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Original Article

Relationship between hip and core muscular endurance and lower extremity injuries in division ii women's soccer

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Abstract

Soccer is popular worldwide and has seen recent growth in the United States, which has been associated with increased lower-extremity injuries. Recent studies have investigated the influence of core muscle endurance on sports injuries, but few studies have researched this in soccer, with none researching this influence on female player injury. The purpose of this study was to compare preseason core muscle endurance of Division II female soccer players who sustained injuries during the season to those who did not. Twenty-two female Division II soccer players (19.5 ± 1.22 years; 67.4 ± 7.42 kg; 166 ± 4.88 cm) participated in this study. Participants completed a series of four muscular endurance tests before and immediately after the season: hip abduction, hip external rotation, prone-bridge, and side-bridge. Hip abduction and external rotation tests were performed to exhaustion, with participants performing movements paced using a metronome at 30 bpm. Tests ended once participants were unable to keep pace. Static side- and prone-bridge tests ended when form could not be maintained. Independent t-tests were conducted to compare injured versus uninjured players. Eleven players sustained a lower limb sprain and/or strain injury during the season. Preseason left hip external rotator endurance and postseason right hip external rotator endurance were significantly lower in injured players ($p<0.05$). No other significant differences between the groups were observed. Preseason right hip external rotator endurance and post-season left hip external rotator endurance approached significance but were not statistically significant ($p>0.05$). Hip external rotator endurance may play a role in reducing injury in Division II women soccer athletes and therefore should be considered by coaches and athletic trainers when designing conditioning programs.

Keywords
Core endurance, Soccer injury, Sprain and strain injuries, Female Sport Injuries

Introduction

Soccer is the most popular sport with estimated 270 million players of different ages worldwide (Austin et al., 2021). In the last few decades, there has been a significant increase in the number of female soccer players (FIFA, 2019). It has been estimated that approximately 13 million women and girls play organized soccer (FIFA, 2019). This significant increase in the number of players is accompanied by an increase in the number of injuries. The cost of injuries is substantial on many levels including the financial cost. The estimated financial cost of injury in the 2008-2009 season of division I and II in Spain was 188 million euros (Fernández-Cuevas et al, 2010). Injuries from all soccer activities costed the Netherlands 1.3 billion euros in 2008 (Barengo et al, 2014). These injuries predominantly consist of different lower limb joints sprains and strains (Ekstrand et al, 2011; Hootman et al, 2007). Kerr et al. (2015) reported that in one soccer season, NCAA women soccer players experienced 15133 injuries, season, the greatest number in all US women's college sports.

Injury prevention continues to be a top priority in all sports and soccer is no exception. In fact, Fédération Internationale de Football Association (FIFA) developed an injury prevention program titled the "FIFA 11+" program in 2006 (Bizzini & Dvorak, 2015; Bizzini et al., 2013). The program has been shown to reduce the risk for injury in different subgroups of soccer players (Bizzini & Dvorak, 2015) as well as improve others aspects, such as balance and muscle strength (Arsenis et al., 2020). However, lack of adherence continues to be a major problem, particularly in amateur settings. One of the greater contributors to the lack of adherence is the time commitment needed. Even though its only 20 minutes, time becomes an issue during the season when many games are scheduled a few days apart (O'Brien et al., 2017). Recognizing the risk factors contributing to sport specific injuries would help pre-screen individuals before sport participation as well as focus prevention programs on these specific risk factors, thus, reducing the time dedicated to prevention.

Males and females experience injuries at a similar rate (Kerr et al., 2015), however, the specific injuries differ by gender. Hägglund et al. (2009) noted that injuries to the hip/groin were more common in male soccer players, while knee injuries were more common in female soccer players. They also reported that joint/ligament injuries (dislocation, ligament sprain, and meniscus/cartilage injury combined) were more common in elite

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female players compared to male (27% vs 19%). The greater number of knee injuries in females may be related to a wider pelvis in females (Lacasse & NJORORAI, 2021). A wider pelvis alters lower limb joint alignment leading to a greater moment arm for adduction moment caused by the ground reaction force. Thus, females experience greater hip adduction and internal rotation during the stance phase of running compared to males. In response, these hip motions likely lead to increased knee abduction and tibial external rotation observed in female runners (Ferber et al., 2003). This ultimately increases the eccentric demands on hip abductors and external rotators, resulting in difficulty to control these movements. The inability of these muscles to control hip movements may result in both acute and overuse knee injuries (Leetun et al., 2004).

