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Changes in Countermovement Jump and Sprint During a Congested Match Schedule in Female
Youth Soccer Players

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 Sport Performance

by

Joanne Spalding

May 2020

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Keywords: Match-congestion, youth, soccer, CMJ, sprint

ABSTRACT

Changes in Countermovement Jump and Sprint During a Congested Match Schedule in Female

Youth Soccer Players

by

Joanne Spalding

Youth soccer players are required to play multiple matches within a short period of time. Participation in congested match schedules like youth soccer tournaments can result in fatigue and a decline in physical performance. The purpose of this study was to examine changes in countermovement jump height variables and sprint time to determine if physical performance was altered. Fourteen youth female soccer players performed countermovement jump testing pre, post-match, and post-tournament, and sprint testing pre and post-tournament. Jump height differed significantly ($p < 0.001$) between time periods during the tournament, and sprint time increased by a statically significant amount ($p = 0.001$). Results also indicated that there were significant effects on CMJ variables; RSI_{mod} ($p = 0.015$), eccentric impulse ($p = 0.022$), concentric impulse ($p = 0.010$), peak power ($p = 0.044$). It was concluded that certain CMJ variables are sensitive to fatigue as well as sprint time and may be useful for coaches to use to monitor fatigue and determine recovery strategies and proper training load before and after a youth soccer tournament.

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DEDICATION

This dissertation is dedicated to my father, John, for his continued love and support over the years and to my late mother Christine for instilling in me the work ethic and belief that has made me the person I am today. I could not have accomplished all that I have without everything that you have done for me. I am truly thankful. This is also dedicated to my brothers, Craig and Stewart, for keeping me grounded and having my back.

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TABLE OF CONTENTS

ABSTRACT.....	2
DEDICATION.....	4
ACKNOWLEDGEMENTS.....	5
LIST OF TABLES.....	8
LIST OF FIGURES.....	9
Chapter 1. Introduction.....	10
Statements of Purpose.....	11
Operational Definitions.....	11
Chapter 2. Review of The Literature.....	13
Congested Match Schedules.....	15
Professional level athletes.....	15
Youth athletes.....	18
Measuring Changes in Performance.....	20
Countermovement jump.....	20
Sprint.....	22
Summary.....	24
Chapter 3. Changes in Countermovement Jump Height and Sprint Time During a Congested Match Schedule in Youth Female Soccer Players.....	25
Abstract.....	26
Introduction.....	27
Methods.....	30
Experimental Approach to the Problem.....	30
Tournament Design.....	30
Subjects.....	31
Vertical Jump Assessment.....	31
20-meter sprint assessment.....	32
Match Load Calculation.....	33
Statistical analysis.....	33
Results.....	34
Discussion.....	37

Practical Applications	39
References	41
Chapter 4. Effects of a Congested Match Schedule on Countermovement Jump Variables in Female Youth Soccer Players	49
Abstract	50
Introduction	50
Methods	52
Experimental Approach to the Problem.....	53
Tournament Design.....	53
Subjects	53
Vertical Jump Assessment	54
Statistical analysis.....	55
Results	56
Discussion	59
Practical Applications	62
References	63
Chapter 5. Summary and Future Investigations.....	70
References	72
VITA.....	90

LIST OF TABLES

Table 3. 1 Warm up protocol	32
Table 3. 2 Mean jump heights throughout tournament.....	34
Table 3. 3 Minutes played and RPE.....	35
Table 3. 4 Differences in jump height between time periods	36
Table 4. 1 Countermovement jump variables and definitions	54
Table 4. 2 Warm up protocol	55

LIST OF FIGURES

Figure 3.1 Jump Heights with 95% confidence intervals.....	35
Figure 3.2 Change in sprint time pre to post tournament	37
Figure 4.1 RSImod with 95% confidence intervals	56
Figure 4.2 Eccentric Impulse with 95% confidence intervals.	57
Figure 4.3 Concentric Impulse with 95% confidence intervals	58
Figure 4.4 Peak Power with 95% confidence intervals	59

Chapter 1. Introduction

Tournaments in which youth soccer players participate can involve congested schedules with up to two matches being played per day or up to four matches in 48-hours. In theory, these schedules would affect physical performance, and have a greater impact on consecutive matches which are typically the decisive matches (final). This theory on physical performance being affected by congested schedules is based on previous literature that has found when the time between matches is reduced, fatigue is accumulated over successive matches, and the lack of recovery affects ensuing physical performance (Andersson et al. 2008; Buchheit et al. 2010; Dupont et al., 2010; Odetoyinbo et al., 2008).

In addition to accumulated fatigue, the physical demand of a congested schedule on youth athletes should be considered. In senior professional soccer players, higher injury rates have been reported when players participated in two matches per week versus one match per week (Dupont et al., 2010). Also, increased muscle damage markers were reported in youth male soccer players who played in four matches in four days (Roswell et al., 2009). This research shows the importance of allowing appropriate recovery time between matches or the need to monitor athletes to assess fatigue and then employ strategies to mitigate accumulated fatigue.

The countermovement jump (CMJ) has been found to be a reliable and valid method to monitor fatigue in sport (Andersson et al., 2008; Ascensao et al., 2008; Gee et al., 2011; Hoffman et al., 2003). Jump height has also been shown to decrease following match play in soccer players (Byrne & Eston, 2002; Horita et al., 2003; Kubo et al., 1999; Oliver et al., 2008). This tool allows sport practitioners to assess and monitor match and training related fatigue in athletes and allows greater control over recovery and match strategies to help alleviate fatigue.

Unfortunately, while there is a growing body of literature on congested match schedules, it primarily addresses professional or elite level male soccer players and utilizes expensive monitoring tools like Global Positioning Systems (GPS). Little knowledge exists concerning the effects of a congested match schedule on female youth soccer players physical performance or the sensitivity of CMJ variables during a congested match schedule.

Statements of Purpose

1. To examine the changes in physical performance variables during a congested match schedule in female youth soccer players.
2. To investigate different countermovement variables during a congested match schedule in youth female soccer players.

Operational Definitions

1. Congested match schedule: Successive matches played within a short time period.
2. Concentric impulse: Force multiplied by time over which the muscle shortens during the upward part of the countermovement.
3. Countermovement jump (CMJ): A vertical jump involving a pre-jump countermovement, which takes advantage of the stretch reflex and stored elastic energy.
4. Eccentric impulse: Force multiplied by time over which the muscle lengthens during the downward part of the countermovement.
5. Fatigue: A reduction in the ability to produce force in a muscle or group of muscles.
6. Jump height: The distance, measured in centimeters (cm), the athlete jumps off the force plate as determined by flight time.
7. Peak force: Largest force generated before take-off.
8. Relative peak force: Largest force generated before take-off relative to body weight

9. Peak power: The highest instantaneous power value found over a range of motion under a given set of conditions.
10. Reactive strength index modified: Ratio between jump height and time to take-off as a measure of explosiveness.
11. Session rating of perceived exertion (sRPE): A subjective measure of training/game session intensity.
12. Stretch-shortening cycle (SSC): The increase in force production due to a rapid pre-stretching (eccentric action) of muscles immediately prior to a concentric action of the same muscles.

Chapter 2. Review of The Literature

There is a growing body of literature on the effects of congested match schedules on physical and physiological match performance in male soccer players at the professional and elite level (Dellal et al., 2015; Dupont et al., 2010; Moreira et al., 2016; Odetoyinbo et al., 2008). Interest in match congestion has grown as players are required to play more matches due to league play and tournaments and it is thought that the increase in frequency of matches results in fatigue and underperformance (Carling et al., 2015). Recent studies have also shown that congested match schedules exist at the elite youth level of soccer (Arruda et al., 2014; Buchheit et al., 2010; Roswell et al., 2009). Limited information on individuals competing in whole matches during a congested match schedule may be due to player rotation or player selection (Carling et al., 2015). Therefore, information on congested match schedules at the youth level is important as it can be used to help identify effects of congested match schedules, and to develop and monitor soccer-specific training for young soccer players.

Competition induces high levels of fatigue in athletes. Numerous studies suggest three or more days are required to return to precompetitive levels of fatigue and performance (Andersson et al., 2008; Ascensao et al., 2008; Cormack et al., 2008; Hoffman et al., 2003). In cases such as youth soccer tournaments, players are required to play up to three to four matches in as little as two to three days. When recovery is inadequate for prolonged periods, injury risk increases while performance stagnates or decreases (Meeusen et al., 2012; Stone et al., 2007; Taylor et al., 2012). The degree of match congestion differs based on level of play (e.g. youth, elite, national team, professional) which is important to consider when making inferences from the literature (Carling & Dupont, 2011; Dupont et al., 2010; Odetoyinbo et al., 2008)

Differences in maturation must also be considered when evaluating effects of congested match schedules. Human growth can be defined as the measurable changes in body size, shape and composition and at a functional level the development of the nervous, skeletal and muscular system (Fairclough & Stratton, 2006). There is a high rate of individuality in the timing of these changes (Baechle et al., 2000). This brings challenges to sport practitioners to be informed of developmental changes in players that can affect adaptation to training and increase injury rates.

