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**TRAINING LOAD MANAGEMENT AND INJURY PREVENTION IN COLLEGIATE
MEN'S SOCCER**

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Health Promotion and Wellness Management

By

Lorenzo Salvatore Tomasiello Jr.

May 2019

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TRAINING LOAD MANAGEMENT AND INJURY PREVENTION IN COLLEGIATE MEN'S SOCCER

Department of Kinesiology

Missouri State University, May 2019

Master of Science

Lorenzo Salvatore Tomasiello Jr.

ABSTRACT

Soccer is a popular sport within the National Collegiate Athletic Association (NCAA) evidenced by 23,602 athletes participating in Men's soccer as of 2014. The sports complexity, coupled with the structure of a collegiate season, demands athletes train to improve performance and prevent injuries. Coaches are able to monitor training through the use of global positioning system (GPS) technology to properly prescribe training loads to meet the individual demands for an athlete. By utilizing an acute to chronic ratio derived from GPS data, coaches are able to determine whether an athlete is prepared for the workloads they are going to be exposed to during a given week. However, this data has yet to be adequately explored within a collegiate setting. Therefore, the purpose of this study was to utilize GPS technology, coupled with a coach's interpretation and thought process, to determine an appropriate acute to chronic workload ratio among NCAA Division-I men's soccer players within the fall 2016, 2017, and 2018 seasons. GPS data from 46 athletes was retroactively analyzed using a paired samples t-test to investigate differences between acute pre-season and in-season with two separate 3x3 [Workload (acute, chronic, acute-chronic ratio) x Season (2016, 2017, 2018)] repeated measures ANOVA used to determine the differences for total distance and distance at high-intensity. No significant differences ($p>0.05$) were seen for acute total distance, chronic total distance, acute-to-chronic total distance workload ratio, acute-to-chronic high intensity workload ratio, and distance at high intensity between pre-season and in-season. Total distance between pre-season and in-season ($p=0.03$), acute high intensity distance ($p<0.001$) and chronic high-intensity distance ($p<0.001$) yielded significant differences. It can be concluded that workloads are greater during the pre-season than in-season and a coach's determination of high-intensity speed may affect workload throughout the duration of a season because of the inverse relationship between intensity and total distance.

KEYWORDS: Acute, Chronic, Soccer, Training Load, Global Positioning System

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In the interest of academic freedom and the principle of free speech, approval of this thesis indicates the format is acceptable and meets the academic criteria for the discipline as determined by the faculty that constitute the thesis committee. The content and views expressed in this thesis are those of the student-scholar and are not endorsed by Missouri State University, its Graduate College, or its employees.

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OPERATIONAL DEFINITIONS

Acute:

Short term workload that can range anywhere from 1 session to entire week (Gabbett, 2015).

Acute to Chronic Ratio:

Acute workload divided by the chronic workload to establish the relationship of an athletes fatigue and fitness (Gabbett, 2015).

Chronic:

Long term workload that can range from 3 to 6 weeks (Gabbett, 2015).

Distance at High Intensity:

Meters covered above 22km/hr during a recorded session as defined by Missouri State Coaching Staff.

External Training Load:

Physical work done by the athlete (Gabbett, 2015).

Hertz (Hz):

The rate at which a GPS unit samples per second (Scott, Scott, & Kelix, 2015).

Internal Training Load:

Physiological or perceptual response by the athlete from a given workload (Gabbett, 2015).

New Body Load:

Arbitrary unit of training load to give a measure of accelerations and decelerations (Ehrmann, Duncan, Sindhusake, Franzen, & Greene, 2016).

Non-Contact Soft Tissue Injury:

Injury sustained by athlete that was not the result of a collision with an external factor like an individual (Ekstrand, Hägglund, & Waldén, 2011)

Total Distance:

Meters covered during an entire recorded session as measured by GPS (Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016).

Training-Injury Prevention Paradox:

A phenomenon whereby athletes accustomed to high training loads have fewer injuries than athletes training at lower workloads (Gabbett, 2015).

INTRODUCTION

The sport of American soccer (hereafter referred to as soccer) is regarded as one of the most popular sports in the world (“World Football Report 2018”). From within the collegiate setting, the National Collegiate Athletic Association (NCAA) reported 23,602 participants in Men’s Soccer, with 5,731 in Division I, 6,045 in Division II, and 11,826 in Division III (“2013-14 NCAA Sports Sponsorship and Participation Rates Report”). Given this participation, Division I Men’s Soccer only generated \$180,000 US Dollars while \$1,630,000 US Dollars was expended in 2015 (“Division I Revenues and Expenses - 2004 – 2015”).

