Exploring Vertical Jump Height During a Congested Calendar Period in Women's Collegiate Soccer

Courtney S. Adams

Major Project/Report submitted to the faculty of Virginia Polytechnic Institute and State University in fulfillment of the requirement for the degree of

Online Masters of Agricultural and Life Science

In

Applied Nutrition and Physical Activity

Agricultural and Life Sciences, Virginia Polytechnic and State University

Dr. Jay Williams, Dr. Angela Anderson, Dr. David Tegarden

May 10, 2023

ACKNOWLEDGEMENTS

I cannot possibly thank the enormous number of people who helped make this research project possible on one page. Dr. Jay Williams thank you so much for your guidance throughout this entire process. I have been so fortunate to have you as a mentor and to have had the opportunity to learn from you. This project and report would not have happened without you! Thank you to my committee members for taking a chance on me and this project, as well as for your help with this study. To my family and loved ones, thank you so much for being willing to always proofread my work at any hour of the day. Megan Albritton, thank you so much for guiding me through the ever-daunting task of deciding to begin working on research and for being my early-morning research-with-coffee buddy. Virginia Tech Women's Soccer, thank you for your dedication to your sport which made this research possible and for your willingness to be involved in this study!

ABSTRACT

This study aimed to explore how vertical jump height, as a measure of fatigue, was affected throughout the pre-season training period in women's division I collegiate soccer. The participants of this study completed three consecutive countermovement jumps with the hands placed on the hips before and after each day of training, throughout a five-day pre-season training period. Participants were placed into one of three groups based on the total minutes of match play each athlete experienced (>60 minutes, 30-60 minutes or <30 minutes). Athletes in the >60 minutes group experienced a larger reduction in vertical jump height than those in the other two groups. The type of training each group participated in following matches one and two was dependent upon the number of match play minutes, as the high minute group participated in a recovery-based training session following each match played. The effects of these group-specific training plans were reflective in the vertical jump heights as there was an increase in jump height for the >60 minutes group and a decrease in height for the 30-60 minutes and the <30 minutes groups. Vertical countermovement jump height was shown to reflect the fatigue experienced by division I collegiate women's soccer players throughout a pre-season training time-period, as reductions in jump height were found amongst high-minute athletes following match play and amongst low-minute athletes following more demanding training sessions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

As concerns for athlete health and well-being are on the rise, the sports performance world is also experiencing an uptick in the amount of data and technology becoming available to coaches daily. Improvements in sports science technology have included technology which monitors running speed, absolute strength, and change of direction abilities. One additional measure of particular interest is the ability to monitor the vertical countermovement jump, as it can provide further insight into athlete fatigue levels (Claudino et al, 2017). While countermovement jump measures have been widely utilized by a variety of team sports programs throughout all training seasons, the time period known as pre-season is of particular importance as athletes experience sharp upticks in the physical demands placed on their bodies (Kennedy et al., 2017). Due to this increase in training load, the risk for increased levels of fatigue and chances of overtraining are also increased. College players also often encounter periods of a "congested calendar" during the season, described as playing multiple matches within a seven-day period (Lago-Peñas et al., 2011). Page and colleagues note several studies showing increased physical demands as well as elevated injury risk during this part of the competitive season (2022). Given this, the need for special attention to be paid to these aspects of the competitive season. In particular, methods to monitor athlete fatigue and training readiness could have the staff better adjust training loads to reduce the physical demands of between successive match days.

This project aimed to examine fatigue throughout a congested calendar in women's collegiate soccer. Previously published literature established the vertical countermovement jump to be a reliable method to measure fatigue (Claudino et al., 2017); however, few studies have utilized this method throughout the pre-season training period. Furthermore, there is a lack of research surrounding congested calendar periods and fatigue within the ever-growing division I women's soccer industry. The final goal of this project was to shed light on fatigue during a congested calendar period in order to help coaches and sports medicine better serve their athletes and promote athlete health and well-being.

Hypotheses

1. Immediately following a competitive match, vertical jump performance will be reduced in players participating in the highest number of minutes.
2. In the days following a competitive soccer match, vertical jump performance will remain reduced in those players participating in the most minutes.