The changes in physical and physiological demands associated with congested competition in soccer players have recently been examined at different playing levels using a variety of methods to better understand how the congested match fixtures affect performance. Global Positioning Systems (GPS) have been used to determine physical performance outcomes using total distance, high speed distance and other variables (Buchheit et al., 2010; Castagna et al., 2009; Mendez-Villanueva et al., 2013). Neuro-endocrine-immune responses have been reported using testosterone, salivary cortisol, and mucosal immunity factors (Freitas et al., 2014; Roswell et al., 2009; Moreira et al., 2013; Mortatti et al., 2016). Heart-rate variability has also been studied during soccer match play (Rabbani & Buchheit, 2015). The abovementioned studies have shown that various physical and physiological variables can be affected by congested match schedules, but little is known regarding congested match schedules in youth female soccer players in the U.S. tournament system, and the methods to monitor fatigue at this level.

The following review of the literature is an analysis of the most common forms of match congestion based on level of play, the way in which performance and physiological characteristics were measured, and how these characteristics were affected.

Congested Match Schedules

The number of matches soccer players must perform in over the course of a season has increased over the past decade (Andersson et al., 2008). The literature on the physical demands of soccer has markedly grown with many studies focusing on fatigue accumulated during one match (Mohr et al., 2003) with newer research focusing on congested match schedules at different levels of play (Arruda et al., 2014; Carling & Dupont, 2011; Dellal et al., 2013; Djaoui et al., 2016; Dupont et al., 2010; Lago-Peñas et al., 2011; Odetoyinbo et al., 2008; Rey et al., 2010). The different levels of play and the way in which match congestion affects performance is discussed in the following paragraphs.

Professional level athletes. Current research on physiological variables on congested match schedules at the professional level is varied. Studies have shown that total distance covered during congested match schedules is unaffected over periods of match congestion (Djaoui et al., 2016; Lago-Peñas et al., 2011; Lago-Peñas, 2009; Vieira et al., 2019). Dellal et al. (2015) examined 16 international male players during three different congested match schedules, with the highest congestion including six games in 18 days. No difference was noted in any physical (high-intensity, medium-intensity, low-intensity and overall distance) or technical (balls lost, successive passes, number of touches per possession and duels won) variables during match play.

The literature on other variables such as total high-intensity running distance, total submaximal running distance, total number of sprints and sprint distance has been varied (Bengtsson et al., 2013; Lago-Peñas et al., 2011; Vieira et al., 2019). Lago-Peñas et al. (2011) reported that Brazilian professional soccer players covered less distance at max and submaximal speeds during the second match in a two-match week which was different than results reported

by Dellal et al. (2015). Dupont et al. (2010) noted no significant difference in high-intensity distance or sprint distance when players performed in one match versus two with 72 to 96 hours separating matches. Authors also noted that although the time separating games was sufficient for recovery it was not enough to maintain a low injury rate (Dupont et al., 2010) It is important to note that the typical congested match schedule in all of these studies was two matches per week over a 4-6-week period. Players had approximately 72-96 hours between matches, which has been suggested as a sufficient amount of time to recover (Nedelec et al., 2013).

As well as the decrease in performance, the increase of injury risk is also of concern during a congested match schedule. Again, the few studies that have been conducted are contradictory. Carling et al. (2012) found no increase in injuries when players competed in eight matches in 26 days (2 matches per week) whereas Dupont et al. (2010) reported that injury rates were significantly higher in players that participated in two matches per week. A study by Dupont et al. (2010) coincides with other research that reported that muscle injury rates increased when players had less than four days recovery between matches, with consecutive matches being more detrimental (Aus Der Funten et al., 2014; Bengtsson et al., 2013). Dellal et al. (2015), indicated that there were no significant differences to total incidence of injury during the congested or non-congested period overall, but that injury rate increased significantly during match-play during the congested period. Although, this may be just a result of more match-play versus training time during a congested period. Various studies have reported similar results in that there were no differences between injury rates during a congested match schedule versus non-congested (Andresson et al., 2008; Carling et al., 2012; Dupont et al., 2010; Lago-Peñas et al., 2011). Another reason that injury rates may not differ is that sport practitioners at the

professional and elite level may have the resources or knowledge to adopt strategies that enable faster recovery or allow for player rotation.

Researchers have investigated endocrine-immune markers in male soccer players to determine if there is evidence to suggest there is an increased risk of injury or a decrease in physical performance during congested match schedules. Although the literature is limited in this area, Morgans et al. (2014) found that a congested match schedule brought perturbations to mucosal immunity in professional soccer players. Moreira et al. (2013) noted that testosterone concentrations decreased in elite male soccer players during a congested match schedule. Also, of note is a study by Andersson (2008) that saw creatine kinase increase which did not return to baseline until 69 hours post-match. Similar results were observed after a second match was played. In the same study, urea and uric acid were changed and returned to baseline after 21 hours (Andersson, 2008).

Most of the literature on congested match schedules at the professional level indicate that performance measures are unaffected. It must be noted that a congested match schedule at this level is typically two matches in one week, with matches typically being separated by at least 48-72 hours. This type of schedule is different than a youth soccer tournament which can consist of up to four matches in 48 hours.

Youth athletes. Literature addressing congested match schedules in youth soccer is lacking. Available literature consists of youth national teams that usually play up to five matches over a 10-day period. Of note is the study by Moreira et al. (2016) on elite level youth soccer players in which five matches were played over three days (two on first day, two on second day, and one on day three). Authors found that total distance and maximal running speed were both unchanged. Although, frequency of accelerations per minute, body load impacts, and body load impacts per minute were decreased (Moreira et al., 2016), suggesting that players may be able to maintain maximal speed but the frequency to perform repeated intervals at maximal speed and the time to maximal speed in consecutive matches may decrease. Also, Hattersley et al. (2008) reported that total distance and high intensity distance saw large reductions during double game weeks.

On the other hand, Zanetti et al. (2018) examined work rate profiles in elite youth soccer players during congested and non-congested match schedules. Accelerations, decelerations, mean metabolic power (MP), and technical performance were examined. Results reported a higher number of accelerations and decelerations per minute, mean MP and higher technical actions per minute during the congested period. Although it should be noted that game duration was shorter during the congested match schedule and players may not have felt the need to pace themselves during the shorter match. Chaves et al. (2018), also found that there were lower values in performance parameters (internal load, total distance, total speed during congested match schedules (two games per week) versus non-congested match schedules (one game per week)).

Even if players can perform at the same level of physical performance, players have reported a higher rating of perceived intensity during congested match schedules (Zanetti et al.,

2018). Male youth soccer players have also reported an increased perception of fatigue during congested match schedules (Hattersley et al., 2008). Several studies have reported that players' rating of perceived exertion (RPE) is negatively affected after competing during a congested match schedule (Chaves et al., 2018; Freitas et al., 2014). In a study by Chaves et al. (2018), RPE and Total Quality Recovery Scale (TQR) were negatively affected, with neither returning to baseline before the last game.

Coaches at the youth level may have limited resources to help enable recovery or the capability to control player schedules. Thus, gaining knowledge on accumulated fatigue in youth players during a congested match schedule is important to investigate. In the current literature, there is limited information available on the effects of match-congestion on youth soccer players (Carling et al., 2012). Available research found that about 10-40% of injuries were overuse injuries and that the chance of injury increased with age. The same study found that players above the age of 14 had similar types and rates of injuries as adult players (Ekstrand et al., 2004). Although, most studies only looked at contact vs non-contact injuries and not the possible risk factors associated with those injuries (Faude et al., 2013). The maturation of players and their biological age may play a factor in the rate and type of injuries, especially if youth players are exposed to more training and game time (Johnson et al., 2009).

Measuring Changes in Performance

Countermovement jump. The stretch-shortening cycle (SSC) is employed during a soccer match and may be important during critical points in a game that include jumping and sprinting (Oliver et al., 2008). The SSC is the successive combination of eccentric and concentric muscle action. It is suggested that when muscle is activated, stretched and then immediately shortened, the muscular force and power is greater than if only a concentric action happened (Cormie et al., 2010). Therefore, any impairment in the SSC caused by fatigue could be detrimental to match performance. Fatigue and muscle damage have been shown to interfere with muscle functions such as the SSC (Enoka & Duchateau, 2008; Ross et al., 2007).

Muscular performance tests are used frequently to assess fatigue after performance (Byrne & Eston, 2002). Vertical jump testing is one of the most popular methods used (Taylor et al., 2012). It has been suggested that vertical jump assessment is useful to examine lower-body explosiveness as it does not fatigue the athlete and is quick and simple to learn (Moir et al., 2004).