Due to the fast pace and high workload demands of the game, participants are susceptible to injury, with non-contact, meaning injuries that are not the result of a collision with an external factor like a player, representing the largest majority (Hawkins & Fuller, 1999). Non-Contact soft-tissue injuries within this population often manifest themselves as muscle and connective tissue injuries to the lower body. In one study where a total of 2908 injuries over 1,175,000 hours almost all muscle injuries occurred from non-contact (Ekstrand et al., 2011). In a report by the NCAA, muscle strains account for 25.8 percent of injuries followed then by ligament sprains at 25.3 percent (“Men's Soccer Injuries - Data from the 2004/05-2008/09 Seasons”). Not only are there significant differences in workload between the demands of playing position, but general populations between teams as well. Aspects such as technical skill and physical ability can be attributed to differences between age, sex, strategy, and competition levels. While professional teams only play one game per week, NCAA soccer athletes can play as

many as three (Carling et al., 2015). With these differences, accumulated workloads from training and match play can vary greatly simply based on the time during the season.

These workloads can be classified as either external, objective measurements of work done by the athlete, and/or internal, an athlete's perceived and physiological response to training (Gabbett, 2015). Due to the constant stimulus of training it is important to monitor accumulated workloads to prescribe proper training loads for athletes to properly prepare them for what their sport demands. Utilizing Global Positioning System (GPS) technology allows coaches to obtain an objective measure for quantifying external work completed by athletes and the overall training loads of their team. By utilizing these measures, coaches can better prescribe training loads based on an individual's acute to chronic workload ratio (Gabbett, 2015) which takes into account an athlete's fatigue level (acute) and fitness (chronic). By monitoring an athlete's training load, including the load athletes are prepared for from calculating the acute to chronic workload ratio, coaches and practitioners can mitigate the risk of injury (Gabbett, 2015).

An athlete's training can be broken down into three different paths, low training load, high training load, and appropriate training load. When an athlete has a training load that is too low fitness will drop off and they will be underprepared for match demands. Although their general fatigue is low, this under-preparedness not only leads to poor performance outputs, but also an increase in injury risk since their bodies are unaccustomed to the workloads something like a match can demand.

When an athlete's training load is too high their fitness is also high which can lead to better performance, however there is a caveat. By prescribing too much of a training load athletes run the risk of becoming too fatigued and even overtraining. Being

in an overly fatigued state while training or competing not only makes it harder to recover, but also can lead to injury risk especially in higher intensity moments. When athletes need to make quick movements they need to be operating to the best of their ability, otherwise one false step can take them out of a match if they get injured.

Finally, when prescribing appropriate training loads you are in a middle ground between high and low training loads. With appropriate prescription fitness and performance are on a high while also reducing injury risk by managing fatigue.

However, these appropriate workload prescriptions for NCAA division I men's soccer athletes is unknown considering current recommendations are derived from elite rugby players and soccer players (Hulin et al., 2016). Given that much of the information regarding workload management and injury prevention revolves around professional athletes and not collegiate we cannot justify applying these principals strictly to our athletes. Collegiate athletes lead very different lifestyles from their professional counterparts with classes, exams, part-time jobs, and other factors that could possibly affect recovery and adaptation.

This data alone does not give us the full picture with training prescription. Ultimately the coach's interpretation of the data determines the training prescription. The data merely provides a direction to take training. A coach who knows his or her athletes can decide to either go with the data or even do the opposite if they see fit. Through the data it may seem like an athlete is under-training exhibiting low training loads and a low acute to chronic ratio. However, the coach may understand that there are external factors that are impeding this athlete's ability to recover this athlete's "adequate training load"

may be another athlete's "low training load". It is here where the "science of coaching" meets the "art of coaching".

It has been suggested that there are specific times within the season that workloads can yield significant differences (Murray, Gabbett, Townshend, Hulin, & McLellaln, 2017). Often these changes in workload are seen between pre-season and in-season. These changes, or spikes, in workload, if great enough, have been found to yield injuries in the athletes that are subject to them. It is for this reason it is important to utilize workload monitoring means to keep a close eye on athletes as they progress through the season and from year to year. Therefore, the purpose of this study was to utilize GPS technology, coupled with a coach's interpretation and thought process, to determine an appropriate acute to chronic workload ratio among NCAA Division-I men's soccer players within the fall 2016, 2017, and 2018 seasons. This research is significant because it will provide a unique insight into the workloads accumulated by collegiate level men's soccer athletes, as well as how the coach manages those workloads to adequately progress the athletes and mitigate injury.

LITERATURE REVIEW

Collegiate soccer games consist of two teams, eleven players on each competing for a total of 90 minutes, broken up into two 45-minute halves with a 15-minute intermission. If the game remains tied after 90 minutes teams can play up to two 10-minute overtime periods with the game ending if a goal is scored. 20% of all NCAA soccer games entering over time (“Scores – College Men’s Soccer DI”). Teams may substitute players during competition, but an athlete substituted off in the first half may not reenter the game until the second half. Players substituted off in the second half may only reenter once during the second half (“NCAA 2018-19 Division I Manual”).

