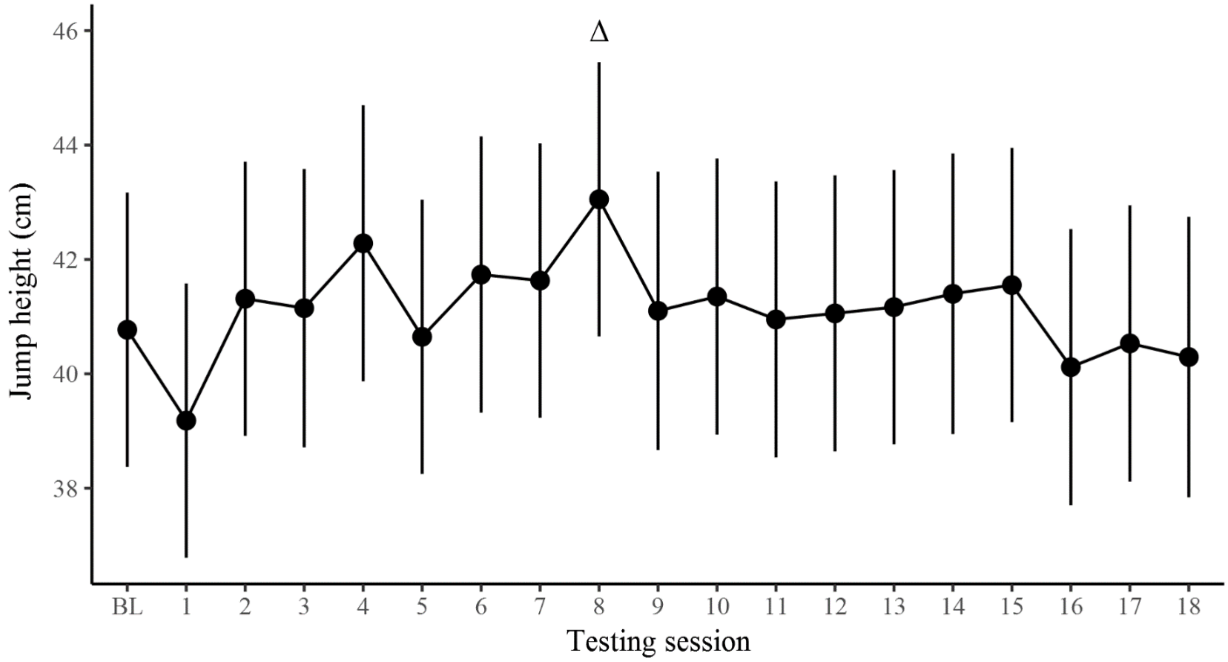

Figure 1. Change in vertical jump height across time, mean ± 95% CI. Δ, statistically significant difference from baseline measurement (*p* = .039). BL, baseline.

Table 1. Change in squat jump height compared to baseline

Testing Session	Difference from Baseline (95% CI), cm	Effect Size (95% CI), magnitude
1	-1.6 (-3.8 – 0.6)	-0.70 (-1.4 – 0.00), M
2	0.5 (-1.7 – 2.8)	0.24 (-0.44 – 0.92), S
3	0.4 (-1.9 – 2.7)	0.17 (-0.53 – 0.87), T
4	1.5 (-0.7 – 3.8)	0.67 (-0.04 – 1.37), M
5	-0.1 (-2.3 – 2.1)	-0.05 (-0.73 – 0.62), T
6	1.0 (-1.3 – 3.2)	0.43 (-0.27 – 1.12), S
7	0.9 (-1.4 – 3.1)	0.38 (-0.3 – 1.06), S
8	2.3 (0.1 – 4.5), Δ	1.01 (0.29 – 1.72), M
9	0.3 (-2.0 – 2.6)	0.15 (-0.56 – 0.85), T
10	0.6 (-1.7 – 2.8)	0.26 (-0.44 – 0.95), S
11	0.2 (-2.1 – 2.4)	0.08 (-0.61 – 0.77), T
12	0.3 (-2.0 – 2.5)	0.13 (-0.56 – 0.81), T
13	0.4 (-1.8 – 2.6)	0.17 (-0.5 – 0.85), T
14	0.6 (-1.7 – 3.0)	0.28 (-0.44 – 0.99), S
15	0.8 (-1.4 – 3.0)	0.34 (-0.34 – 1.03), S
16	-0.7 (-2.9 – 1.6)	-0.29 (-0.98 – 0.4), S
17	-0.2 (-2.5 – 2.0)	-0.11 (-0.79 – 0.58), T
18	-0.5 (-2.8 – 1.9)	-0.21 (-0.92 – 0.51), S

Δ, significantly different from baseline (*p* = .039)
ES magnitudes: T, trivial; S, small; M, moderate

Training load relationship to changes in squat jump height

A small (25), statistically non-significant positive correlation (*r* = 0.18, *p* = .48) was observed between TL and changes in SJ height. A large (25), statistically significant positive correlation (*r* = 0.55, *p* = .02) was observed between single-lag TL and changes in SJ height.