Enoka and Duchateau (2008) reported that fatigue and muscle damage have been shown to impair neuromuscular function. Therefore, countermovement jumps (CMJ) are commonly used to assess players fatigue as neuromuscular factors negatively affect the SSC which is a major component of the CMJ (Ross et al., 2007). Impairment of the SSC have been shown to impact CMJ performance and underlying variables which provides support for its use as a fatigue monitoring tool versus other jumps (Andresson et al., 2008; Fowles, 2000; Hoffmann et al., 2003; Nindl et al., 2002; Raastad & Hallen, 2000; Skurvydas et al., 2007).

A study by Quagliarella et al. (2011) analyzed 117 young male soccer players that were grouped into three different age groups; 11-12 years (prepubertal), 13-14 years (peripubertal),

and 15-20 years (postpubertal). The authors reported statistically significant differences in CMJ performance based on age. Understanding differences in CMJ based on age is important as Pearson, Naughton and Torode (2006) reported that motor skills have been found to be strongly dependent on growth. Based on this, variables such as peak power and max jump height may change, especially during times of greatest physical development which is highly individual (Pearson et al., 2006). Lara et al. (2006) reported puberty is accompanied by differences in the use of the contractile force and velocity during the push-off phase of a jump which may explain differences in reported CMJ performance.

Previous studies have reported that jump performance was impaired following match play in Australian Rugby (Andreson et al., 2008; Cormack et al., 2008), rugby league (Twist & Highton, 2013) and soccer (Magalhaes et al., 2010; Mohr et al., 2010). It has also been reported that jump performance was decreased following soccer-specific intermittent exercise, and there was a greater reduction in jumps that utilized the stretch shortening cycle (Oliver et al., 2008).

Studies have reported decrements in countermovement jump performance following match play, and up to 48 hours following the match (Russell et al., 2015). Other studies have reported no change in CMJ performance after 75 minutes of match play or after playing in two matches in one week (Carling et al., 2015; Carling & Dupont, 2011). Lundberg and Weckstrom (2017) examined 16 field players during a regular one-match week and again during a congested three-match week. Authors conducted tests 72 hours post-match and found no change in jump performance (Lundberg & Weckstrom, 2017)

A study by Cormack, Newston and McGuigan (2008) reported that only six (mean force, flight time, relative mean force, peak power, relative peak force, and peak force) out of 18 variables had a statistically significant difference when used as fatigue monitoring tool in match

play. In the same study, those six variables returned to baseline at different times suggesting that these variables may be sensitive to fatigue in different ways (Cormack et al., 2008). Gibson et al. (2018) grouped 30 youth soccer players into high (>250min) and low (<250min) match exposure groups. Authors reported that there was no change in lower body power in players who participated in a congested versus non-congested match schedule. Therefore, the results from these studies suggests that further research is needed to establish how CMJ variables are affected when fatigue is accumulated during a congested match schedule.

Based on the current literature, it is important to understand how jump performance is affected after multiple bouts of training or match play (Malone et al., 2015). Studies have shown that CMJ performance was not statistically altered following a multiple training session during a soccer season (Malone et al., 2015; Oliver et al., 2008; Reilly & Ekblom, 2005). Kinugasa and Kilding (2009) reported that there was a $0.6 \pm 6.7\%$ drop in jump height immediately post-match in 28 young players aged 14 ± 0.7 . The high variability in jump height results post-match may be due to sport practitioners adjusting playing time or the alterations in strength and maturity of each player.

Sprint. The ability to accelerate during soccer match play is important and constitutes 1-11% of total distance covered during match play, with sprinting action occurring every 90 seconds (Bangsbo,1994). It has also been determined that periods of sprinting where players are making a break, intercepting, tackling or shooting, are crucial moments in the game (Comfort et al., 2014).

Single sprint tests of 30m have been used in previous studies to examine the effects of match play on sprint time. Krustup et al. (2006) found that sprint performance was reduced during and following match play. Interestingly, another study noted that sprint performance

lacked sensitivity as a post-match indicator of fatigue in semi-professional soccer players (Brownstein et al., 2017). It has been suggested that evaluating longer sprint distances may be more sensitive to fatigue (Marques-Jimenez et al., 2017). It should be noted that there is a drawback to using sprint testing to monitor fatigue as it carries an injury risk and may carry residual fatigue (Carling et al., 2012; Nagahara et al., 2016).

Using sprint tests to evaluate fatigue has been called into question as some findings have reported that sprint time returned to baseline in around 5-hours even after declining $-3.0 \pm 0.5\%$ and the same results occurred after the second match (Andersson et al., 2008). This is supported by studies that reported sprint performance unchanged following match play (Oliver et al., 2008). These conflicting results of sprint test performance may be due to the methodological differences within the research (Byrne & Eston, 2002; Oliver et al., 2008).

In a review by Haugen and Buchheit (2015), authors reported that there was approximately 0.03 s standard error of measurement and 2% CV for sprint testing. It is suggested that only one part of the body breaks the beam of the timing gate, and it be the same body part (Haugen & Seiler, 2015). Although, it has been suggested that sprint tests may be fatiguing, data from Haugen and Seiler (2015) suggests differently for short distances. When junior soccer players repeated a set of 15, 20-m sprints with one-minute recovery, there was no indication of fatigue (Haugen & Buchheit, 2015). In fact, sprint time was 0.02 s faster in the last sprint compared to the first sprint, even though athletes were instructed to sprint maximally.

Despite these conflicting results, there is enough literature to support sprint performance to be a valid and reliable method of evaluating neuromuscular fatigue (Gathercole et al., 2015; Krustup et al., 2006; Sommerville, 2009). Procedures and methods of sprint testing seem to

differ within the literature and studies show trivial to somewhat-large differences (Haugen & Buccheit, 2015) in results, so consistency is key when reporting.

With that being said, a lack of sprint research has been conducted during congested match schedules at any level. This may be due to the fact that recent studies have utilized Global Positioning Systems to analyze high speed running distances at different speeds (Sanchez-Sanchez et al., 2019).

Summary

Further research is required to determine how practical methods such as the 20m sprint and vertical jump assessment are sensitive to fatigue during congested match schedules. Most of the literature consists of male elite soccer players, elite youth male soccer players, and professional or elite female soccer players. The literature also consists primarily of manufactured, international, or professional style congested match schedules. These schedule styles are drastically different than what youth female soccer players participate in the U.S. and at the non-elite level. To the authors knowledge, there is little to no literature on youth female club level players or within a U.S. youth style tournament congested schedule. The majority of research that has been conducted in youth soccer has been in elite level males (Mohr et al., 2004). The benefit of monitoring fatigue in youth players could provide useful information and guidelines for coaches as they face reduced recovery time frames and other commitments outside the sport that elite level players do not (Bahr & Krosshaug, 2005).

Chapter 3. Changes in countermovement jump height and sprint time during a congested match schedule in youth female soccer players

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Changes in Countermovement Jump Height and Sprint Time During a Congested Match Schedule in Youth Female Soccer Players

Abstract

The purpose of this study was to examine changes in jump height and sprint time along with the relationship between jump height and accumulated training load during a congested match schedule in youth female soccer players. This study was conducted with 14 youth female soccer players who performed countermovement jump testing pre, post-match and post-tournament, as well as sprint testing pre and post-tournament. A One-way repeated measures ANOVA was conducted to compare changes in jump height over the course of the tournament. A paired sample t-test was conducted to compare sprint time pre to post-tournament, and Pearson product moment correlations were calculated to determine the relationship between percent change in jump height and accumulated training load. Jump height was statistically significant ($p < 0.001$) between time periods during the tournament, and sprint time increased significantly ($p = 0.001$). There was no significant relationship between percent change in jump height and accumulated training load. In conclusion, this study found that jump height decreased over the course of the tournament and there was a significant increase in sprint time from pre to post-tournament. These results suggest that recovery strategies as well as proper training during a youth soccer tournament is needed to help players handle the demands of a congested youth schedule.

Key words: youth soccer, CMJ, sprint, congested match schedule

Introduction

Sports such as soccer place stress on the body's physiological systems over the course of a match and involve periods of high-intensity activities (e.g. sprinting, running, kicking, jumping, tackling) separated by lower-intensity activities (e.g jogging and walking) (Bangsbo, 1994; Reilly & Rigby, 2002; Rey et al., 2010). Soccer also includes technical and tactical components. Research suggests that performance in high-intensity activities temporarily declines after intense periods of the game (Brownstein et al., 2017; Mohr et al., 2003; Mohr et al., 2005; Thomas et al., 2017). This decline in physical performance has been linked to match-related fatigue, and it has been suggested this decline can last up to 72 hours post-match (Bangsbo et al., 1991; Barros et al., 2007; Bloomfield et al., 2005; Bradley et al., 2009; Carling et al., 2015; Ispirlidis et al., 2008; Krstrup et al., 2006; Reilly & Rigby, 2002; Roe et al., 2018).