The sport of soccer is characterized by short sprints, rapid accelerations, decelerations, turning, jumping, kicking, cutting, rotating, and tackling (Bangsbo & Michalsik, 1999). Although aerobic energy production accounts for more than approximately 90% of total energy consumption, anaerobic energy production also plays an essential role during soccer matches (Bangsbo, 1994). During a match athletes will spend a larger amount of time jogging or walking utilizing their aerobic energy system. However, the anaerobic energy system comes into play during their more explosive fast paced movements. Within NCAA Division I Men’s Soccer, athletes have shown to cover up to 8,900-9,900 meters per match while 1,300-1900 meters are performed at speeds greater than a jog (Curtis et al., 2018). Additionally, these athletes average speeds between 87-97 m/min (Curtis et al., 2018). A significant difference has also been shown between the various playing positions during match play supporting training prescriptions being based on the requirements of an athlete’s specific position (Di Salvo et al., 2007).

An athlete's playing position on the pitch can often dictate what training load they will yield. For example a forward will always travel a greater distance than that of a goalie so their training for that position needs to match their demand.

Comparing demands of the sport among various populations competing at different levels are difficult due to differences in physical ability and playing style. The rules and seasons can be structured differently from other governing bodies such as the International Federation of Association Football (FIFA). On average professional soccer athletes compete once per week (Carling et al., 2015) while, Collegiate athletes average 1.67 games per week, but can compete in up to 3 (Curtis et al., 2018). This in turn creates unique and sometimes difficult circumstances for practitioners and coaches.

Not only are there scheduling differences, but the individual lives of collegiate athletes are significantly different from their professional counterparts as they are often confronted with consistent academic demands as well as other external factors. In addition to the 20-hours per week that are spent training and competing, athletes must be enrolled in at least 12 academic credit-hours' worth of classes to maintain eligibility. External factors such as class time, internships, projects, part-time jobs, and studying can occupy as much as an additional 15-30 hours per week of an athlete's schedule (Favero & White, 2018). These factors coupled with the training they are doing as an athlete may yield compromises in sleep, recovery and adaptation (Buboltz, Brown, & Soper, 2001). Therefore, proper periodization and training prescription are a vital piece to athletic development, and success, with recovery and injury mitigating remaining a primary focus.

The demands during a soccer match, in combination with external factors endured by a collegiate athlete, may rapidly increase causing players to fatigue at different times potentially impairs their physical and technical performance at submaximal exercise intensities (Bangsbo, 1994). Fatigue, coupled with high velocity movements, predisposes soccer athletes to musculoskeletal injuries such as muscle strains and ligament sprains due to the high speed running and rapid change of direction. According to the NCAA, more than 55,000 injuries out of 7.1 million athlete exposures occurred in men's soccer from 2004-2009 ("Men's Soccer Injuries - Data from the 2004/05-2008/09 Seasons"). Among these injuries muscle strains were the most prevalent, followed by ligament sprains, accounting for 25.8% and 25.3% of all injuries, respectively ("Men's Soccer Injuries - Data from the 2004/05-2008/09 Seasons"). Furthermore, non-contact injuries accounted for 47% of all injuries (Hawkins & Fuller, 1999). There is a reported trend between a higher number of days lost to injury and lack of team success indicating that injury prevention should be a priority (Arnason et al., 2003). The probability of these injuries can often be predicted and sometimes prevented with the monitoring of training loads for athletes (Ehrmann et al., 2016). Increases in training load, as defined by an arbitrary measurement of training load (i.e. New Body Load) predisposes soccer players to injury (Ehrmann et al., 2016); however, the physical demands can vary considerably across performance levels, populations, and positional roles in soccer (Curtis et al., 2018).

Training load is oftentimes categorized as either internal, which is the physiological or perceptual response to training, or external, which is the physical work done by an athlete (Gabbett, 2015). While internal training load is quantitatively

measured via blood markers, heart rate, or a rating of perceived exertion (RPE), external training load includes variables such as distances covered as monitored by Global Positioning Systems (GPS) technology. It is often argued that the internal load is a superior measurement of training load due to the individuality component between athletes (i.e. comparing an “unfit” athlete versus a “fit” athlete). However, it has been shown that an internal load could be described by physical external load by predicting a player’s RPE from GPS training and match data (Rossi et al., 2017). With this given the lack of training age of the collegiate athlete population RPE may not be a suitable measurement to determine workload.

In order to obtain external load metrics and quantify an athlete’s workload, teams utilize GPS technology which often includes an accelerometer, magnetometer and gyroscope, to monitor their athletes during training and matches. These GPS units also utilize triaxial accelerometers that use the sum of the accelerations in 3 planes (X, Y, and Z) to produce a composite vector magnitude (expressed as G-force). This is used to quantify all the forces acting on an athlete defined as player or body load (Cummins, Orr, O'Connor, & West, 2013). Prior to training and matches athletes will wear a GPS unit in a constructed harness from the manufacturer for a given period of time allowing coaches to track and monitor an entire team simultaneously while other tracking techniques such as video analysis only has the ability to track one athlete’s movements (Aughey, 2010).