Although the importance of the core (lumbo-pelvic-hip) to maintain postural control and prevent injury is recognized (Abdallah et al., 2019), few prospective studies investigated the relationship between core musculature measures and athletic injuries. Wilkerson et al. (2012; 2015) found a relationship between sprain and strain injuries sustained and core muscle static endurance in American college football players. Leetun et al.(2004) reported weaker hip abductors and external rotators in injured basketball players and runners compared to the uninjured. Abdallah et al. (2017; 2021) found that male soccer players with lesser prone-bridge and side-bridge times experienced more lower limb sprain and strain injuries than uninjured players. However, they tested trunk endurance variables and hip strength variables. Moore et al. (2011) reported an increase in soccer injuries as time passes suggesting fatigue is a major contributor. Thus, it is important to test muscle endurance in all core regions. In addition, since male and female players experience different types of injuries, it is likely female player injuries are related to different core variables, particularly hip related variables.

Thus, the purpose of this study was to compare core pre- and post-season muscular endurance of Division II women soccer players who sustained injuries to those who did not throughout the season. We hypothesized that players with greater muscular endurance would experience fewer low extremity injuries.

Materials And Methods

All methods and procedures were approved by our university's institutional review board in accordance with the declaration of Helsinki prior to data collection. Twenty-two, NCAA Division II female soccer players (19.5 ± 1.22 years; 67.4 ± 7.42 kg; 166 ± 4.88 cm) participated in this study. Participants were excluded if they were not cleared to play. Participants were instructed to arrive in proper workout attire; tennis shoes, shorts, and athletic top. Prior to testing, participants read and signed an informed consent, and completed a health history questionnaire. Participants then completed a dynamic warm up similar to what they typically do prior to game practice. This included a 100 m run at their own pace followed by a series of high knees, butt kicks, toe touches, side lunges, high kicks, and quad stretch. Upon completion, participants performed each of the following core muscular endurance tests in a counterbalanced order: Hip abduction, hip external rotation, prone plank, and side planks. Each endurance test was completed until failure. Testing was first conducted before the start of the season, participants came back for retesting after the end of the season (three months later). In this study, the core was operationally defined as the lumbo-pelvic-hip complex.

Endurance tests

Hip abduction (Figure 1)

Procedures for this test were similar to those used by Van Cant et al. (2016) with a modification of hip abduction angles. In their study, Van Cant et al., used hip abduction range of motion between -10° and 30°. Since the hip is typically slightly abducted in a typical standing position, we used hip abduction range of motion between 10° and 30°. Participants were instructed to get into a side-lying position on the examination table with their evaluated hip placed superiorly in neutral alignment. Four points of contact were to remain against wall at all times during the test; the back of their head, shoulder blades, buttocks, and ipsilateral heel. While keeping their ipsilateral knee extended, hip in neutral rotation and aligned with the trunk and maintaining their pelvic frontal plane alignment. The non-testing limb was flexed at the hip and knee to increase their base of support. Their top arm was placed on their hip, while their head rested on their bottom arm, to encourage neutral alignment of the body across all points. The 10° and 30° hip abduction angles were determined using a goniometer and markers for these angles were placed on a wall. The marker at 10 degrees represented the start position (Figure 1a), while the marker at 30 degrees indicated the ending point for each repetition (Figure 1b). Wall markers were also used for tactile feedback. If participants were unable to feel the marker, researchers placed their hands on the wall to provide feedback. Participants were asked to perform their maximum number of hip abduction movements at a rate of one repetition of abduction for every two seconds, as given by a metronome. Repetitions were counted and recorded. Faults in positioning for hip abduction were classified as: any of the four points of contact moving off of the wall, inability to keep pace with the metronome, or incompletion of a full repetition. Participants received a verbal warning once a first fault took place and the test ended once a second fault took place.