DISCUSSION

The purpose of this study was to examine the effectiveness of an athlete monitoring program in managing athlete fatigue as measured by weighted squat jump testing. A secondary purpose of this study was to investigate the relationship between accumulated training load and changes in squat jump height. No statistically significant decreases in SJ height were observed across the season. A small, statistically non-significant positive relationship was found between TL and changes in SJ height, while a large, statistically significant positive relationship was found between single-lag TL and changes in SJ height. These results suggest the athlete monitoring program was successful in maintaining SJ height across the season. Furthermore, the correlation values may have been a result of the athlete monitoring program's focus on fatigue management.

There were no statistically significant declines in SJ height across the season, although testing session 1 displayed a trend toward a moderate practical reduction in vertical jump height. Testing session 1 was carried out at the end of the pre-season period prior to the first match of the season. Moreover, the accumulated TL in the seven days preceding testing session 1 was the greatest of any testing sessions across the season (Figure 2). Collectively, these results highlight the differing training foci between the pre-season and in-season periods. The pre-season in collegiate soccer is two weeks long and follows a three-month summer break in which the NCAA forbids athletes from discussing their training with the coaching staff. While some athletes play in summer leagues, anecdotal experience suggests athletes often complete relatively little training over the summer and enter the pre-season in a detrained state. Therefore, greater TL is applied during the pre-season in effort to re-establish soccer-specific fitness in preparation for conference and post-season play, where TL is reduced and maintenance of physical performance is emphasized. While the pre-season TL experienced by the athletes is lower than that reported at the professional level (2, 29, 31), the loading was sufficient to moderately reduce their SJ height. Without summer TL information, however, it is impossible to determine whether this reduction occurred as a result of the TL itself or as a result of disruption in the athletes' acute-to-chronic workload ratios (19). NCAA rules make collection of such data impossible, thus limiting accurate calculation of acute-to-chronic workload ratios. Further data collection is necessary to understand the relationship between pre-season TL and changes in physical performance tests such as the SJ. Furthermore, alteration to NCAA reporting rules is necessary to allow for accurate calculation of acute-to-chronic workload ratios during early stages of the season.

In comparison to previous research with these athletes in which a negative relationship existed between TL and SJ height (zero-order: r = -0.24; single-lag: r = -0.96) (39), the present study found a positive relationship between TL and SJ height (zero-order: r = 0.18; single-lag: r = 0.55). These differences in findings may be related to differences in the training protocols. The initial work by Sams (39) was observational in nature and made no attempt to influence the athletes' TL, whereas the present analysis involved active collaboration between the coaching and sport science staffs. As mentioned above, when athletes displayed supra-normal TL values or a decline in SJ height, they were flagged for reductions in training volume, extra recovery-oriented training, and/or reduced minutes in games. The team's proactive approach to TL application and focus on maintenance of vertical jump performance across the season may have contributed to the altered relationship between time-lagged TL and changes in SJ performance. That is, the extra recovery afforded to athletes who displayed supra-normal TL may have prevented the decline in SJ performance in the subsequent week that was observed previously (39). Importantly, however, this approach to TL application could prove detrimental if the athletes are underprepared for sudden increases in TL—transition from single- to multi-game weeks, tournaments, etc. Readers are referred to Gabbett (19) for a discussion on balancing training with recovery and the acute-to-chronic workload ratio.