The metrics these devices record, including distances at variable speeds, total distance, and duration allow for teams to determine a benchmark to develop and periodize their training to properly prepare their athletes for competition (Curtis et al., 2018). GPS technology allows coaches the opportunity to manage their training to

improve performance and mitigate injury risk. Ehrmann et al. (2016) found a general increase in intensity during training sessions potentially leads to injury supporting the findings of Gabbett (2004) which found a positive relationship between the incidence of training injuries and the intensity, duration, and load of the session. The training load was calculated by utilizing session RPE multiplied by the duration of the session which can be accurately represented from external loads such as GPS variables.

It has been found that greater distances covered in very low ($0-1 \text{ m/s}^2$), low ($1-3 \text{ m/s}^2$), and moderate intensity ($3-5 \text{ m/s}^2$) running were associated with a lower risk of soft tissue injury, such as hamstring strains, while greater amounts of high-intensity running ($5-7 \text{ m/s}^2$) and very high intensity ($>7 \text{ m/s}^2$) were associated with an increased risk of soft-tissue injury (Gabbett & Ullah, 2012). A simple restriction in the amount of sprinting performed in preparation for an elite team sport competition may reduce the risk of soft tissue injury (Gabbett, 2004); however, doing so should be done with caution as training athletes with higher intensities could have a preventive effect on injury. By reducing workloads in an attempt to mitigate the risk of injury, you may have a negative effect on the athlete's fitness, which is a necessary factor to uphold to reduce injury risk as well as workload (Gabbett, 2015).

Results also suggest that low chronic high speed distances, defined in this particular study as distances (m) covered above 20 km/hr, underprepare the players for the risk of high acute workloads, compared to high chronic high speed distances (Bowen, Gross, Gimpel, & Li, 2017). Therefore, it is important to track training load from a short and long-term time frame. This concept is often referred to as the workload-performance model (Hulin et al. 2016).

The acute to chronic ratio looks at the absolute workload performed in 1 week (acute workload) relative to a 4-week average (chronic workload). The time frames of 1 week for acute and 4 weeks for chronic are flexible. Gabbett (2015) proposes that the acute training loads can be as short as one session. 1 week appears to be logical and convenient while the chronic training loads can be represented anywhere from 3-6 weeks (Gabbett et al., 2015). This ratio provides an indication of whether the athlete's recent acute workload is greater, less than, or equal to the workload that the athlete has been prepared for during the previous chronic period (Hulin et al., 2016). This is opposed to the workload-injury model which only investigates workload in relationship to injury and does not divide the workload into acute and chronic (Colby, Dawson, & Heasman, 2014). Chronic training loads are analogous to a state of 'fitness' and acute training loads are analogous to a state of 'fatigue' (Banister, Calvert, Savage, & Bach, 1975). Players who were training with an acute workload (i.e. fatigue) similar to their chronic workload (i.e. fitness) were associated with a smaller risk of injury assuming their chronic workload was high (Hulin et al. 2016).

Hulin et al. (2016) defined workload as absolute total distance (m) covered during all field-training sessions and matches then factoring that into the acute to chronic workload ratio. It has been noted, the acute to chronic ratio can be calculated for any variable deemed relevant to the practitioner (Blanch & Gabbett, 2016). It was found that a high chronic workload combined with moderate, and moderate-high workload ratios had a smaller risk for injury compared to other combinations of workloads (Hulin et al., 2016). Meanwhile the greatest risk for injury that was demonstrated in this study came from when a high chronic workload was combined with a very high acute to chronic

workload ratio (~ 1.5). In summary, this can be defined as the workload-injury paradox. This paradox states that higher chronic workload protects against non-contact injury when acute workload is similar to chronic workload (Hulin et al., 2016).

When looking at training data from different phases of a season (preseason, early-competition, and late-competition), small increases in training load resulted in large increases in injury likelihood (Gabbett, 2010). Players that exceeded the training load threshold were 70 times more likely to yield a non-contact, soft-tissue injury, whereas players that did not exceed the training load threshold were injured 1/10 as often (Gabbett, 2010).

It has been proposed that the appropriate training “sweet spot” for the acute to chronic ratio ranges between 0.8-1.3 while values greater than or equal to 1.5 fall under the “danger zone” of injury risk (Gabbett, 2015). When the acute to chronic ratio is less than 0.8, athletes run the risk of undertraining and increase injury risk as well eliminating the protective effect training has against injury. Excessive and rapid increases in training loads are likely responsible for a large proportion of non-contact, soft tissue injuries (Gabbett, 2015). In a study conducted on elite Australian football players, a very high acute to chronic workload ratio of greater than 2.0 increased the risk of sustaining a non-contact soft-tissue injury in the week the workload was performed (Murray et al., 2017). Greater increases in acute workload relative to chronic workload also resulted in an increase in injury in the subsequent week (Murray et al., 2017).