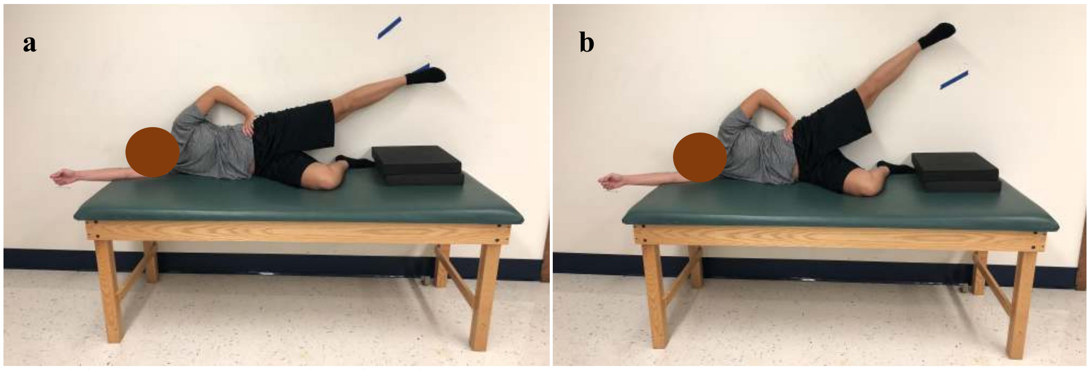

Figure 1. Hip abduction test a. start position b. end position.

Hip external rotation (Figure 2)

Participants were instructed to get into a similar side-lying position as the hip abduction test, but brought both knees into a flexed position (Figure 2a). Participants externally rotated their top leg until it reached maximum external rotation (Figure 2b), then moved their leg back down to starting position. This test was completed at a rate of on repetition for every two seconds per metronomic beat. The same rules as hip abduction applied to hip external rotation to determine when to end the test.

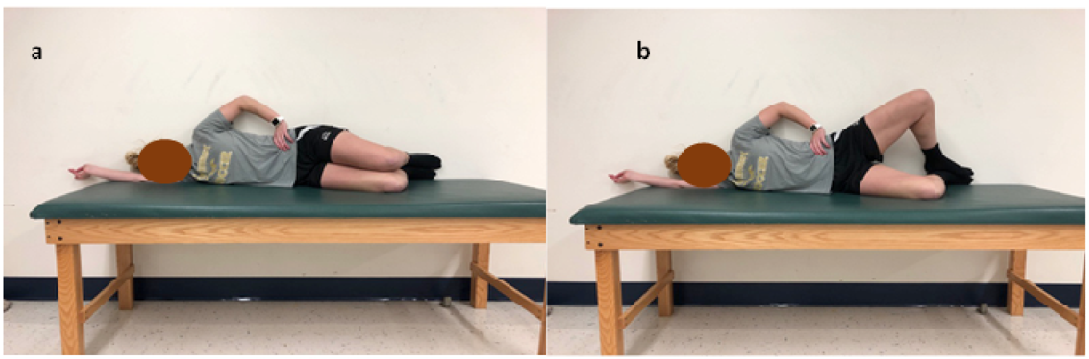

Figure 2. Hip external rotation test a. start position b. end position.

Prone plank (Figure 3)

Participants were instructed to hold a standard plank position i.e. a prone bridge supported by the forearms and feet (McGill et al., 1999) until failure. Elbows were placed directly below the shoulders with the forearms neutral, fingers extended, and hands stacked. Their neck was kept in a neutral position so that the body remained straight across all points. A break in form was determined by: hips dropping or raising, shifting too far left or right, breaking away from neutral alignment. Time to failure was measured with a stopwatch.

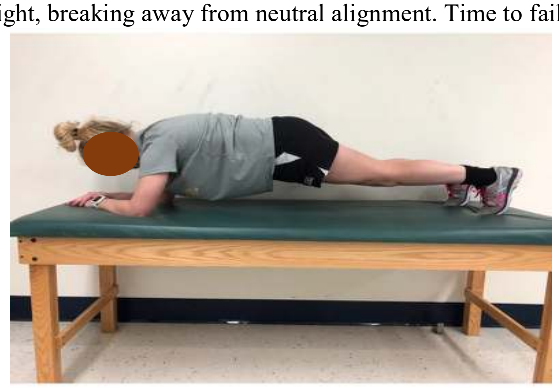

Figure 3. Prone plank test

Side plank (Figure 4)

Participants were instructed to lay on their side prior to beginning the test. Once participants were ready, they stacked one foot on top of the other, with their bottom arm perpendicular to the examination table, with their top arm extended up vertically (McGill et al., 1999). Participants were encouraged to hold this position until failure. A break in form was determined by: hips dropping or raising, shifting too far left or right, breaking away from neutral alignment. Time to failure was measured with a stopwatch.