In the modern soccer game, periods of fixture congestion (two or more games in a week) occur at all levels, especially for those teams competing in multiple events (e.g. leagues, tournaments, friendlies). Players that are subjected to a congested schedule over a short period of time could potentially suffer from residual fatigue and underperformance due to lack of recovery time while increasing the risk of injury (Carling et al., 2015; Dupont et al., 2010). Although, the degree of congestion can differ depending on the level of play. Elite soccer players can play two or three matches in the same week, while youth players play in two to three matches within the same weekend when participating in competitive soccer tournaments (Fowler et al., 2015).

Match congestion is not only a negative for player performance but also the players' health. Research found that approximately 10-40% of injuries in youth soccer were overuse injuries and the chance of injury increased with age. A study found that players above the age of 14 had similar types and rates of injuries as adult players (Ekstrand et al., 2004). However, limited information is available on the effects of match-congestion on youth soccer players

(Carling et al., 2012). Although most studies have addressed frequency and total amount of contact vs non-contact injuries in soccer, they have not addressed the possible risk factors associated with contact and non-contact injuries (Faude et al., 2013). The maturation of players as well as their biological age may play a factor in the rate and type of injuries, particularly if youth players are exposed to increased amounts of training and game time (Johnson et al., 2009).

The assessment of physical performance during competitive matches has been investigated in detail during single-match weeks and recently during congested match schedules (2-3 games per week). Current research has used a variety of methods, but the vast majority of the literature has used Global Positioning Systems (GPS) to analyze and monitor performance variables during congested match schedules (Castagna et al., 2010; Harley et al., 2010; Mendez-Villanueva et al., 2013; Castagna et al., 2009). Surprisingly, authors found that total distance and distances covered at high-intensity were not influenced by short recovery periods between matches (Lago, 2009; Lago-Peñas et al., 2011; Lago-Peñas, 2009; Dupont et al., 2010; Rey, et al., 2010; Odetoyinbo et al., 2008). However, despite the growing body of literature on congested match schedules for elite or professional level players, there is a gap in the literature on the fatigue induced by matches played during youth soccer tournaments, mostly in female players.

Skill-related performance has been studied during congested-match play and it is thought that players are able to sustain performance (e.g. pass percentage, number of balls lost, total number of touches per possession and percentage of duels won) (Bradley et al., 2009; Carling & Dupont, 2011; Dellal, 2015). Current literature indicates that technical performance is not influenced negatively as a result of a congested match schedule (Moreiraa et al., 2016). It has been suggested that players adapt pacing strategies that prevent skill deterioration when competing in a congested match schedule (Carling et al., 2012; Carling & Dupont, 2011).

However, most of the literature has focused on professional or elite level soccer players. With that said, youth players may not have the knowledge or experience to implement pacing strategies during match play to help reduce skill deterioration during a congested match schedule.

Performance measurements have also been used as an indicator of fatigue in soccer, specifically jumping and sprinting performance as they both utilize the stretch-shortening cycle (SSC). Therefore, any fatigue that hinders the SSC may have implications on performance. Decrements in SSC are easily monitored through countermovement jump (CMJ) testing and previous research has shown that fatigue negatively impacts CMJ performance (Byrne & Eston, 2002; Horita et al., 2003; Kubo et al., 1999). Most studies have only evaluated jump performance in adult or elite athletes. Oliver, Armstrong and Williams (2008) have studied jump performance in youth soccer players. However, the study only included a 42 min soccer-specific exercise and not a full match, but authors found similar results to other studies that reported jump performance decreased due to fatigue.

Sprint performance is important for soccer players as they can spend up to 11% of game time sprinting as well as it being critical during important moments (e.g. counterattacks, intercepting, tackling and shooting) (Bangsbo et al., 2006; Comfort et al., 2014). Andersson et al. (2008) found that sprint performance significantly decreased immediately following one match but returned to baseline within five hours in elite female soccer players. This is similar to other studies that saw a reduction in sprint performance after just one 90-minute match (Marquis-Jiménez et al., 2017; Roe et al., 2018; Silva et al., 2018; Watkins et al., 2017).

Due to the lack of literature investigating how sprint and vertical jump performance are affected during a congested match schedule in female soccer players, these variables should be

analyzed. The purpose of this study was to analyze changes in jump height and sprint time and the relationship with minutes played and Session of Rate of Perceived Exertion (sRPE), during a competitive youth soccer tournament in female players.

Methods

This study focuses on assessing changes in CMJ height and sprint time during a congested match schedule as well as the relationship between CMJ minute played and sRPE. Vertical jump testing, RPE collection, minutes played, and sprint testing took place as a normal part of a Youth Monitoring Program. Institutional Review Board (IRB) approval was obtained for a retrospective analysis of athlete monitoring data.

Experimental Approach to the Problem

The study sought to examine the relationship between total minutes played, estimated match load and vertical jump performance during a competitive youth soccer tournament. Match load as measured via sRPE and minutes played were calculated. Vertical jump testing occurred before and after the tournament and every match.

Tournament Design

The tournament was held in Tennessee, USA, approximately four and half hours by road from the players home and comprised three matches across two days. Travel occurred the day before the first match. The first match consisted of 40-minute halves with a 10-min recovery for half-time. The subsequent two matches were contested over two, 35-minute halves with 10-minutes of recovery for half-time. Matches changed in duration due to tournament scheduling and to prevent conflict with incoming inclement weather. Matches one and two were played on

the same day, separated by approximately four hours. Unlimited substitutions were allowed for all matches.

Subjects

A total of 20 Division I State League female soccer players (age: 14.7 ± 0.2 years, weight: 58.1 ± 1.9 kg, height: 116 ± 1.2 cm) participated in the study. Athletes took part in the team's normal athlete monitoring program during the spring tournament season. All athletes were not available for some sessions or games due to scheduling conflicts. As a result, the number of athletes for testing was 14.

Vertical Jump Assessment

Vertical jump assessment was performed pre-tournament, after each match (three matches), and post-tournament. The pre-tournament assessment occurred during the last training session before the tournament and prior to any physical activity. All athletes were in a rested state prior to testing. Post-match assessment was performed within 30 minutes of the match ending. The post-tournament assessment occurred at the next training session after the tournament ended and prior to any physical activity.

Vertical jump kinetic data was collected via one 2-axis force platform (PS-2142; PASCO, Roseville, CA), measuring at 1,000 Hz. The plate was positioned in a custom frame to prevent slippage. The top of the force plate was flush with the frame. Jumps were analyzed using a custom spreadsheet (Chavda et al., 2018), specifically designed to analyze CMJ and variables associated with CMJ.

Subjects completed a standardized dynamic warm-up protocol prior to vertical jump testing during the pre and post-tournament sessions. It was unnecessary for subjects to perform the warm-up again post-match. Players completed the warm-up protocol listed in the Table 3.1.

Table 3. 1

Warm-up protocol

Exercise – 20mx2
Jog
High knees/back kicks
Side shuffle
Quads/hamstring sweeps
Groins/lunge with a twist
Knee hugs/cross knee hugs
Kicks straight ahead/kicks across body
Hips open/hips closed
Sprint build-ups (70%, 90%, 100% of max sprint)

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

20-meter sprint assessment

Subjects performed the 20 m sprint test immediately following the vertical jump assessment. Subjects performed two trials each, with 90 sec rest between each trial. The time taken to run 20 m was measured using optical timing gates (Bower; Draper, Utah, USA). The subjects started from a standing position three inches before the timing gate. This ensured that the torso first broke the line. When ready, the subject sprinted through the next timing gate at max effort. The best of two trials was reported for comparison between pre and post-tournament (Lopez-Segovia et al., 2011; Wisloff et al., 2004).

Match Load Calculation

Rating of perceived exertion (RPE) was assessed approximately ten minutes following each match, modified Borg CR 10-scale as described in Foster et al. (1995) was used. Session rating of perceived exertion was calculated by multiplying the players RPE by total minutes played (Acros et al., 2014). sRPE is a subjective measure of game intensity as reported by players.

Statistical analysis

Calculations of intrasession reliability for jump height included coefficient of variation (CV). Coefficient of variation was calculated as the standard deviation divided by the mean score between trials (and multiplied by 100 to represent as a percentage). One-way repeated measures ANOVA with 95% confidence interval was performed to compare changes in jump height pre-tournament (PRE), game one (G1), game two (G2), game three (G3) and post-tournament (POST). Cohen's d effect sizes were also calculated. A Greenhouse-Geisser adjustment was used when Mauchly's test of sphericity ($P < 0.05$) demonstrated a violation of the assumption of sphericity. Post-hoc tests were completed using Bonferroni correction. A paired samples t-tests was conducted to compare sprint time pre-to post-season tournament. Pearson product-moment correlations were calculated to assess the relationship between jump height percent change from PRE to G1, G2, G3 and POST with total accumulated training load. The strength of a relationship as measured by Pearson product-moment correlation coefficients were evaluated with the following scale: $r = 0.0-0.1$ (trivial); $r = 0.1-0.3$ (small); $r = 0.3-0.5$ (moderate); $r = 0.5-0.7$ (large); $r = 0.7-0.9$ (very large); $r = 0.9-1.0$ (nearly perfect) (Hopkins et al., 2009). The critical alpha level was set at $p \leq 0.05$. Statistical analyses were conducted using JASP software (JASP Team, JASP (Version 0.9), 2018).