LITERATURE REVIEW

Introduction

Athlete health, readiness, and fatigue have become popular topics of discussion throughout much of the sports performance world. As the incorporation of various technologies has become commonplace, these matters have become particularly popular in the collegiate soccer world. Throughout a soccer training year, the athlete undergoes many varying intensities and types of physical demands. Harsh increases in demand on an athlete's body can result in fatigue and has the potential to impair athlete functioning and performance for several days (Thorpe et al., 2015). Such fatigue has been categorized into "perceived fatigue" and "performance fatigue," the latter of which can also be described as neuromuscular fatigue (Ellis et al., 2022; Enoka & Duchateau, 2016). A decrease in the contractile functioning and activation of the muscle results when neuromuscular fatigue is experienced. Alarmingly enough, fatigue related to the stretch-shortening cycle has been established as reflective in immediate neuromuscular functioning decreases, with recovery windows four to eight days later (Gathercole et al., 2015). Despite this, there are currently few tools available that allow coaches to regularly assess fatigue in large groups of athletes. Such a tool would provide opportunities for regular fatigue, recovery, and readiness to train assessments.

Previous studies have explored this notion of fatigue within various team sports, including elite soccer and rugby; however, few have centered their focus on division I women's collegiate soccer. There is also a lack of research which narrows in on fatigue throughout congested calendar periods, typical of pre-season training and what types of movement demands are placed on the athlete. A study examining training load measures, countermovement jump variables, and dose-response relationships was conducted (Ellis et al., 2022). While researchers focused on the pre-season training period, they found that countermovement jump height was generally preserved throughout pre-season, with the largest reduction occurring three days prior to the day of a match. Thorpe and colleagues conducted research in which fatigue throughout the competitive in-season time period of elite soccer players was monitored (2015). Interestingly, researchers found significant correlations between countermovement jump height and total high-intensity running distance, suggesting a possible post-activation potentiation effect, resulting from increased total high-intensity running distance. While this study was centered around countermovement jump height and fatigue, it failed to assess the time-period known as pre-season, which is comparable to congested calendar periods. Moreover, while the Thorpe et al. study did utilize multiple methods of measuring fatigue, they failed to find strong variations in countermovement jump height. In another study conducted by Thorpe et al., a myriad of tools were used to measure the effects of acute training load changes on fatigue in elite soccer players (2017). Researchers concluded that perceived ratings of fatigue and submaximal heart rate were significantly sensitive to these total high-speed running distance fluctuations. While countermovement jump was evaluated, a jump mat was utilized to acquire the data and the countermovement jumps were only conducted pre-training, not post-training.

Demands of Soccer

Without question, soccer is physically a high demand sport. Previous research indicates that players may cover more than 10km during a 90 min match (Sausman et al., 2019; Vescovi et al, 2021; Vescovi, 2014; Williams et al., 2020). For example, Williams and colleagues found that female collegiate players covered approximately 9.5 km for total distance, with nearly 2km of that being considered high intensity (2020). Furthermore, energy expenditure averaged nearly 50 kJ/kg (or about 850 kcal) per match with heart rates averaging around 165 bpm or ~83% of maximal heart rate. As such, physical performance may not recover in time for the next match play. It is important to note that both high speed distance and total distance covered during a match can vary considerably based on numerous factors including competitive level, player position, and strength of the opponent (Vescovi, 2014).

Recovery following a competitive collegiate soccer match can span several days. Goulart and colleagues reviewed multiple studies documenting recovery of performance, physiological, and perceptual parameters (2022). They found physical performance was mostly recovered within 72 hours of match play. However, plasma markers of muscle damage and inflammation remained elevated at this time point. Additionally, perception of muscle soreness, fatigue, and vigor were depressed 24 hours post-match. McCormack found that when matches are separated by 42 hours (Friday night – Sunday afternoon matches), high speed running distances and high-intensity efforts were reduced in the second match, compared to the first. Additionally, Snyder and colleagues focused on vertical jump recovery following collegiate matches (2019). Researchers found jump height and knee extension and flexion strength to be reduced 12 hours post-match.

Based on the above, collegiate soccer matches clearly represent significant physical demands. In addition, it requires several days for players to recover from a match physically and mentally. Thus, coaches and sports medicine professionals must consider these variables when designing training sessions to meet the needs of individual athletes.