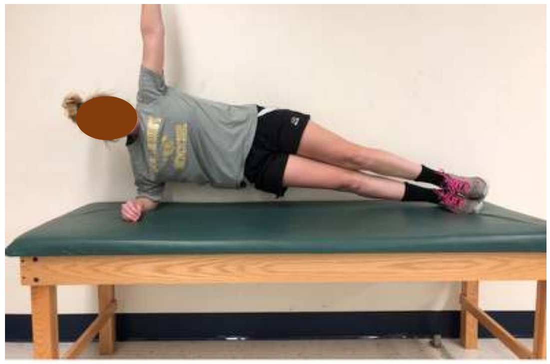

Figure 4. Side plank test

Team athletic trainers recorded and provided all injuries experienced by players throughout the season (August 18 – October 28), which included 20 games. Lower limb and trunk sprain and strain injuries that led to missed practice or game time were used in our comparison. A series of one-tailed paired t-tests were used to compare endurance test performance of players that experienced injury to those who did not. P values of less than 0.05 indicated significance.

Results

Table 1 shows all injuries experienced during the season with time loss and minutes played for players that experienced injury. Eleven players sustained a total of 19 lower limb and/or trunk sprain and/or strain injuries throughout the season. Ankle injury was the most common with six injuries, followed by the knee with five injuries. No players experience a recurrence of the same injury.

Table 1. Complete list of injuries resulting and time loss from practice and games.

Subject	Body Part	Injury Type	Side	Days Lost	contact/noncontact
1	Knee	Patellar subluxation	Left	5	contact
1	Thigh	Rectus femoris strain	Right	1	noncontact
4	Ankle	Anterior talofibular sprain	Right	3	noncontact
4	Ankle	Deltoid ligament sprain	Right	3	noncontact
5	Foot	Midfoot ligament sprain	Right	2	contact
9	Knee	Patellar tendinitis	Left	<1	noncontact
11	Ankle	Tibialis anterior strain	Right	<1	noncontact
11	Ankle	Anterior talofibular sprain	Right	<1	noncontact
12	Knee	Patellar fat pad syndrome	Right	1	noncontact
12	Foot	Inflammation of the foot	Right	7	noncontact
13	Hip	Partial tear of the labrum	Right	30	contact
14	Knee	Patellar osteochondritis dissecans	Left	<1	noncontact
14	Knee	Mediopatellar plica	Right	<1	noncontact
14	Ankle	Transverse ligament sprain	Right	4	noncontact
16	Thigh	Semitendinosus strain	Left	7	noncontact
16	Foot	Midfoot ligament sprain	Left	2	contact
16	Ankle	Anterior talofibular sprain	Right	<1	noncontact
20	Lower Back	Erector spinae strain	Left	3	noncontact
22	Thigh	Quadriceps contusion	Right	<1	contact

Table 2 displays descriptive data measurements taken prior to pre- and post-season testing, in addition to the means and standard deviation for all endurance tests in uninjured and injured players. Both injured and uninjured players showed similar age, weight, and height. With the exception of hip external rotator endurance, both injured and uninjured players showed similar muscle endurance test results.

Table 2. Mean and standard deviation descriptive statistics and test scores for injured and uninjured players.