Results

Means and standard deviations for jump height (m) for each time point are reported in Table 3.2 and Figure 3.1. Small variation was found for intrasession jump height (CV = 5.14). Minutes played and RPE for each match, and total accumulated sRPE for the tournament is reported in Table 3.3. A statistically significant difference in jump height was found for time (F(2.663,11.724) = 9.061, $p < 0.001$). Post hoc testing revealed multiple significant differences in jump height as shown in Table 3.4

Table 3. 2

Mean jump heights throughout tournament

Time periods	Mean \pm DC (meters)
Pre	0.239 \pm 0.041
G1	0.222 \pm 0.044
G2	0.227 \pm 0.037
G3	0.210 \pm 0.038
Post	0.227 \pm 0.046

Figure 3. 1

Mean Jump heights with 95% confidence intervals

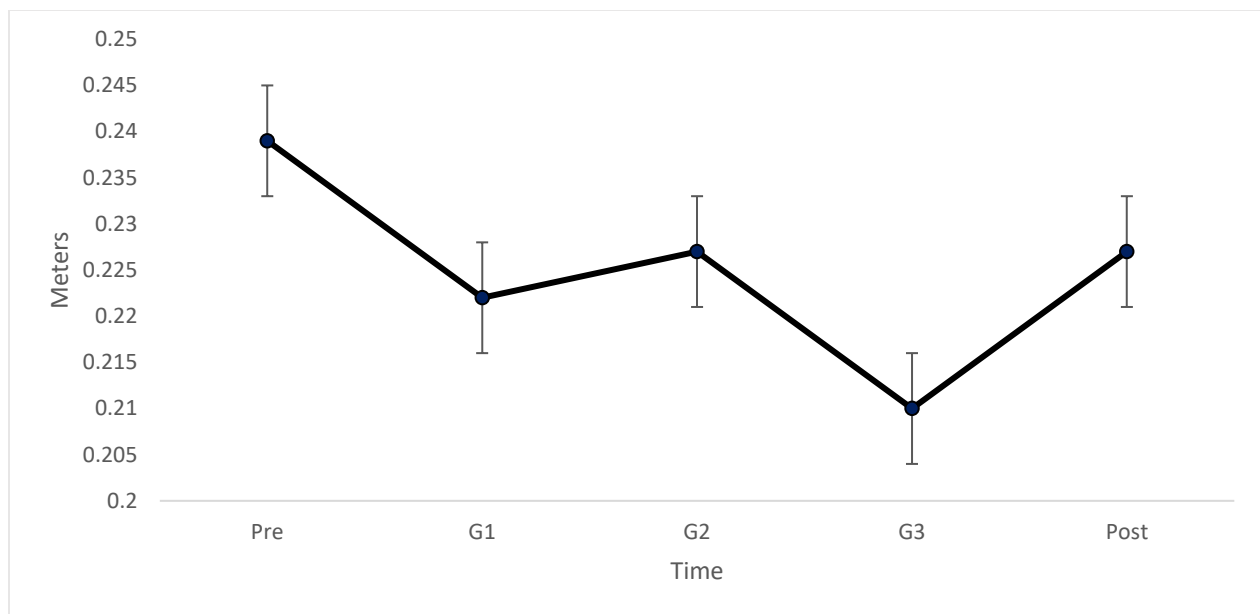


Table 3. 3

Minutes played and RPE

Athlete	Game 1		Game 2		Game 3	
	Minutes played	RPE	Minutes played	RPE	Minutes played	RPE
1	112.37	9	92.3	7	79.15	8
2	112.37	9	73.31	7	100.2	8
3	44.02	7	49.8	7	57.7	8
4	84.82	8	77.49	9	70.55	8
5	96.33	8	73.05	6	56.45	6
6	112.37	6	90.25	5	100.2	5
7	112.37	9	90.25	8	100.2	8
8	112.37	9	82.25	8	100.2	8
9	102.18	8	67.25	7	81.21	9
10	45.64	7	68.25	7	82.55	8

Athlete	Game 1		Game 2		Game 3	
	Minutes played	RPE	Minutes played	RPE	Minutes played	RPE
11	112.37	9	78	9	81.1	8
12	84.45	8	76	8	74.24	8
13	112.37	8	82.25	8	86.1	7
14	112.37	8	71.25	8	100.2	7

Table 3. 4

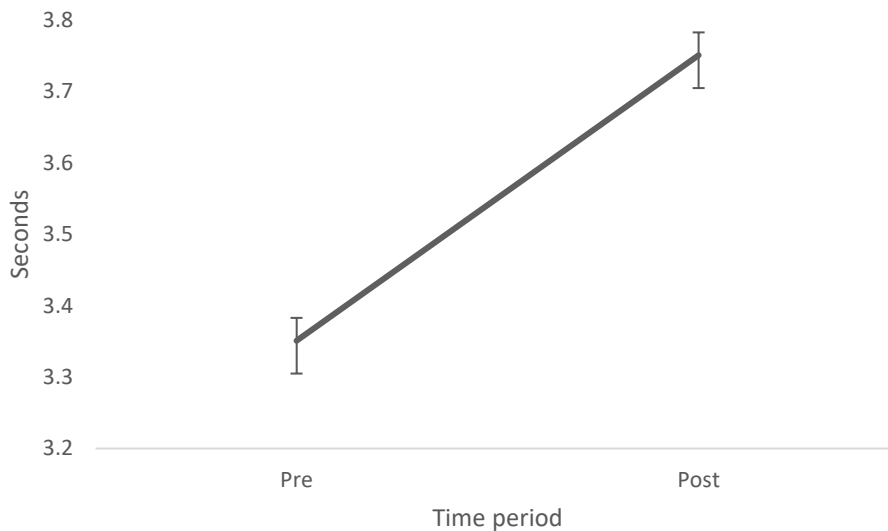
Differences in jump height between time periods

	Time	Cohen's d	P bonf
Pre	G1	1.468	0.001
	G2	0.525	0.713
	G3	1.619	< .001
	G4	0.605	0.414
G1	G2	-0.218	1.000
	G3	0.630	0.346
	Post	-0.232	1.000
G2	G3	1.204	0.006
	Post	0.002	1.000
G3	Post	-1.059	0.016

As illustrated in Figure 3.2, there was a significant difference ($t(13)=12.12$, $p = 0.001$) between pre-sprint time (mean = 3.351 ± 0.12) and post-sprint time (mean = 3.751 ± 0.17). The effect size for this analysis ($d = -3.240$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$).

Figure 3. 2

Change in sprint time pre to post-tournament



Discussion

The purpose of this study was to determine the changes in performance variables and relationship between those variables during a youth female soccer tournament to highlight fatigue accumulation. The results from the study revealed there were changes in jump height between pre-tournament and post-match across different time periods during the tournament, and sprint time increased from pre to post-tournament.

Statically significant differences were found between pre-tournament jump height and post-match jump height at different time periods, and at no point equal to what pre-tournament jump height was. These findings agree with other studies (Thomas et al., 2017; Watkins et al., 2017) that found decreases in performance of soccer players from pre to post-match during a congested match schedule. Although it should be noted that these players were male and played at a semi-professional level. Krstrup et al. (2010) results disagree with this study as they found no difference in jump height. However, these female players were elite level players and the

study only included one match. This study showed that even after one match jump height was decreased and players never reached pre-tournament levels indicating that there may not be sufficient recovery time between matches. This may increase the chance of injury during match play (Bengtsson et al., 2013; Dellal et al., 2015).

The statistically significant percent change in jump height from pre-tournament to G1 may indicate that players performance is decreased after only one match. Results from this study are similar to those reported by Andersson et al. (2008) who observed that jump performance was negatively impacted after just one match. Also, Oliver, Armstrong and Williams (2008) saw decrements in jump performance after 42 minutes of soccer-specific exercise. The significant change in jump height for pre-G3, G2-G3, and G3-post may indicate that match three is when the most fatigue is accumulated and therefore the chance of injury is greatest. The results from this study are similar to previous studies that have found a relationship with post-match fatigue and an increase in injury (Aus Der Funten et al., 2014; Bengtsson et al., 2013; Dupont et al., 2010; Odetoynbo et al., 2008). To the authors knowledge no other studies have monitored match-to-match performance variables in female soccer players.

There was a significant increase in sprint time from pre to post-tournament indicating that players performance could be affected even 24 hours post tournament. This could have implications on training design. This study differs from that of Brownstein et al. (2017) where the authors found that straight-line sprint performance in 10-20m distances had shown to lack sensitivity as a post-match (24-48h) indicator of fatigue. Other studies have shown that sprint time can be recovered within 5-96 hours (Ispirlidis et al., 2008; Meeusen et al., 2012) but will decrease again if there is a subsequent match (Andersson et al., 2008; Ascensão et al., 2008; Djaoui et al., 2016; Fatouros & Jamaurtas, 2016). Although, only Andersson et al. (2008)

evaluated the sprint and jump ability of youth soccer players, all other studies observed adult players. Although there is variability in recovery time with sprint time in the studies mentioned, this study authors believe that the 20m sprint is a practical tool to monitor fatigue in soccer players after a youth soccer tournament.