Congested Calendar

In 2010, Carling et al. compared injury incidence in matches played with few recovery days and those separated by longer recovery. They found that the sorter rest period resulted in a greater number of injuries, particularly muscle strains. Researchers suggested that a congested calendar, defined as multiple matches played within a week, increases the risk of injury. Since then, multiple studies have shown that limiting the time between consecutive matches impact physical performance as well as technical abilities (Lago-Peñas et al., 2011; Dellal et al., 2015; Djaoui et al., 2022). In collegiate players, McCormack et al. found that physical performance was reduced in matches following a 42-hour recovery period compared to longer between-match interval (2015). These studies suggest there is a need to monitor and evaluate fatigue in players during these short match intervals. Unfortunately, there is no data available which describes the degree of short-term (i.e. immediately post-match) or long-term (i.e. days after a match) during a congested calendar.

Due to the structure of the competitive in-season time-period for soccer, players must often compete in matches on a weekly and biweekly basis (Thorpe et al., 2015). In order to prepare for athletic demands as such, the time period prior to the competitive season, known as pre-season, takes place (Favero & White, 2018; Pinasco & Carson, 2005). This shorter training season occurs after the athletes have been away from their coaches and have been training on their own. Not only are the athletes adjusting to new climates and new expectations, but this period is oftentimes characterized by a sharp increase in the amount of physical demand placed upon the athlete. Furthermore, this shorter training season typically has a combination of practice, conditioning and/or weight training sessions in one day, resulting in high intraday stress loads. These characteristics of the pre-season training time-period have the potential to result in dramatic increases in athlete fatigue (Favero & White, 2018).

Pre-season training mimics a congested calendar period during the season, there are times when NCAA women’s soccer teams play two matches per week. Typically one match is played on Thursday evening and a second on Sunday afternoon. Often, these matches are separated by a travel day. NCAA rules allow for nearly unlimited substitutions during a match, meaning that players could participate in up to a full 90-minute match or relatively few minutes. In order to ensure athlete health and well-being, this risk for high variations in fatigue calls for a means necessary to measure, monitor, and understand the level of fatigue experienced by each player. Such will allow coaching staffs to construct training sessions designed to meet each player’s needs. Implementation of this could look like a recovery session for those who played more minutes or a more demanding training period for those who saw limited or no playing time.

Use of Vertical Jump

There are many types of jumps which both researchers and coaches have utilized as tool to monitor various athlete metrics, including the vertical countermovement jump. It has been established that countermovement jump (CMJ) height is a suitable method to measure neuromuscular fatigue (Thorpe et al., 2017). Typically, countermovement jump height is measured using ground reactive force methods or flight-time methods (Ellis et al., 2022). Due to the cost efficacy and administration ease, many studies have been conducted using the flight-time method, most of which suggest a time-period of increased neuromuscular fatigue beginning after match-play, lasting up to 72 hours (Ellis et al., 2022). Gathercole and colleagues conducted a study in which the reliability of countermovement-jump analyses as measures of fatigue were assessed (2015). Through the participation and examination of eleven male collegiate team-sport athletes, researchers were able to conclude that countermovement jump testing is a practical method for monitoring neuromuscular fatigue in athletes. Furthermore, researchers established that the reliability of the countermovement jump with intraday and interday testing is also high.

Rantalainen and colleagues conducted a series of studies using wearable technology to measure vertical jump performance (2018a; 2018b; Spangler et al, 2018). Researchers compared the reliability and validity of hip- and torso-worn accelerometers and found very high day-to-day repeatability. In addition, accelerometer-derived jump heights were consistent compared to other devices such as a jump mat, force plate, and video analysis. It was concluded that wearable inertial measurement unit (IMU) devices can be used to confidently assess performance.

Recently, Hines conducted an extensive study of the reliability and applicability of using trunk-mounted accelerometers to measure vertical jump performance (2021). In this study conducted on collegiate female soccer players, accelerometer data obtained from a STATSports APEX GPS-imbedded IMU was used to measure vertical jump height (identical to the devices used in the present study). The results showed that measurements were very consistent across jumps performed within and across multiple days. When used across a week of training, changes in jump height mirrored the volume and intensity of the training session. This suggests that this device can be reliably used to assess physical performance in large groups of athletes, on regular basis.

Conclusion

There is much discussion surrounding how to best monitor training loads and fatigue within the collegiate and professional sports industries. Increased training load and duration paired with increased potential for injury, demand that athlete health and readiness be a central focus throughout congested calendar training periods. The goal of this study is to explore the relationship between division 1 women's soccer congested calendar training and fatigue via vertical countermovement jump height.