	Pre-season		Post-season	
	Uninjured	**Injured**	**Uninjured**	**Injured**
Age (Years)	19.45 ± 1	19.55 ± 1	19.45 ± 1.3	19.55 ± 1.2
Height (cm)	166.55 ± 4	165.45 ± 5	166.55 ± 4.7	165.45 ± 5.3
Mass (kg)	68.97 ± 6	65.73 ± 8	68.52 ± 7.0	66.15 ± 7.0
Right Hip Abduction (Reps)	45.27 ± 13	46.18 ± 24	49.82 ± 23.4	50.60 ± 13.6
Left Hip Abduction (Reps)	44.55 ± 12	51.82 ± 34	50.55 ± 13.5	52.10 ± 28.6
Right Hip External Rotation (Reps)	72.55 ± 37	51.09 ± 37	128.64 ± 50.6	70.80 ± 53.2
Left Hip External Rotation (Reps)	74.00 ± 50	42.91 ± 29	114.09 ± 48.9	76.20 ± 58.8
Right Side Plank (s)	51.30 ± 14	55.27 ± 22	47.64 ± 8.6	61.67 ± 33.8
Left Side Plank (s)	50.80 ± 12	56.64 ± 24	49.89 ± 9.7	67.23 ± 46.1
Standard Plank Time (s)	82.73 ± 17	87.00 ± 37	86.05 ± 16.0	87.39 ± 39.0

Figure 5 shows preseason hip external rotator endurance on the right and left sides for both injured and uninjured players. Both right and left external rotator endurance appear to be greater in the uninjured players. However, our statistical analysis shows significantly greater endurance on the left side only (p<0.05), while that on the right side approached significance (p=0.09).

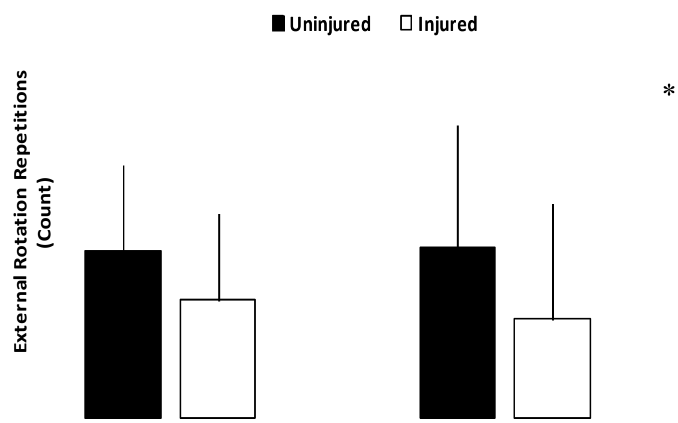

Figure 5. Mean ± s preseason hip external rotator endurance for uninjured and injured players. * indicates significance p<0.05

Figure 6 shows postseason hip external rotator endurance on the right and left sides for both injured and uninjured players. Similar to the situation in preseason, both sides appear greater in the uninjured players, however, only the right was statistically greater (p<0.01), while the left side approached significance (p=0.06).

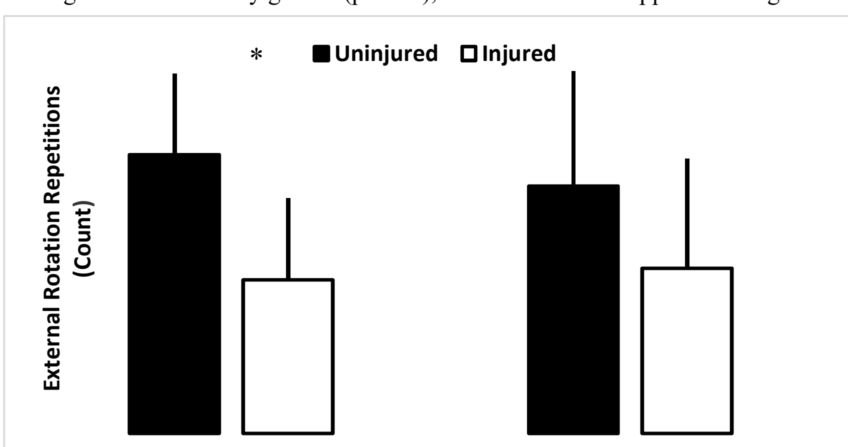

Figure 6. Mean ± s postseason hip external rotator endurance for uninjured and injured players. * indicates significance p<0.05

Discussion

The purpose of this study was to compare pre- and post-season core muscular endurance of players who sustained injuries to those who did not throughout the season. Uninjured players had greater hip external rotator endurance than injured, both pre- and post-season. Specifically, left side pre- and right-side post-season hip external rotator endurance were significantly different. However, both the right side pre- and left side post-season hip external rotator endurance approached significance. We speculate that if we had more participants, both would show significance. No other dependent variables were significantly different.