In summary, jump height was different at different across time periods over the course of the tournament with jump height never reaching pre-tournament scores. Percent changes in jump height from pre-tournament to match three increased and showed a large relationship compared to other time points ($p < 0.01$, $r = 0.846$), indicating that match three may be a significant time point in this type of congested schedule. There was a significant change in sprint time from pre to post-tournament with sprint time increasing indicating that it may be used to monitor fatigue in youth soccer players.

While the methods used in this study are sound, there are limitations. The data were collected from one team of the same age group over the course of a single tournament. Future research should focus on a longer observational period in which players participate in multiple competitions of varying congestion. It would also be beneficial for researchers to observe multiple age groups and determine if induced fatigue differs depending on maturation.

Practical Applications

CMJ height and 20m sprint may be appropriate monitoring tools for sport practitioners to indicate induced fatigue during a competitive youth soccer tournament. Although CMJ height may be a more practical means by which to measure fatigue from match-to-match during a congested match schedule compared to 20m sprint testing. Also, if players are required to participate in three matches or more it would be beneficial for coaches and players to employ recovery and substitution strategies (data on minutes played for each player) for fatigue

management. This study may also be beneficial for youth practitioners and coaches for injury prevention during a congested match schedule as results showed there is a significant change in CMJ performance. This may also help practitioners prescribe training load for youth soccer players leading into and after a congested match schedule. Training load can be adjusted so that players are better able to handle the demands of the congested match schedule, and also afterwards so that practitioners and coaches can avoid overtraining.

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Chapter 4. Effects of a congested match schedule on countermovement jump variables in female youth soccer players

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EFFECTS OF A CONGESTED MATCH SCHEDULE ON COUNTERMOVEMENT JUMP VARIABLES IN FEMALE YOUTH SOCCER PLAYERS

Abstract

The purpose of this study was to determine changes in countermovement jump variables during a congested match schedule in youth female soccer players. This study was conducted on 14 youth female soccer players who performed countermovement jump testing pre-tournament, post-match and post-tournament. Eight one-way repeated measures ANOVA were performed to compare CMJ variables (RSImod, eccentric impulse, concentric impulse, concentric impulse, peak power, relative peak force, peak force, and duration of eccentric impulse). Results indicated that there was a significant effect on RSImod ($p = 0.015$), eccentric impulse ($p = 0.022$), concentric impulse ($p = 0.010$), and peak power ($p = 0.044$). Post hoc analysis indicated that CMJ variables were statistically different at game three from other matches within the tournament. In conclusion, the findings suggest that some CMJ variables (RSImod, eccentric impulse, concentric impulse, and peak power) are more sensitive to fatigue than others. Results showed that game three may indicate when fatigue had the most impact on variables that are sensitive to fatigue.

Key words: youth soccer, CMJ, sprint, congested match schedule

Introduction

In the modern soccer game, youth players are required to play consecutive matches in a short period of time (e.g. four games in 48 hours at a competitive tournament) (Nedelec et al.,

2014). Participation in a match can lead to fatigue which may result in a decline in physical performance for up to 72 hours post-match (Andersson et al., 2008; Ascensao et al., 2008; Ekstrand et al., 2004; Ispirlidis et al., Manzi et al., 2010; 2008; Rollo & Williams, 2011). Research has indicated that players who participate in consecutive matches may increase the chance of injury (Dupont et al., 2010). During a congested match schedule, it is important to monitor and manage fatigue to ensure performance and health of the athlete (Nedelec et al., 2014). Available fatigue research has focused on a single match (Di Salvo et al., 2007; Krusturup et al., 2006; Rampinini et al., 2009) or during a season (e.g., pre-season, off-season etc.) (Mohr et al., 2003; Rey et al., 2010). To the authors knowledge few studies have investigated congested match schedules, particularly in youth soccer.

Soccer match play has been shown to cause substantial neuromuscular fatigue (Halson & Jeukendrup, 2004). Current research suggests that high-intensity activities (e.g., sprinting, running, kicking, jumping, tackling) decline over the course of a match (Bangsbo, 1994; Reilly & Rigby, 2002 Rey et al., 2010). The stretch-shortening cycle (SSC) is also important during high-intensity activities and any fatigue induced-impairment to the SSC function could affect player performance (Malone et al., 2015; Oliver et al., 2008)

For sport practitioners and coaches, it is important to have clear insight into the accumulated fatigue associated with a congested match schedule (Doeven et al., 2017). Coaches should understand the ensuing fatigue and the ability of individual players to recover from that fatigue so that decreases in performance can be minimized (Maso et al., 2002). The use of individual electronic monitoring or camera-based devices are not readily accessible for teams involved in youth soccer especially below the elite level. Fortunately, there are more practical

methods to monitor fatigue in players by using a countermovement jump (CMJ) (Byrne & Eston, 2002).

The CMJ has been related to competitive success in sports such as soccer (Arnason et al., 2004; Carvalho et al., 2012; Castagna & Castellini, 2013). It has been demonstrated that jump performance is impaired after exercise, suggesting that jump testing may be an indicator of fatigue (Balsalobre-Fernandez et al., 2014; Cormack et al., 2008; Jimenez-Reyes et al., 2017). Reporting of CMJ includes different kinematic and kinetic variables (e.g. take off angle, modified RSI, peak power, peak velocity, concentric phase etc.) that all have differing sensitivity in determining an athlete's neuromuscular fatigue (Baker & Nance, 1999; Comfort et al., 2012; Cronin & Hansen, 2005). Current literature shows that CMJ can be sensitive to sport performance (Byrne & Eston, 2002; Horita et al., 2003; Kubo et al., 1999; Oliver et al., 2008) and previous research has shown that CMJ was impaired after only one soccer match (Anderson et al., 2008; Magalhaes et al., 2010; Mohr et al., 2010).

Even with the increasing popularity of female soccer, research related to female soccer players is lacking and limited (Castagna & Castellini, 2013). To the author's knowledge, no studies have examined fatigue resulting from congested match play among youth female soccer players. Therefore, the aim of this study was to determine changes in countermovement jump (CMJ) variables in youth female soccer players during a congested youth soccer tournament schedule.

Methods

This study focused on evaluating changes in various CMJ variables during the tournament. Vertical jump testing took place as a normal part of a youth monitoring program.

Institutional Review Board (IRB) approval was obtained from a retrospective analysis of monitoring data.

Experimental Approach to the Problem

This study sought to examine the changes in CMJ variables during a congested match schedule to determine if movement strategies changed. Vertical jump testing occurred before and after the tournament and every match.

Tournament Design

The youth soccer tournament consisted of three matches across two days and was approximately four and half hours from the players home (Tennessee, USA). Players traveled the day before the first match. Match one was 80 minutes in length (40 minute halves) with a 10 minute half-time. Matches two and three were 70 minutes (35 minutes halves) with a 10-minute half time. Matches one and two were held on the same day with four hours between each match, and match three was held on the second day. Rules allowed for unlimited substitution for all matches.

Subjects

A total of 20 Division I State League (Fourth league in the state) female soccer players (age: 14.7 ± 0.2 years, weight: 58.1 ± 1.9 kg, height: 116 ± 1.2 cm) participated in the study. Players participated in the team's normal athlete monitoring program during the spring season. Due to scheduling conflicts, not all athletes were available for all sessions. As a result, the number of athletes for testing was 14.

Vertical Jump Assessment

Vertical jump assessment was performed prior to the tournament, after each match, and again post-tournament. Pre-tournament jump testing occurred at the last training session before the tournament and before any training occurred. All athletes had rested 48 hours prior to testing. The last training session consisted of a warm-up, set-piece practice, and a cool-down. Post-tournament jump testing occurred the day after the tournament concluded and before any training occurred.

Vertical jumps kinetic data was collected via one 2-axis force platform (PS-2142; PASCO, Roseville, CA), measuring at 1,000 Hz. The plate was positioned in a custom frame to prevent slippage. The top of the force plate was flush with the frame. Jumps were assessed using a custom spreadsheet (Chavda et al., 2018). Variables assessed using the custom spreadsheet along with definitions can be found in Table 4.1.

Table 4.1

Countermovement Jump Variables and Definitions

CMJ Variable	Definition
Reactive Strength Index modified (RSImod)	Demonstrates an athlete's ability to rapidly change from an eccentric motion into a concentric muscular contraction
Peak power	The highest instantaneous power value found over a range of motion under a given set of conditions
Peak force	Measured as the largest force generated before take-off.
Concentric impulse	Force multiplied by the time over which the muscle shortens during the upward part of the countermovement
Eccentric impulse	Force multiplied by the time over which the muscle lengthens during the downward part of the countermovement

Subjects completed a standardized dynamic warm-up protocol prior to vertical jump testing during the pre and post-tournament sessions. It was unnecessary for subjects to perform the warm-up again post-match. Players completed the warm-up protocol listed in the Table 4.2.