Purpose and Objectives

It is known that fatigue happens as a result of the demands in collegiate soccer. Studies have found that injury occurrences tend to be higher during the pre-season training time-period due to the sharp increase in physical demands placed upon the athlete (Kennedy & Drake, 2017). While we are aware that fatigue and injury are linked, what we do not know are the specific variables throughout the soccer congested calendar training season which contribute the most to fatigue. Results gathered from this study can be used to further educate coaches and sports medicine professionals and enhance the safety of division I collegiate soccer players.

METHODS

Participants consisted of 31 female, division I, collegiate soccer players. Participants performed three vertical jumps with the hands on the hips before and after three training sessions and two match days within a five-day congested calendar training time-period. On match days all players dressed, participated in the warm-up, and were available to participate in matches; however, only 15-16 of the participants played in the matches. Participants were placed into one of three groups based on their playing time throughout the matches (>60 min, 30-60 min, and <30 min). Training days 1 and 3 were utilized as recovery sessions for the participants who partook in 60 minutes or more of match play. Recovery sessions consisted of participating in the warm-up, followed by light stretching, and jogging. Those who played in fewer than 60 minutes of the match participated in reserve training, consisting of a standard practice session, characterized by technical training and small sided scrimmages. Training day 2 consisted of a pre-match day in which everyone participated in a lighter session, composed of technical and tactical (i.e. set pieces) training and walk-through drills.

The 3-jump protocol was followed for all vertical jumps. All participants wore a STATSports APEX unit (18Hz GPS, 952Hz tri-axial accelerometer, 10Hz magnetometer, 952 Hz tri-axial gyroscope), located on between the scapulae at the T2 level, through the use of a manufacturer provided vest. Following a standard warm-up, the participants completed three, maximal effort, countermovement vertical jumps with the hands placed on the hips. Each jump was performed to a depth that was self-selected. Participants were asked to stand motionless and upright for several seconds leading up to the first jump and following the third jump.

Vertical jump measures were calculated as described by Hines (2021). Raw data was downloaded from the Apex unit and raw countermovement jump accelerometer and gyroscope data were exported to .csv files through the use of the STATSport APEX software at the conclusion of the training day. A sampling frequency of 100 Hz was utilized through the APEX software for presenting raw data. In order to improve the data resolution, data from the accelerometer and the gyroscope were up sampled to 1000 Hz. A complementary Kalman filter was then utilized in order to fuse the data and to correct unit orientation from a local to a global reference frame. Noise was removed through filtering the tri-axial data at 40 Hz. Trapezoidal integration of the accelerometer and gyroscope signals were used to compute movement velocities and trunk angles. Take off time (TOT) and touchdown time (TDT) were determined as the times of maximal positive and negative vertical velocities for each CMJ. Adjustment of the timescale was then completed to make the TOT equal zero. The difference between TDT and TOT was used to calculate flight time (FT), which was then used to calculate CMJ height (CMJH). CMJH was calculated through the following equation, $CMJH = 1/8 * g * FT^2$ where g equals gravitational acceleration.

The maximal jump height of each three-jump series was recorded. Post-session jump height minus pre-session jump height was used to calculate pre-post change. Minutes played by each participant was determined using the published box scores.

Differences in specific variables between days were determined using repeated measures ANOVA with a Tukey follow-up, when indicated. Relationships between variables were determined using Pearson-Product Moment correlations.

RESULTS

Table 1 shows the difference in minutes played between the three groups of players. The majority of the players fell into the <30 minutes of match play group (n = 19), while the fewest number of players were in the 30-60 minutes group (n = 3). The highest playing load group, >60 minutes of match play, consisted of 9 participants (n = 9).

Table 1. Minutes played in the matches by the three groups of players.

	>60 min	**30-60 min**	**<30 min**
n	9	3	19
Min Played	73.78 ± 0.82	38.17 ± 2.17	6.51 ± 0.29

Values are means ± SEM.

Table 2 shows the changes in vertical jump height during the two matches. >60 minutes players experienced a greater reduction in height from pre-match to post-match than the other two groups (match 1 = -14.50 ± 1.42; match 2 = -11.89 ± 1.32). The change in height of the 30-60 minutes group (match 1 = -8.22 ± 2.06; match 2 = -6.36 ± 3.24) was approximately 60% of that seen in the >60 minutes group. The <30 minutes group showed very little change in jump height following the match (match 1 = -1.17 ± 1.01; match 2 = 1.63 ± 0.87).

Table 2. Changes in pre-post vertical jump height during the two matches.