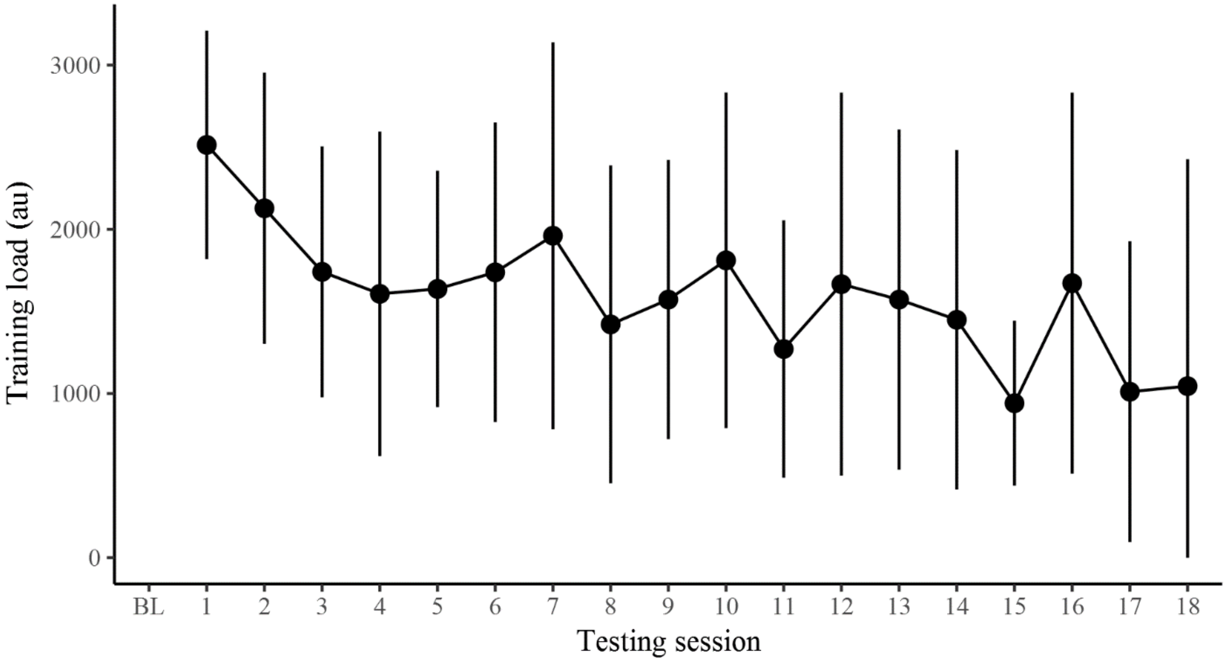

Figure 2. Training load values in the seven days preceding each testing session, mean ± 2SD. BL, baseline; au, arbitrary units.

Several limitations exist in interpreting these findings. First, generalization to teams that do not employ a sport science staff or do not have an athlete monitoring program in place is difficult. Second, 17 data points split among 10 of the athletes were missing across the collection period due to class and work obligations. Linear mixed modeling was employed to combat the unbalanced nature of the analysis, but it is still possible the missing data could influence the results of the study. Finally, future research comparing different training groups (e.g. starters, substitutes, redshirts, goalkeepers) could help practitioners understand how individualized TL programming strategies influence athletes' preparedness. Importantly, information on goalkeeper training is severely lacking and should be the subject of future investigation.

PRACTICAL APPLICATIONS

This study highlights the potential benefits of an athlete monitoring program and collaboration between a sport science staff and coaching staff in managing neuromuscular fatigue in a season of Division I men's collegiate soccer. The data revealed a moderate, statistically non-significant reduction in SJ height after the pre-season, but no other statistically or practically significant declines in performance were observed across the season. This stability in SJ height and positive relationship between SJ performance and accumulated TL suggests the athlete monitoring protocol and the training alterations for flagged players may have aided in prevention of excessive fatigue accumulation in the athletes studied. Importantly, the athlete monitoring methods employed in the present study are cost-efficient—sRPE collection is free—and can be easily implemented in an applied setting. Further, with the rise of athlete monitoring dashboards, in-depth athlete monitoring can be accomplished with minimal time commitment. Readers are referred to McFarland and Bird (32) for an example of how a dashboard might be used to monitor athletes.

ACKNOWLEDGEMENTS

The authors would like to thank the team’s coaches and players for their willingness to participate in the athlete monitoring program.

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CHAPTER 6

SUMMARY AND FUTURE INVESTIGATIONS

The purposes of this dissertation were to examine common athlete training and monitoring practices in men's collegiate soccer and to report the programming strategies and monitoring outcomes for an NCAA Division I men's collegiate soccer team whose coaching and sport science staff collaborated on a daily basis. To fulfill these purposes, the following were examined as individual research projects: 1) an investigation of common athlete training and monitoring practices in men's collegiate soccer via a custom questionnaire, 2) an examination of the training loads employed by an NCAA Division I men's collegiate soccer team with active collaboration between the coaching and sport science staff, and 3) an examination of changes in squat jump (SJ) height across the competitive season.