Table 4. 2

Warm-up protocol

Exercises – 20mx2
Jog
High knees/back kicks
Side shuffle
Quads/hamstring sweeps
Groins/lunge with a twist
Knee hugs/cross knee hugs
Kicks straight ahead/kicks across body
Hips open/hips closed
Sprint build-ups (70%, 90%, 100% of max sprint)

For each CMJ, each subject completed two trials with 20 seconds rest between each trial. Athlete’s self-selected CMJ with no pause occurring between eccentric and concentric phases. Subjects stood upright on the force platform and were given the command “3, 2, 1, jump”. If a trial was deemed a bad jump by the tester (e.g. submaximal effort, lifting legs prior to landing, or jumping to one side), a third trial was completed. The average of the two trials was taken for statistical analysis.

Statistical analysis

Calculations of intrasession reliability for CMJ variable included coefficient of variation (CV). Coefficient of variation was calculated as the standard deviation divided by the mean score between trials (and multiplied by 100 to represent as a percentage). Eight one-way repeated

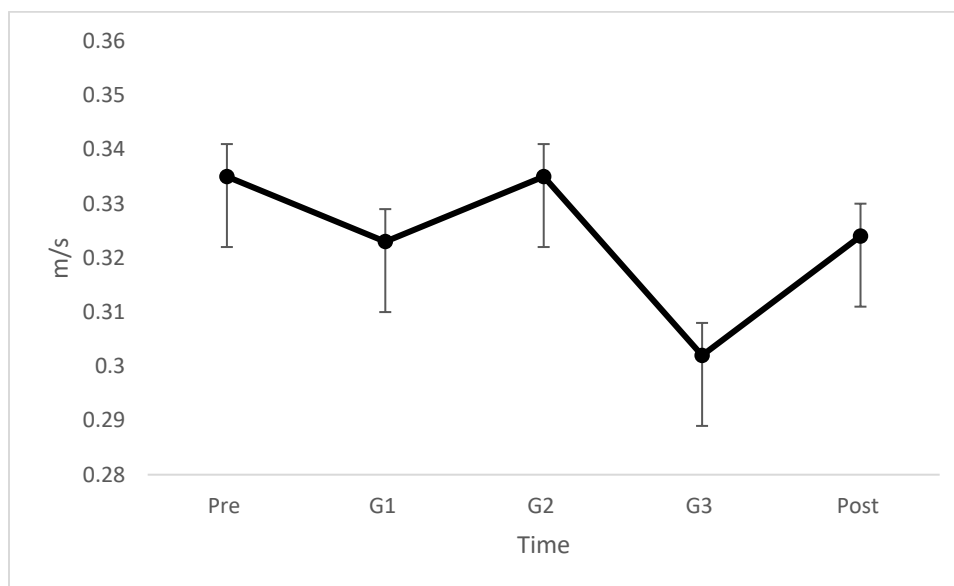
measures ANOVA were performed to compare changes in countermovement jump height variables at different time points; PRE, G1, G2, G3 and POST over the course of the tournament. Cohen's d effect sizes were also calculated. Post hoc tests were completed using Bonferroni correction. A Greenhouse-Geisser adjustment was used when Mauchly's test of sphericity ($P < 0.05$) demonstrated a violation of the assumption of sphericity. Statistical analyses were conducted using JASP software with a level of significance set as $p \leq 0.05$. (JASP Team (2018). JASP (Version 0.9) [Computer software].

Results

The results of the present study show that there was a significant effect on Modified Reactive Strength Index (RSImod) ($F(4,48) = 3.435$, $p = 0.015$). RSImod yielded the largest intrasession variability in terms of CV (7.61). Results showed statistically significant differences in time points G2-G3 ($p = 0.027$) (Figure 4.1.). The effect size for this analysis ($d = 1.047$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$).

Figure 4. 1.

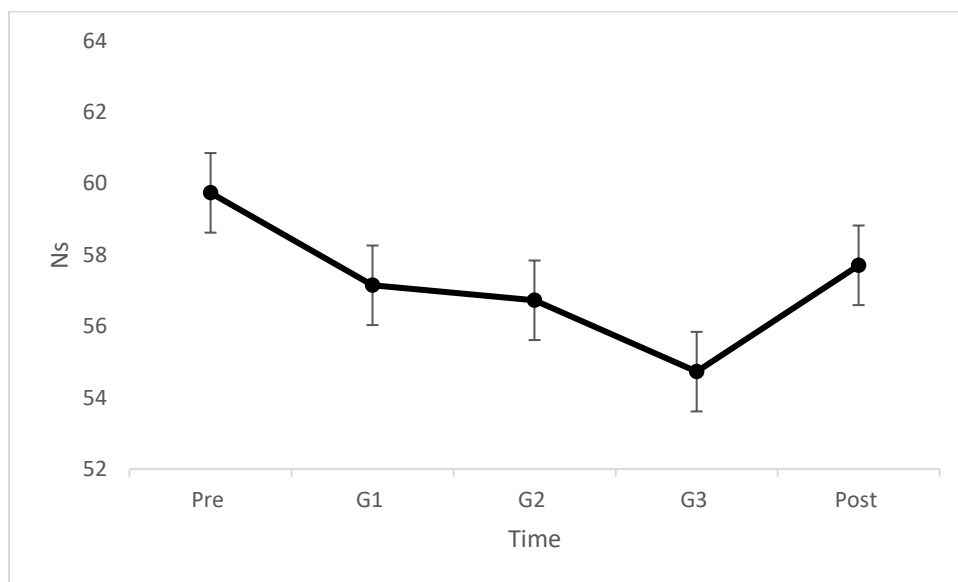
RSImod. with 95% confidence intervals



Analysis of variance showed a main effect of eccentric impulse over different time points ($F(4,48) = 3.147, p = 0.022$). CV (5.60) showed small intrasession variation for eccentric impulse. Results indicated significant differences between Pre-G3 ($p = 0.038$) (Figure 4.2). The effect size for this variable ($d = 0.992$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$).

Figure 4. 2.

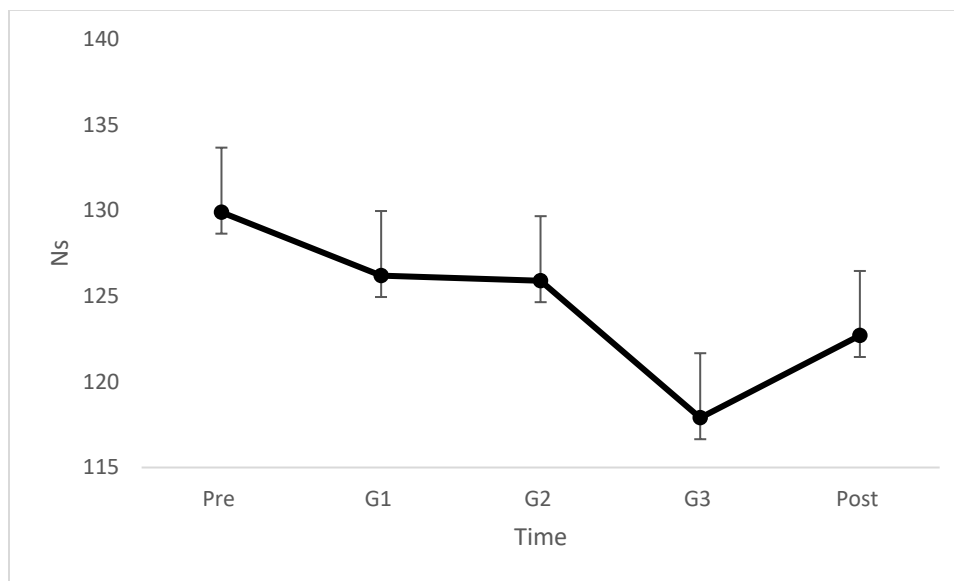
Eccentric impulse with 95% confidence intervals



Results indicated a significant effect on concentric impulse ($F(2.513,30.156) = 4.194, p = 0.010$). Concentric impulse yielded the smallest variation (CV, 3.46) in all the CMJ variables. There was statistical significance at Pre-G3 ($p = 0.003$), G1-G3 ($p = 0.049$), G2-G3 ($p = 0.034$), and G3-Post ($p = 0.041$) (Figure 4.3). The effect size for this variable ($d = 0.992$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$).

Figure 4. 3.