Match	**>60 min**	**30-60 min**	**<30 min**
Match 1	-14.50 ± 1.42	-8.22 ± 2.06	-1.17 ± 1.01
Match 2	-11.89 ± 1.32	-6.36 ± 3.24	1.63 ± 0.87

Values are means ± SEM and expressed as a percentage.

Figure 1 shows the relationship between the number of minutes played during each match and the change in VJ performance. As can be seen, post-match jump height tended to decline as the athletes playing time increased. The correlation coefficient for this relationship was r = -0.85.

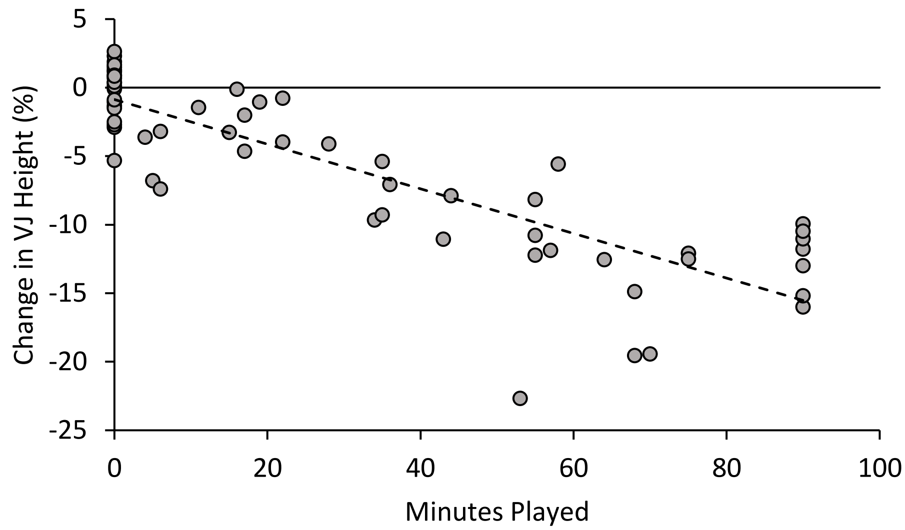

Figure 1. The relationship between the change in vertical jump height (expressed as a % of pre-match) and the number of minutes played in each match.

Changes in jump height during the training sessions are shown in Table 3. For Training 1 and 3, recovery days, the >60 minutes group showed little change (training 1 = 0.87 ± 0.34; training 3 = -0.92 ±0.55). Whereas the other two groups saw 5-6% reductions (training 1 = -5.82 ± 1.04 and -5.03 ± 0.42; training 3 = -6.31 ± 0.46 and -5.37 ± 0.21). This reflects the light, recovery day encountered by the group playing the most minutes the previous night. The two groups that underwent reserve training, experienced more work throughout training and, hence, a larger reduction in jump height. Thus the goal of Training days 1 and 3 was accomplished, allowing the >60 minutes group to recover from the previous night's match while providing the lower minute groups a noticeable training stimulus.

Table 3. Changes in pre-post vertical jump height during the three training sessions post-match.

Training	>60 min	30-60 min	<30 min
Training 1	0.87 ± 0.34	-5.82 ± 1.04	-5.03 ± 0.42
Training 2	-2.89 ± 0.32	-0.72 ± 0.42	0.31 ± 0.29
Training 3	-0.92 ±0.55	-6.31 ± 0.46	-5.37 ± 0.21

Values are means ± SEM and expressed as a percentage.

Figure 2 shows changes in vertical jump height across all sessions and groups. Jump height was for the > 60 minutes group was greatly reduced following both Matches 1 and 2, has smaller reductions following the recovery training sessions and returned near baseline following the pre-match practice. The 30-60 minutes and the <30 minutes group experienced a large reduction in vertical jump height following the recovery training session, in which they participated in reserve training.