Muscle fatigue can be defined as “any exercise induced loss of ability to produce force with a muscle or muscle group” (Taylor et al., 2006). Thus, low muscle endurance can lead to injury under similar mechanisms to muscle weakness, only at a later time during performance, when a muscle can no longer sustain the same force production it was able to earlier. Since the gluteus maximus (GM) is the primary hip external rotator (Neumann, 2010), we believe it is the primary muscle responsible for the difference between groups. GM function not only affects transverse plane movements but also affects sagittal plane movements since it is the primary hip extensor (Neumann, 2010). Thus, even though hip extensor endurance was not assessed, it is likely that sagittal plane injury mechanisms may also have been involved in the resulting injuries.

Ankle and foot injuries:

Ankle injuries were most common in our study making up 32% (6 out of 19) of injuries. Few studies have shed light on the relationship between hip muscle strength and ankle injuries. De Ridder et al. (2017) reported reduced preseason GM strength in male youth soccer players who experienced ankle injury compared to those who did not. They attributed these findings to a decrease in the ability to control body center of mass (CM) movements during closed kinetic chain activities. Under normal circumstances, excessive CM movements are controlled through eccentric actions of the GM. However, if the forward momentum is beyond the capacity of the GM to resist, CM movement would be controlled by passive structures including ligaments, which can result in their rupture. In fatigued conditions, joint work is redistributed to be more proximal (Sanno et al., 2018), thus increasing the load on the GM and reducing the load on ankle muscles. When the GM is unable to produce enough force, redistribution of load is less likely, thus increasing the load on ankle muscles, making the ankle joint more suasible to injury (De Riddle et al., 2017).

Even with our findings, we cannot say with certainty that reduction in hip external rotator strength led to ankle sprain and not the other way around. Participants in our study were injury free, however, we recognize that ankle injuries are the most common soccer (Roos et al., 2017) and are one of the most underreported injuries as athletes tend to underestimate the seriousness of injury with more than 55% of injured individuals not seeking treatment from a healthcare professional (Hertel, 2002). In addition, Dedieu et al. (2017) reported a change in hip mechanics in injury free individuals between one and three years after ankle injury. Thus, it is possible and even likely that players in our study have experienced previous ankle sprains that influenced hip musculature many years after the initial injury. Webster and Gribble (2013) reported reduced GM activation during a closed chain task in individuals with chronic ankle stability compared to controls. However, they were unable to confirm whether reduced GM activation led to chronic instability or vice versa since participants displayed both at the time of testing. Similarly, Delahunt et al. (2006) reported reduced hip external rotation in individuals with ankle instability compared to controls right before impact with the ground during a landing task. Whether it was a reduction in hip external rotator endurance that led to injury or vice versa, improving endurance can be beneficial in reducing future injuries.

Knee and thigh injuries:

Weak hip external rotators have been associated with lower limb injuries similar to what our participants experienced. This is consistent with the retrospective studies that reported lesser hip external rotator strength in women with patellofemoral pain syndrome (PFP) compared to controls (Souza & Powers, 2009; Bolgla et al., 2008; Cichanowski et al., 2007; Piva et al., 2005; Ireland et al., 2003). Souza and Powers (2009) also observed increased hip internal rotation during running, stepping down, and landing from a jump in patients with PFP compared to controls. Reduced hip external rotator strength can lead to the inability to control hip internal rotation, leading to an increase in Q-angle, resulting in increased lateral compressive forces at the patellofemoral joint (Ireland et al., 2003; Powers, 2003). Souza and Powers (2009) also reported a decrease in hip extensor endurance in patients with PFP. In a prospective study, Boling et al. (2009) reported that individuals who developed PFP had increased internal rotation. However, their participants also had increased hip external rotator strength compared to those who did not. They hypothesized their participants experienced greater internal rotation resulting from abnormal foot mechanics, a repeated attempt to limit internal rotation experienced during different activities resulted in stronger external rotators. However, in our study, participants who experienced injury had lesser hip external rotator endurance; thus, we hypothesize they experienced repeated excessive hip internal rotation later in games, when it was difficult for external rotators to resist the motion.