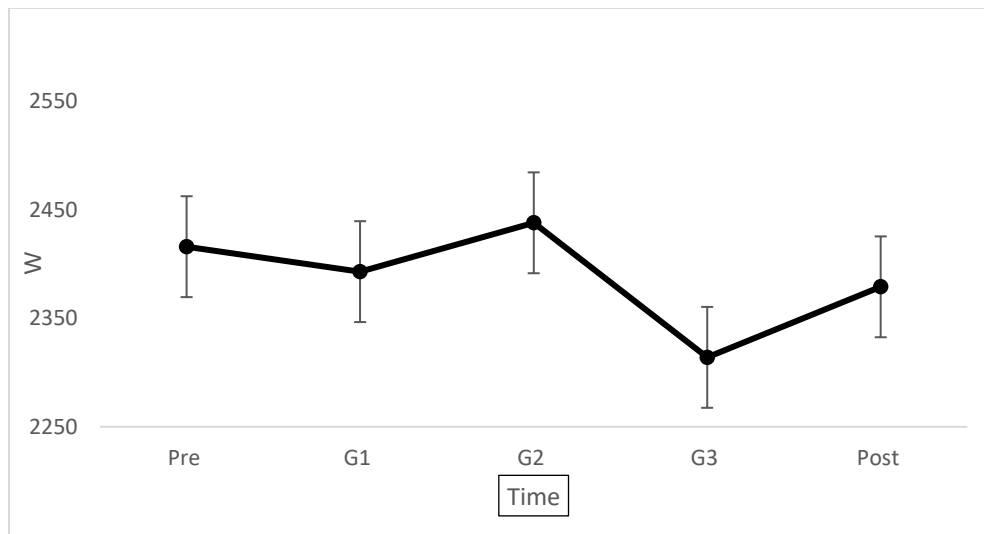
Concentric impulse with 95% confidence intervals



Results showed that there was a significant effect on peak power ($F(2.237,26.839) = 3.384, p = 0.044$) and there was a statistical significance at G2-G3 ($p = 0.007$) (Figure 4.4). Peak power produced small (CV, 4.66) intrasession variation. The effect size for this variable was found to exceed Cohen's (1988) convention for a large effect ($d = .80$) at time points Pre-G3 ($d = 1.383$), G1-G3 ($d = 0.954$), G2-G3 ($d = 1.010$), G3-Post ($d = 0.98$).

Figure 4. 4

Peak power with 95% confidence intervals



There was no statistical significance for peak force ($p = 0.892$), relative peak force ($p = 0.673$), and duration of eccentric impulse ($p = 0.531$). The effect size for this variable ($d = 1.520$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$).

Discussion

The aim of this study was to determine changes in countermovement jump (CMJ) variables in youth female soccer players during a congested match schedule.

The first main finding from this study is that RSI modified (RSImod), eccentric impulse, concentric impulse and peak power may be sensitive to fatigue in female youth soccer players. The second finding from this study is that match three may be the point in which youth female soccer players fatigue during a congested match schedule and indicate that congested match schedules do not allow adequate time for recovery.

RSImod has been identified and validated as a monitoring tool in the CMJ (McMahon et al., 2017) and is an indicator of an athlete's reactive, explosive ability (McClymont, 2003; Suchomel et al., 2015). Although previous research has shown that RSImod varies between

different explosive exercises and therefore any accumulated fatigue may cause impairment in RSI_{mod} values (Ebben & Petushek, 2010). Impairment to RSI_{mod} may cause decreases in performance of high-intensity activities (e.g. jumping or sprinting during soccer).

Eccentric impulse demonstrated a downward trend throughout the congested match schedule and most significantly between pre-tournament and match three. This may show that game three is an indicator of when the most fatigue is accumulated during a congested match schedule. Concentric impulse also showed a downward trend throughout the congested match schedule with a slight increase post-tournament. Significant differences between pre-tournament and game three, game one and game three, game two and game three, and game three and post-match indicate that game three is when the most impairment in concentric impulse is seen.

The concentric phase of the CMJ is preceded by an eccentric phase that lowers the body to a certain depth, changes in this depth have been proven to affect CMJ height (Mandic et al., 2015). Previous research has attributed differences in CMJ height to subjects being able to self-select a movement pattern or CMJ depth (Cormie et al., 2010; Mandic et al., 2015; Markovic et al., 2014; Moir et al., 2004). This is supported by studies that indicate CMJ height is insensitive to CMJ depth and that force and power are a better indicator (Bobbert et al., 2008; Domire & Challis, 2007). In contrast, other studies have suggested that CMJ depth does influence CMJ height (Kirby et al., 2011). This difference could be explained by the discrepancies in CMJ depth cited by available research (Mandic et al., 2015). These findings are similar to this study as both eccentric and concentric impulse were significantly impaired during the congested match schedule which may explain why other variables were impacted.

Peak power increased slightly after game two compared to pre-tournament and game one before seeing a significant decrease between game two and game three. These results may

explain at what point fatigue is highest during a congested youth soccer schedule. Results may also explain why peak power has been shown to be a useful recovery marker in previous research (Nedelec et al., 2013; Nedelec et al., 2014; Russell et al., 2015). Research has suggested that peak power is an indicator of athlete's ability to perform high-intensity activities (Bangsbo, 1994; Gajewski et al., 2017; Reilly & Rigby, 2002; Rey et al, 2010) and if impaired may impact an athlete's performance (Mohr et al., 2003). Although no other research has been conducted on youth female soccer players during a congested match schedule, the results from this study are similar to other studies that saw decreases in peak power over just one game in elite adult male and female soccer players (Moreira et al., 2016; Russel et al., 2016; Russell et al., 2015)

In summary, the findings from this study suggest that some CMJ variables are more sensitive to fatigue than other variables. Although all variables decreased throughout the congested match schedule those that were significantly altered were RSImod, eccentric impulse, concentric impulse and peak power. Also, game three seemed to be when fatigue had most impact on the variables previously mentioned. With that being said, more research is needed to fully understand how sensitive these variables are and if only sensitive at a certain level of fatigue.

While the methods used in this study are sound, there are limitations. The data were collected from one team in one age group over the course of one tournament. Future research should focus on a longer observational period in which players participate in multiple competitions of varying congestion (minutes played) and include a large cohort. It would also be beneficial for researchers to observe multiple age groups and determine if induced fatigue differs depending on maturation.

Practical Applications

Within the confines of the limitations reported, reviewing different variables of the CMJ may allow practitioners to have a more precise indication of player fatigue as these variables may help indicate a negative impact on performance. It is also recommended that coaches and sport practitioners monitor players throughout a congested match schedule to realize the moment fatigue sets in. If players are required to participate in three matches or more it would be beneficial for coaches and players to employ recovery strategies for fatigue management. This study may also be beneficial for youth practitioners and coaches for injury prevention during a congested match schedule as results showed there is a significant change in CMJ performance.

Coaches may have to adopt a substitution management policy when appropriate to help distribute minutes to try and mitigate fatigue during a congested schedule. If possible, it may be advantageous for coaches to implement a squad rotation strategy, where players are rotated out weekly for rest, so that players are not being exposed to congested match schedules every week. Also, coaches may be able to organize training structure to help prepare players for an upcoming congested match schedule or alter training structure after a congested match schedule.

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Chapter 5. Summary and future investigations

The purposes of this dissertation were to examine the effects of a congested match schedule on female youth soccer players physical performance, and the sensitivity of CMJ variables during that congested match schedule. To fulfill these purposes, the following were examined as individual research projects: 1) an investigation of the changes in jump height and sprint time during a youth soccer tournament and 2) an examination of changes in CMJ variables during a youth soccer tournament.

The results of study one indicated that a congested match schedule did affect jump height. It also indicated that there might not be sufficient time within the tournament format for players to recover, as jump height never reached pre-tournament scores. In addition, match three appeared to be a significant time point during the tournament. This may be an indication that fatigue is at its peak. Coaches should employ strategies to mitigate fatigue and reduce injury risk. The congested match schedule also affected sprint times indicating it may be a useful tool for coaches to monitor fatigue pre to post-tournament.

Study two examined the effects of a congested match schedule on different CMJ variables. Results from study two saw all variables (Relative Strength Index modified, eccentric impulse, concentric impulse, peak power, peak force, relative peak force) negatively affected by fatigue associated with the congested match schedule. Although, Only RSI modified, eccentric impulse, concentric impulse and peak power were significantly altered. Again, results indicated that match three was a key point during this congested format. Understanding these results may help sport practitioners to better understand how fatigue affects young female soccer players during a congested match schedule and the variables in a CMJ that may need to be monitored.

While this study was successful at highlighting the effects of a congested match schedule on sprint and CMJ performance in young female athletes during a congested match schedule, further research is needed at different age ranges, playing levels, and tournament formats. Also, a positional analysis, at the 11v11 age ranges, could be beneficial to help coaches further plan training sessions to accommodate accumulated fatigue during congested match schedules. To help enhance monitoring during matches, the use of GPS and accelerometry may help establish volume loads during a congested match schedule. Furthermore, injury rates should be utilized to help better understand the relationship between physical performance, fatigue and injury risk. Understanding these relationships will enhance player wellbeing and monitoring.

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