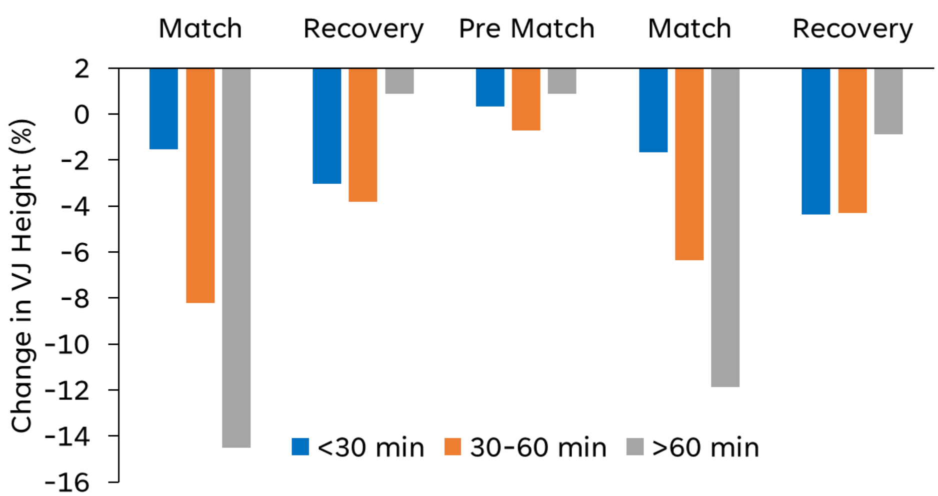

Figure 2. Changes in vertical jump height across sessions.

Table 4 shows the pre-training vertical jump heights in the three groups, across all sessions. For the >60 minutes group, jump heights were reduced the day following Match 1 (25.71 ± 1.13). It remained depressed on Training day 1, then returned to near normal the following training day (28.69 ± 1.50). By Match 2, it appears that pre-session jump height is fully recovered (31.62 ± 1.79). For the other two groups, pre-session jump heights are not noticeably reduced across the training days.

Table 4. Pre session vertical jump heights for each day.

Session	**>60 min**	**30-60 min**	**<30 min**
Match 1	31.21 ± 1.50	30.41 ± 1.62	28.84 ± 1.01
Training 1	25.71 ± 1.13	29.29 ± 1.89	28.78 ± 0.99
Training 2	28.69 ± 1.50	29.03 ± 2.02	27.71 ± 0.99
Match 2	31.62 ± 1.79	31.22 ± 3.41	28.42 ± 1.00
Training 3	24.83 ± 1.40	29.65 ± 3.03	28.18 ± 0.94

Values are means ± SEM and expressed in cm.

DISCUSSION

The goal of this study was to explore the relationship during congested calendar periods between soccer training and fatigue, utilizing the vertical countermovement jump as a marker of fatigue. The majority of participants experienced less than 30 minutes of match-time and experienced the smallest reduction in vertical jump height following both matches. The >60 minutes group however, experienced the greatest decrease in vertical jump height post-matches 1 and 2. Training goals were reflective in vertical jump height, as on training days 1 and 3 the >60 minutes group experienced very small decreases in vertical jump height, while the 30-60 minutes group and the <30 minutes group experienced large reductions in vertical jump height. Additionally, overall fluctuations in vertical jump height were experienced in the >60 minutes group, as jump height was reduced on the day following match 1, increased close to normal levels following training day 2, returned to normal levels on the day of match 2, then decreased again following match 2.

A reduction in countermovement jump height was seen following both matches. The greatest reduction in jump height, 12-15%, was found in the >60 minutes group, while those who experienced less match play, such as the 30-60 minutes group, saw a smaller reduction in jump height, 6-8%. This larger reduction in countermovement jump height amongst high-minute players agrees with many studies but not all, such as a study conducted by Thorpe and colleagues (2015). While small, these researchers noted a positive correlation between countermovement jump height and total high-intensity running distance.

The recovery of countermovement jump height was also of special interest. In players who participated in >60 minutes of match play, jump height remained reduced the day following the first match. Interestingly however, jump height was recovered by the start of the second match. Alternatively, reserve training on the two post-match days (Training 1 and 3) resulted in reduced jump height in the other two groups (30-60 min and <30 min). On these reserve training days, players participating in less than 60 minutes of match play are expected to undergo full training while those who participated in more than 60 minutes of match play participate in a different type of training session designed to promote recovery. After comparing the vertical countermovement jump height of the high-minute athletes with the lower minute athletes, reserve training appears to have been an effective training stimulus. This effective training stimulus agrees with some but not all studies, such as that conducted by Alijanpour and colleagues (2022). When monitoring training monotony and training strain, researchers found that throughout the early- and mid-season, non-starting players did not receive an adequate training stimulus to effectively develop their soccer abilities.