Gabbett (2015) reported that in order to properly utilize his designed regression model to predict injuries, it is best suited to the population from which it was derived. Different sports will have different training load-to-injury relationships and applying the

recommendations should be done with caution until more data is available (Gabbett, 2015). In comparison, the NCAA competition schedule also has a tendency for a dense and sometimes aggressive layout that could have athletes competing up to three times within a given week. Therefore, the purpose of this study was to utilize GPS technology, coupled with a coach's interpretation and thought process, to determine an appropriate acute to chronic workload ratio among NCAA Division-I men's soccer players within the fall 2016, 2017, and 2018 seasons.

METHODS

Participants

Forty-six NCAA Division I men's soccer athletes were included in this study. Field positional players who were cleared for physical activity by the University's sports medicine department and were on the active roster from the first day of pre-season conditioning during one or more of the fall 2016, 2017, and 2018 season(s) were included. Data was collected on all athletes, regardless of match time, as the primary objective was to monitor distances covered by the individual to establish a training load. This study was approved by the University's Institutional Review board (IRB #: IRB-FY2019-435) on February 28, 2019 (Appendix A.), the athletic department, and the soccer program to utilize secondary data collected by the team's sport coaches. In order to help provide insight into the utilization and application of the GPS data, the sport coach consented to an interview (Appendix B.).

Data Collection

Workload data were collected utilizing a 10-Hz VXSport VX 95 (74mm x 47mm x 17 mm, 50 grams; VXsport, New Zealand) wearable tracking device with a built in GPS. Workload variables consist of total distance and high intensity distance. High intensity was defined as speeds greater than 22 km/hr as determined by athletic coaches and training staff based on the team's needs and abilities. The validity and reliability of distance measurements with 10Hz GPS units is largely positive and displays good intra-unit reliability (Scott et al., 2015). In terms of speed and velocity, 10Hz units have 'good

to moderate' validity for measures of instantaneous velocities during constant running and running involving accelerations regardless of initial velocity while the intra-unit reliability is 'encouraging' during sprinting and team sport simulated movements (Scott et al., 2015).

GPS devices were worn by all athletes during every training session (i.e. on-field practice), match, and extra training session beginning on the first day of pre-season conditioning. Only data recorded by the VXSport unit was utilized for this study. No assumptions were made to missing data based on technical errors, due to the unpredictable nature of soccer training within a given week. Prior to the start of these events, athletes wore a harness created by the manufacturer where it positions the GPS unit directly between the scapulae approximately 3 centimeters from the vertebral border. Prior to training sessions the GPS units were activated by the individual before the start of the warm-up and were not turned off until activity ceased. Prior to matches the GPS units were turned on after the warm-up and turned off after the end of the match (with the exception being players who stayed after for extra conditioning prescribed by coaching staff).

Immediately following each training session and match, data were downloaded and analyzed using VX View software (VXSports, New Zealand). Following the completion of the season, data were retroactively collected from the coaching staff. Certified athletic training staff members at the university classified all injuries. An injury was defined as any non-contact "time-loss" injury obtained during training or competition that resulted in a missed training session or missed game (Rogalski, Dawson, Heasman, & Gabbett, 2013).

In order to determine how the coaching staff determined appropriate workloads and thresholds, two interviews were conducted. The first was a preliminary interview to help develop specific questions pertinent to the training management process. The second interview took place utilizing the questions developed from the initial interview to gain a specific understanding into the thought process and application when applying the workload data observed from the GPS data and acute to chronic workload ratio data.

Data Analysis

Workload data were categorized into weekly blocks from Monday to Sunday. The workloads were then independently used to calculate an acute-to-chronic ratio as previously described by Gabbett (2015) and were separated into pre-season and in-season for comparison. Our acute-to-chronic ratio was calculated by summing the previous seven days' workloads and dividing it by the rolling average (the previous three weeks of the current week being measured as the acute) of the previous three weeks workload (Gabbett et al., 2015).

$$\text{Acute to Chronic Workload Ratio} = \frac{(\Sigma \text{current week's workload})}{(\text{Avg. of the previous 3 weeks' workload})}$$

The time frames chosen for the acute (1 week) and chronic (3 weeks) variables were determined by the unique nature, as specified previously with season structure and athlete lifestyle, of the NCAA men's soccer season. The time frames, as stated by Gabbett (2015), can be flexible to be more specific to the population. Given the compressed nature of their season anything longer or shorter than the given time frame may not be an accurate representation of the fatigue and fitness relationship as proposed by Banister et al. (1975).