The results of study I indicated that while coaches employed training variation in their training plans, fewer coaches recognized the importance of an athlete monitoring program. In addition, a number of coaches monitored their athletes through purely subjective measures (e.g. the "eyeball test") and did not record their data longitudinally. This training by "feeling" and lack of longitudinal data collection prevents the formation of relationships between training, performance, and injury incidence. Furthermore, a lack of historical data prevents evidence-based modifications to subsequent years' training plans. Coach education programs concerning the development and implementation of athlete monitoring programs should be a primary concern for strength and conditioning coaches and sport scientists working in men's collegiate soccer.

Previous observational research in professional soccer athletes has shown a lack of training variation at the phasic and daily level. Monotonous training has been linked to stagnating performance and increased injury risk. Therefore, study II sought to examine the programming strategies employed by an NCAA Division I men's soccer team whose coaching and sport science staff collaborated on a daily basis. In contrast to the research on professional soccer athletes, study II demonstrated phasic and daily variations in training load experienced by starters, substitutes, and redshirts. These variations in training load reflected the player groups' match involvement.

Study II was successful in demonstrating the benefits of collaboration between coaches and sport scientists in varying athletes' training loads across a season. Therefore, study III sought to examine how this collaborative approach to programming managed athletes' neuromuscular fatigue across the competitive season as measured by changes in SJ height. No statistical declines in jump height were evident across the season, although a moderate practical reduction in jump height occurred following the pre-season. The results of study III suggest the athlete training and monitoring program was successful in managing the athletes' fatigue across the season and that regularly monitoring athletes' vertical jump performance may serve as a useful fatigue monitoring tool for men's collegiate soccer athletes.

Overall, studies II and II highlight the effects of coordination between a coaching and sport science staff on in-season programming and fatigue management. While budgetary constraints may prevent hiring a dedicated sport scientist, reaching out to a university's exercise or sport science department can serve the same purpose (as is the case for this dissertation). A "sport performance enhancement group" (SPEG) can be created through this relationship. This SPEG is an athlete-focused collaborative effort between the coaches, sport scientist(s), strength and conditioning professionals, sports medicine staff, and other support staff. The groups communicate with one another on a regular basis and take a joint approach to the training process. Both Dotterweich et al. (2013) and Reed and colleagues (2017) provide a comprehensive overview of the development and implementation of a SPEG.

While this dissertation was successful in highlighting the potential benefits of collaboration between a coaching and sport science staff, further research is needed to understand how such programming strategies influence athletes' fatigue, on-field performance, and injury risk. Furthermore, comparisons of weekly mini-tapering strategies are needed to enhance our understanding of maximizing athletes' preparedness. Finally, future research in this area should compare changes in vertical jump performance to other markers of athlete preparedness and performance. Understanding these relationships will enhance soccer athlete training and monitoring at all levels of play.

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APPENDIX

Athlete Monitoring Survey

ATHLETE MONITORING IN MEN'S COLLEGIATE SOCCER

This is a voluntary research project in which you will be answering questions regarding the training and athlete monitoring practices your team uses. The questions are designed to gain a better understanding of typical in-season training practices used at the collegiate level. Through the results of this project, we hope to provide sport scientists and strength and conditioning professionals insight as to how they may optimize your athletes' readiness for competition while minimizing fatigue and injury potential.

SECTION A: DEMOGRAPHICS

1. What is your position?
    a. Head coach
    b. Head strength and conditioning coach
    c. High performance manager
    d. Sport scientist
    e. Other
2. How long have you worked in a coaching capacity?
    a. < 1 year
    b. 1-5 years
    c. 5-10 years
    d. 10-20 years
    e. 20+ years
3. What is the highest degree or level of education you have completed? If currently enrolled, select highest degree completed.
    a. High school
    b. Associate's degree
    c. Bachelor's degree
    d. Master's degree
    e. Doctorate degree
    f. Other
4. What is your college's division?
    a. NCAA Division I
    b. NCAA Division II
    c. NCAA Division III
    d. NAIA
    e. Other