The match periods were selected due to both matches being played at home. This allowed for field conditions to be similar between matches and athletes to not to have undergone travel. Nonetheless there were several limitations to this study. First, data was collected during a single week of the season. Results could differ between matches played early in the season compared to those played near the end of the season. Second, a number of match-related variables were not controlled during the study. For example, playing time and substitutions were established by the coaching staff while the researchers had no influence on these decisions. Additionally, the quality of the opponents was not controlled. For the first match, the opponent’s end of season ratings percentage index (RPI) was in the top 15 nationally, whereas the second opponent's RPI was nearly 300. Environmental conditions such as weather were also not controlled. Despite match 1 starting at 7:00 pm and match 2 beginning at 1:00 pm, weather conditions were similar (70-75%, ~90% humidity, partly cloudy). Finally, factors such as player readiness, diet, sleep, etc. was not controlled. Each of these factors could have impacted both pre- and post-session vertical countermovement jump heights.

These results suggest that the 3-jump protocol and vertical countermovement jump heights can be used as a measure of short- and long-term fatigue. This concept is supported by the match-induced changes in jump height during match days and in the pre-session heights on the two recovery days. Results also suggest that player readiness can be evaluated by vertical jump height. Players who showed recovered jump height (pre-session) the days after training or match play would be considered "ready" for training and recovered from the previous sessions. On the other hand, athletes showing depressed pre-session jump heights might be considered as less than fully physically ready to train. This type of information could be extremely useful to coaching and/or strength and conditioning staffs when designing training sessions when attempting to match each player's readiness to training plans. This level of individualization throughout each training season not only has the potential to best prepare each athlete for future competition, but it allows coaches the ability to promote the health and well-being of athletes, while helping to mitigate injury.

CONCLUSION

When examining the countermovement jump height of the <30 minutes and the 30-60 minutes groups, there was a noticeable decrease in performance throughout the span of the congested calendar training time-period. This lack of variance could be due to the fact that these participants did not receive a high enough load during both training and match play to result in increased levels of fatigue. Information such as this could provide further insight for coaches to adequately dose training stimuli. This in turn would better prepare athletes for the demands of subsequent training sessions. Similarly, the reduction in countermovement jump height following match play that was experienced by athletes who played in the highest number of minutes is an important discovery for the health and longevity of athletes. With the increased understanding that the recovery window from high minute match play can extend 48 hours following the match, coaches can better structure practices for these athletes, aiding in promoting recovery and preparation for the next match.

Future recommendations for this study could include examining countermovement jump height throughout the entire span of the pre-season training time-period as well as into the in-season training period. In doing so, an increased understanding of athlete fatigue as well as how prepared the athletes were for the lengthy duration of the in-season training period would result. Additionally, expanding this study to a larger population could provide more reliable results. While the >60 minutes training group had 9 athletes in it, the <30 minutes group only had 3 athletes in it. Since collegiate soccer teams are limited by roster sizes, this could be accomplished through examining multiple teams throughout the same seasons.

REFERENCES

Alijanpour N., Nobari H., Bolboli L., Afroundeh R., Garcia-Ramos A. (2022). Using global positioning system to compare training monotony and training strain of starters and non-starters across of full-season in professional soccer players. *Sustainability.* 14, (6): 10.3390/su14063560

Carling C, Orhant E, LeGall F. (2010). Match injuries in professional soccer: inter-seasonal variation and effects of competition type, match congestion and positional role. *International Journal of Sports Medicine*. 31(04): 271-276.

Claudino, J. G., Cronin, J., Mezêncio, B., McMaster, D. T., McGuigan, M., Tricoli, V., Amadio, A. C., & Serrão, J. C. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. In *Journal of Science and Medicine in Sport* (Vol. 20, Issue 4, pp. 397–402). Elsevier Ltd. https://doi.org/10.1016/j.jsams.2016.08.011

Djaoui L, Owen A, Newton M, Nikolaidis PT, Dellal A, Chamari K. (2022) Effects of congested match periods on acceleration and deceleration profiles in professional soccer. *Biology of Sport*. 39(2): 307-317.

Dellal A, Lago-Peñas C, Rey E, Chamari K, Orhant E. (2015) The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *British Journal of Sports Medicine*. 49(6): 390-394.

Ellis M, Myers T, Taylor R, Morris R, Akubat I. The Dose–Response Relationship Between Training-Load Measures and Changes in Force–Time Components During a Countermovement Jump in Male Academy Soccer Players.

International Journal of Sports Physiology and Performance. 2022 Oct 11;17(11):1634-41.