Statistical Analysis

Differences in total distance and distance at high intensity between pre-season and in-season across the 2017 and 2018 seasons were determined using a paired samples t-test. 2016 was excluded due to a lack of pre-season data. Two separate 3x3 [Workload (acute, chronic, acute-chronic ratio) x Season (2016, 2017, 2018)] repeated measures ANOVA was conducted to assess the differences for total distance and distance at high-intensity. If significant main effects were found, simple effects were determined using a Bonferroni post-hoc adjustment. Sphericity was determined using Mauchly's test of sphericity with a Greenhouse-Geisser correction implemented if it was not assumed. All analyses were conducted using JASP computer software (V0.92, Amsterdam, The Netherlands) with significance set at $p < 0.05$. Qualitative data collected from the interviews with the coaching staff were analyzed by transcribing the data and examining themes related to the workload progression and modification.

RESULTS

Quantitative Results

The paired samples t-test revealed there was no significant difference ($p>0.05$) for distance at high intensity between pre-season and in-season; however, total distance was significantly greater ($p=0.03$) in the pre-season (M: 28606.1 m, SD: 1051.1 m) than in-season (M: 26259.1 m, SD: 943.1 m) (Table 1). A significant main effect was seen for acute high-intensity distance ($F(2,16) = 15.62, p < 0.001, \eta^2 = 0.66$) with subsequent post-hoc measures finding significant differences ($t(8) = 6.99, p < 0.01, d = 2.33$) between the 2017-2018 seasons (Table 2). Similarly, a significant main effect for chronic high intensity distance ($F(2,16) = 12.77, p < 0.001, \eta^2 = 0.62$) was found while post-hoc analysis found significant differences ($t(8) = 6.99, p < 0.01, d = 2.33$) between the 2017-2018 (Table 3). The repeated measures ANOVA showed there were no significant differences ($p>0.05$) seen for acute-to-chronic high intensity workload ratio (Table 4), acute total distance (Table 5), chronic total distance (Table 6), and acute-to-chronic total distance workload ratio (Table 7).

Qualitative Results

Upon conducting an interview with the coaching staff the conversation was broken down into four separate scenarios: Injured Athlete, Freshman/Transfer/Non-Starter, Returner/Non-Starter, and Returner/Starter. These four specific scenarios provided the groundwork into the thought process of applying the GPS data and the acute to chronic workload ratio to training load management through the coach's lens.

When observing the Injured Athlete, we are assuming the athlete had a significant time off from play. The return to play protocol would be administered by athletic training staff and when it was deemed appropriate the athlete would return to the field, but under restricted conditions. The goal from the start would be a gradual return to high-intensity through low intensity controlled environment running (no interference from other players or in game scenarios). The idea being is to slowly rebuild the athlete's capacity for running. As the athlete grows closer to full return to play high-intensity running is slowly introduced, however still in a controlled environment. Upon showing competency for high-intensity, the athlete will then be put into more stressful situations, such as small sided games, being closely monitored and to their tolerance. As the athlete progresses, they will then be utilized as a substitute or potentially start as a passive defender, or a position that does not have high stress situations that could exacerbate the issue. Finally, moving forward as the athlete begins to show full potential the athlete will be utilized as they were previous to the injury, but will play conservatively and monitored closely. During this time the athletes GPS data as well as acute to chronic ratio data is kept in check by coaching staff. The ratio for this athlete would be monitored closely to ensure it does not reach the higher levels of Gabbett's recommended range.

When observing the Freshman/Transfer/Non-Starter, it is important to note the coaching staff has little to no information on the capabilities or capacity of this athlete like that of returners. It is for this reason it is important to develop a baseline for them. This can be done through scenarios such as fitness tests or put them into sport specific training environments and see what they do to their own tolerance while monitoring GPS data. Once a baseline has been established you begin to gradually build them up staying

within their capacity levels based on how they performed previously with the baseline. Extra fitness may be utilized to help meet the standards of the team or demands of the position for specific individual. For this athlete the ratio may push the higher boundaries assuming they are not starting and have the capacity to train at higher intensities.

The Returner/Non-Starter scenario is similar, however we have information from previous seasons. Given the prior information we already have a good idea of what they are capable of and we can use this information to guide training along with preliminary baseline fitness tests. Due to the lack of playing time the focus of the season will be training focused. This allows the athlete to build on performance levels and be utilized in practice scenarios, this in turn could cause high-intensity distance and ratio data to be higher than others. Although training is the focus it is important to note this athlete needs to be prepared to play if necessary. This athlete would in turn yield similar ratio numbers as the Freshman/Transfer/Non-Starter.

Finally, for the Returner/Starter, the previous information again provides us with a baseline along with preliminary fitness tests as to where to take training. The reactions for these athletes are more day-to-day and are kept at a closer to maintenance level to make sure they are prepared for upcoming games. These athletes are, however, still building gradually throughout the season. How you handle the Returner/Starter can be goal dependent for the season as well. For example if you are focused on in-season matches you may hardly build them and focus primarily on readiness from game to game. Where on the other hand if your goal is to win the conference tournament you may use the season to build into the tournament. This in turn would yield a ratio closer to 1.0 for the maintenance approach, and slightly higher if building.