SECTION B: TRAINING DESIGN

1. Do you develop and follow an overall in-season training plan?
    a. Yes
    b. No
2. Do you vary daily overall training volume and/or intensity in season or are they relatively constant?
    a. Volume
    b. Intensity
    c. Both
    d. Neither
3. Do you vary weekly overall training volume and/or intensity in season or are they relatively constant?
    a. Volume
    b. Intensity
    c. Both
    d. Neither
4. On average, how many team practice sessions do you complete a week in season?
    a. 1-2
    b. 2-4
    c. 4-6
    d. > 6
5. On average, how long is each team practice session in season?
    a. < 30 minutes
    b. 30-60 minutes
    c. 60-90 minutes
    d. > 90 minutes
6. On average, how physically intense is each in-season team practice?
    a. (Likert scale) 1-Very Easy to 10-Maximal
7. On average, how physically intense is team practice the day before a game
    a. (Likert scale) 1-Very Easy to 10-Maximal
8. Do you monitor your athletes’ practice training load and/or fatigue?
    a. Yes
    b. No

(OPTIONAL BASED ON RESPONSE TO 8) SECTION C: ATHLETE MONITORING

1. Why do you monitor your athletes? (they can select multiple)
    a. Reduce injuries
    b. Maintain performance
    c. Prevent overtraining
    d. Monitor the effectiveness of a training program
2. What is the main focus of monitoring your athletes?
    a. Load quantification
    b. Monitoring fatigue/recovery
    c. Equal focus on load quantification and fatigue monitoring
3. How effective do you feel your monitoring program is?
    a. (Likert scale) 1-Minimally Effective to 5-Extremely Effective

4. How is data collected and analyzed?
    a. Specially designed software
    b. A custom web interface
    c. Excel or another similar program
    d. Pen and paper
    e. Other
5. Which of the following do you use to quantify practice training load? (Can select multiple)
    a. Session RPE
    b. Training duration
    c. Heart rate load
    d. GPS data
    e. Other sport specific measurement device
    f. None of the above
    g. Other
6. Which of the following do you use to monitor athlete fatigue/recovery?
    a. Self-report questionnaires
    b. Performance tests (jumps, sprints, etc.)
    c. Hormonal profiling
    d. Tracking performance within the sport
    e. Other
7. If applicable, how frequently do you use each of the following to monitor athlete fatigue/recovery? (Grid containing Every session, Daily, Multiple days/week, Weekly, and Monthly)
    a. Self-report questionnaires
    b. Performance tests
    c. Hormonal profiling
    d. Tracking performance within the sport
    e. Other (described above)
8. If you use self-report questionnaires, which do you currently use?
    a. REST-Q
    b. DALDA
    c. TQR
    d. POMS
    e. Custom questionnaire
    f. Other
9. If applicable, which type of performance test(s) do you use to monitor fatigue/recovery?
    a. Sub-maximal running/cycling
    b. Jump testing
    c. Strength testing
    d. Sprint testing
    e. Sport-specific testing
    f. Other

10. When an athlete is identified as being fatigued, how is their training modified? (Can select multiple)
    a. Less training time/more recovery time
    b. Modified duration/intensity of training
    c. Use of "recovery" sessions
    d. Other
11. Is training modified based only on individual trends, or do you also look at team trends?
    a. Only individual trends
    b. A mixture of individual and team trends
    c. Team trends only
    d. Other

SECTION D: TRAINING RESPONSES

1. How does your team change from the beginning to the end of the season in the following areas? (Grid containing much worse, worse, no different, better, much better, N/A)
    a. Competitive performance
    b. Skill
    c. Fitness/conditioning
    d. Strength
    e. Speed
    f. Explosiveness
2. In general, how common are each of the following non-contact injury situations? (Grid containing None, Very Uncommon, Uncommon, Common, Very Common)
    a. Athlete is out for one day
    b. Athlete is out for several days
    c. Athlete is out for several days to a week
    d. Athlete is out for multiple weeks
    e. Athlete is out for the season
3. In general, are your team's non-contact injuries new or recurrent?
    a. Mostly new injuries
    b. A mix of new and recurrent injuries
    c. Mostly recurrent injuries
    d. Unsure

VITA

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    East Tennessee State University (ETSU), TN
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East Tennessee State University Men's Soccer
    Head Sport Scientist, 8/2012 to Current
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    Graduate Student Researcher, 8/2012 to 8/2015
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    Sport Physiology and Performance Intern, 8/2011 to 8/2012
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Publications:

DeWeese, B. H., Serrano, A. J., Scruggs, S. K., & **Sams, M. L.** (2012). The pull to knee—proper biomechanics for a weightlifting movement derivative. *Strength and Conditioning Journal*, *34*(4), 73-75.

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