Enoka RM, Duchateau J. (2016) Translating Fatigue to Human Performance. Medicine Science in Sports and Exercise. 48(11): 2228-2238.

Favero TG, White J. (2018) Periodization in college soccer. Strength & Conditioning Journal. 40(3): 33-44.

Gathercole, R., Sporer, B., Stellingwerff, T., & Sleivert, G. (2015) Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. *International Journal of Sports Physiology and Performance*, *10*(1), 84–92. https://doi.org/10.1123/ijspp.2013-0413

Goulart KN, Coimbra CC, Campos HO, Drummond LR, Ogando PH, Brown G, Couto BP, Duffield R, Wanner SP. (2022) Fatigue and recovery time course after female soccer matches: A systematic review and meta-analysis. Sports Medicine-Open. 8(1): 1-21.

Hines DS. (2022) The Feasibility of Accelerometer-Derived Measures of Vertical Jump Height as a Marker of Neuromuscular Performance in Collegiate Soccer Players (Master's Thesis, Virginia Tech).

Kennedy, R. A., & Drake, D. (2017) The effect of acute fatigue on countermovement jump performance in rugby union players during preseason. *Journal of Sports Medicine and Physical Fitness*, *57*(10), 1261–1266. https://doi.org/10.23736/S0022-4707.17.06848-7

Lago-Peñas C, Rey E, Lago-Ballesteros J, Casáis L, Domínguez E. (2011) The influence of a congested calendar on physical performance in elite soccer. The *Journal of Strength & Conditioning Research*. 25(8):2111-2117.

McCormack WP, Hoffman JR, Pruna GJ, Scanlon TC, Bohner JD, Townsend JR, Jajtner AR, Stout JR, Fragala MS, Fukuda DH. (2015) Reduced high-intensity-running rate in college women's soccer when games are separated by 42 hours. International Journal of Sports Physiology and Performance. 10(4): 436-439.

Page RM, Field A, Langley B, Harper LD, Julian R. (2022) The effects of fixture congestion on injury in professional male soccer: a systematic review. *Sports Medicine*, 17:1-9.

Pinasco A, Carson J. Preseason conditioning for college soccer. Strength & Conditioning Journal. 2005 Oct 1;27(5):56-62.

Rantalainen T, Gastin PB, Spangler R, Wundersitz D. (2018) Concurrent validity and reliability of torso-worn inertial measurement unit for jump power and height estimation. Journal of Sports Sciences. 36(17): 1937-42.

Rantalainen T, Hesketh KD, Rodda C, Duckham RL. (2018) Validity of hip-worn inertial measurement unit compared to jump mat for jump height measurement in adolescents. Scandinavian Journal of Medicine & Science in Sports. 28(10): 2183-8.

Sausaman RW, Sams ML, Mizuguchi S, DeWeese BH, Stone MH. (2019) The physical demands of NCAA division I women's college soccer. Journal of Functional Morphology and Kinesiology. 4(4): 73.

Spangler R, Rantalainen T, Gastin PB, Wundersitz D. (2018) Inertial sensors are a valid tool to detect and consistently quantify jumping. International journal of sports medicine. 39(10): 802-8.

Snyder BJ, Hutchison RE, Mills CJ, Parsons SJ. (2019) Effects of two competitive soccer matches on landing biomechanics in female division I soccer players. Sports. 7(11): 237.

Thorpe, R., Strudwick, A., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2017) The Influence of Changes in Acute Training Load on Daily Sensitivity of Morning-measured Fatigue Variables in Elite Soccer Players. In *International Journal of Sports Physiology and Performance* (Vol. 12, Issue 2). http://researchonline.ljmu.ac.uk/

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2015). Monitoring fatigue during the in-season competitive phase in elite soccer players. *International Journal of Sports Physiology and Performance*, *10*(8), 958–964. https://doi.org/10.1123/ijspp.2015-0004

Vescovi JD, Fernandes E, Klas A (2021) Physical demands of women's soccer matches: A perspective across the developmental spectrum. Frontiers in Sports and Active Living. 3, 634696.

Vescovi JD. (2014) Motion characteristics of youth women soccer matches: female athletes in motion (FAiM) study. International Journal of Sports Medicine. 35: 110-117.

Williams JH, Hoffman S, Jaskowak DJ, Tegarden D. (2019) Physical demands and physiological responses of extra time matches in collegiate women's soccer. Science and Medicine in Football. 3(4): 307-312.