LIMITATIONS

Due to the nature of NCAA collegiate soccer eligibility rules, the roster was subject to change each year. While the sample size across all three seasons included 46 participants, only 8-9 participants (variable dependent) were present for two consecutive years and could be used to in the repeated measures ANOVA. Between the fall 2017 and 2018 seasons the “high-intensity” threshold was also changed from 17 km/hr to 22 km/hr determined by the coaching staff. This potentially could have inflated the significance when comparing high-intensity distance from 2017 and 2018. Also, this could have skewed results when comparing pre-season versus in-season. This study could also not account for technical errors that may have occurred with or to the GPS unit during training sessions and matches. When this study was first proposed, injury risk was going to be calculated from information gathered from athletic training staff. Upon gathering this information there were only a total of 7 non-contact time-loss injuries. In the 2016 fall season 3 injuries occurred, with 3 injuries occurring in 2017, and only 1 injury occurring in 2018. Due to the lack of injuries, this risk could not be calculated.

DISCUSSION

The purpose of this study was to utilize GPS technology, coupled with a coach's interpretation and thought process, to determine an appropriate acute to chronic workload ratio among NCAA Division-I men's soccer players within the fall 2016, 2017, and 2018 seasons. Results indicate NCAA Division-I men's soccer players cover more total distance, regardless of intensity, during the pre-season versus in-season. Similar results were found in studies that included total distance comparisons with pre-season to in-season (Murray et al., 2017). Given the nature of the typical NCAA collegiate soccer pre-season, this was not unexpected due to the nature of a collegiate soccer schedule with practice and games. It is important to mention that in fall 2018 pre-season, the average amount of games played per week was 1.5 (3 games in 2 weeks) and the in-season average was 1.4 games per week (17 games in 12 weeks). While in 2017 the pre-season average was also 1.5 (3 games in 2 weeks), but the in-season average was 1.5 games per week (17 games in 11 weeks). This is important, because we may not be able to place the majority of cause on the game schedule.

When observing the results of the repeated measures ANOVA it is also thought that high-intensity distance was impacted by the change in threshold, more specifically in acute and chronic. From 2017 and 2018, there was a decrease of 1,424 meters and 1,498 meters in acute high-intensity distance and chronic high-intensity distance, respectively. With this, there was an inverse relationship between the changes of high-intensity distance and total distance. This could be explained by the change in the speed threshold (22 km/hr) in 2018. This change in threshold could have been the cause of the drop in

high-intensity distance from 2017 to 2018. When, if it would have remained the same, it may have more closely resembled the trend of total distance (Tables 2, 3, 5, and 6).

However, we can still get a good idea of how their workloads were changing within each season by looking at the variable of the acute to chronic workload ratio. Since the workload ratio is a measure in what the athlete is prepared for based on what they have been done versus what they are doing and not an absolute workload measurement, this gives us an accurate representation as to if there were any spikes in workload. Originally the purpose of this study was to create our own ratio range, as dictated by Gabbett (2015) for NCAA men's soccer athletes; however, from 2016-2018, only 7 non-contact time loss injuries occurred eliminating the ability to determine injury risk.

However, the mean ratio for each year stayed with Gabbett's recommended range of 0.8-1.3, meaning the athletes were either improving or maintaining their volume of work from week to week. This is important because the ratio of work being done by these athletes was never truly excessive and was kept at a deemed adequate range which has been proven in previous studies to mitigate the risk of injury.

Analyzing total distance across all three seasons can provide an idea of how the volume of work has changed for these athletes. Although there were no significant differences found, the change in acute workload for total distance between 2017 (25,876 meters) and 2018 (33,350 meters) increased by 28.9%. Although this was not deemed significant, it is still important to note due to the increase in total workload. This tells us that the team in 2018 compared to 2017 is doing almost a third more of the workload than

they did in 2017. Granted this variable is total distance and can include several speeds of locomotion, some not being as physiologically demanding.

With the data presented in this study along with the results of the interview, it is important to mention this information does not provide an exact decision making process for coaching staffs or a true injury prediction method. However, based on the data recorded from GPS technology in conjunction with the calculated acute to chronic workload ratios, this study simply acts as a guide for coaches to determine an appropriate training load prescription. Moving forward it is recommended that further GPS and workload ratio data be collected along with injury data to observe fluctuations in training load as well as potential risk for injury if sufficient data is collected.

TABLES

Table 1. Pre-Season vs. In-Season Acute Total Distance

Period	N	Min (m)	Max (m)	Mean (m)	Std. Dev
Pre-Season	35	16916.0	39499.0	28606.1	6218.6
In-Season	36	13360.1	35900.0	26529.1	5658.7

Table 2. Acute High-Intensity Distance (m)

Year	N	Mean	SD	<i>p</i>
2016	9	1594.1	560.0	0.145
2017	9	2339.4	692.3	0.051
2018	9	915.2	197.3	<0.001*

*Significant differences between 2017-2018

Table 3. Chronic High-Intensity Distance (m)

Year	N	Mean	SD	<i>p</i>
2016	9	1571.8	696.4	.229
2017	9	2349.3	740.0	0.082
2018	9	851.3	196.0	<0.001*

*Significant differences between 2017-2018

Table 4. Acute to Chronic Workload Ratio High-Intensity Distance

Year	N	Mean	SD
2016	8	1.151	0.146
2017	8	1.114	0.414
2018	8	0.996	0.048

Table 5. Acute Total Distance (m)

Year	N	Mean	SD
2016	9	31774	12708
2017	9	25876	3787
2018	9	33350	1554

Table 6. Chronic Total Distance (m)

Year	N	Mean	SD
2016	9	29354	13901
2017	9	24137	3868
2018	9	33576	1640

Table 7. Acute to Chronic Workload Ratio Total Distance

Year	N	Mean	SD
2016	9	1.089	0.226
2017	9	1.097	0.301
2018	9	0.974	0.016

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APPENDICES

Appendix A. Human Subjects IRB Approval

Date: 5-20-2019

IRB #: IRB-FY2019-435

Title: Training Load Management and Injury Prevention in Collegiate Men's Soccer

Creation Date: 1-18-2019

End Date:

Status: **Approved**

Principal Investigator: Jacob Gdovin

Review Board: MSU

Sponsor:

Study History

Submission Type	Initial	Review Type	Expedited	Decision	Approved
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Key Study Contacts

Member	Jacob Gdovin	Role	Principal Investigator	Contact	jacobgdovin@missouristate.edu
Member	Lorenzo Tomasiello	Role	Primary Contact	Contact	tomasiello729@live.missouristate.edu

Appendix B. Interview Consent Form

Consent to Participate in a Research Study

Missouri State University College of Health and Human Services

Study Title: Training Load Management and Injury Prevention in Collegiate Men's Soccer

Primary Investigator

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Purpose of this study:

The purpose of this study is to retroactively analyze GPS data, injury data, and coaches' interpretations to determine an appropriate acute to chronic workload ratio range for NCAA Division I collegiate men's soccer players.

What you will be asked to do for this study:

1. Supply the GPS and injury data for the Missouri State University men's soccer team from the previous three seasons (fall 2016-2018). This will require approximately ten minutes of your time to allow the lead researcher access to the data.
2. Participate in a two part interview to determine your decision making process when observing the GPS and acute to chronic ratio data. The preliminary interview will take approximately one hour and be used to create a decision tree on training workloads so formal questions can later be developed for the final interview.
3. The final interview will take approximately one hour and will provide a definite understanding of how coaches manage workloads in collegiate men's soccer players.

Videotaping / Audiotaping:

Interviews will be audio-recorded to transcribe all conversations. Upon completion of the transcription, the original audio recording will be deleted from the device by the lead researcher.

Time required for this study:

This study will take approximately 2 hours and 10 minutes in total.

Possible risks from participation:

No adherent risks from participating in this study.

Benefits from your participation:

Although there will be no benefit to you personally for participating in this study, you will gain insight into what training loads collegiate male soccer athletes can withstand while actively reducing the potential risk for injury. Also, gain a better understanding to the decision making process when observing the GPS and acute to chronic ratio data.

Confidentiality:

Any information obtained from or for this research study will be kept as confidential (private) as possible. The records identifying your name will be (1) stored in a locked cabinet and/or in a password-protected computer file, (2) kept separate from the rest of the research records, and (3) be accessible to only the researchers listed on the first page of this form and their staff. Identity on the research records will be indicated by a case number rather than by name. Data may be used for educational conferences or published in scientific journals; however, specific names will not be used.

Confidentiality and Use of Video/Audio Tapes:

Interviews will be audio-recorded and kept confidential under the password protected computer of the lead researcher. Upon completion of the transcription, the original audio recording will be deleted from the device by the lead researcher.

Right to Withdraw:

You are not required to participate in this study. If you decide to participate, but later change your mind, you can withdraw at any time. There are no penalties or consequences of any kind if you decide to withdraw. Your participation in this study may be terminated at any time by the investigators if they believe that it is in your best interest to do so or if you fail to follow the study procedures.

Compensation for Illness OR Injury:

There are no adherent injury/illness risks from participation in this study.

IRB Approval

This study has been reviewed by Missouri State University's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by state and federal law and University policies. If you have any questions or concerns regarding your rights as a research participant, please contact the IRB at 417-836-5972 or researchadministration@missouristate.edu

Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, then decide if you want your child to be in the study or not.

Statement of Consent

I have read the above information. I have been given an unsigned copy of this form. I have had an opportunity to ask questions, and I have received answers. I give my consent to participate in the study.

Furthermore, I also affirm that the experimenter explained the study to me and told me about the study's risks as well as my right to refuse to participate and to withdraw.

Signature of Participant: _____ Date: _____

Printed Name of Participant: _____

Signature of Investigator: _____ Date: _____