Similar to the situation with patellofemoral pain. When the GM becomes fatigued, individuals will go into a more upright posture to move the ground reaction force vector closer to the hip joint. This results in an increase in the moment arm of the ground reaction force at the knee joint, thus, increasing the load on the quadriceps. This increase in quadriceps load would ultimately lead to its strain. (Powers, 2010). A reduction in

GM activation can also result in an increase in hamstring load, which could be the cause of the semitendinosus strain observed in another one of our participants.

Lower back injury:

One player experienced an erector spinae strain. The erector spinae is functionally coupled with the GM in controlling trunk flexion and extension (Leinonen et al., 2000; Kankaanpää et al., 1998). Leinonen et al. (2000) reported that patients with low back pain activated the erector spinae before the GM at the start of trunk flexion compared to healthy controls who activated both muscles simultaneously. They also reported that patients with low back pain relaxed both muscles simultaneously at the end of flexion, whereas controls relaxed the erector spinae before the GM. Eccentric muscle actions are contributors to muscle strain injuries since muscle forces are higher during lengthening (Kirkendall & Garrett Jr, 2002). Thus, we propose that with a fatigued GM, the erector spinae would be left bearing a greater load while controlling truck flexion, ultimately leading to muscle strain.

Hip external rotation endurance improved over the season (Figures 5 & 6), which may have been caused by the in-season fitness program provided by the team strength and conditioning staff. The program emphasized lower body power and muscle endurance. In addition, during the action of a soccer kick, there is transverse rotation of the pelvis, which causes the external rotators on the kicking side to contract concentrically, while the external rotators on the opposite leg contract eccentrically. These contractions occur repeatedly throughout the season, thus, may be have significant contribute to the improved external rotator endurance observed at the end of the season.

Since the difference between groups was consistent before and after the season, it may be tempting to consider screening at any point throughout the season. This may be more complicated considering the number of repetitions performed by uninjured players before the season were similar to those performed by injured players after the season. It should be noted that nine out of the 19 injuries experienced occurred in August (first 2 weeks of the season), thus, there may be a specific level of endurance that may give athletes a level of protection. A more detailed study is warranted.

Finding in our study are limited to female Division II soccer players compared to different gender and level players. Professional male soccer players have been found to experience more injuries when they have lesser trunk muscle endurance (Abdallah & Hegazy, 2021). In addition to structural differences between men and women, level of play is also important to consider. In our study, participants were Division II soccer players, participants in the Abdallah and Hegazy study were professional players. In addition to the longer play time professionals experience (professional games allowed 3 substitutions at the time, college soccer allows unlimited substitutions), the professional game is more intense with a faster pace. Our results may have been different had we studied Division I or professional women soccer players.

Sample size is a limitation in this study as well. However, we were limited to the players on the team who met the inclusion criteria. Future studies should recruit players from different teams to get a larger sample and better representation of Division II female soccer players.

Lastly, it is important to recognize that hip muscle endurance is one of several factors contributing to lower limb injuries in Division II female soccer athletes. Thus, should be thoroughly investigated. Most studies focus on strength only and ones that include endurance have focused on primarily trunk endurance combined with hip strength (Abdallah & Hegazy, 2021). Khayambashi et al. (2016) assessed preseason hip muscle strength and found that strength accounts for only 11% of the variation in ACL injury. It is possible their results would have been different, had they considered hip muscle endurance.

Conclusions

The increase in female soccer participation has been accompanied by a rise in injury rates. Previous studies have explored the association between injuries and core muscle strength and endurance. However, limited research has focused specifically on female soccer players. This study aimed to investigate the relationship between core muscle endurance and injury occurrence among Division II female soccer players.

To assess core muscle endurance, hip external rotation, hip abduction, prone-bridge, and side-bridge exercises were used. A comparison was made between players who sustained injuries during the season and those who remained uninjured.

The findings revealed that uninjured players exhibited significantly greater hip external rotation endurance compared to injured players both before and after the season. These results suggest that emphasizing the development of hip external rotation endurance during the preseason may be beneficial for injury prevention.

Further research should be conducted to explore the significance of the number of hip external rotation repetitions at different points in the season. Additionally, a more comprehensive investigation into the relationship between hip external rotator endurance and injury across various levels of play is warranted.

In conclusion, this study contributes to our understanding of the importance of core muscle endurance in preventing injuries among female soccer players. Coaches and trainers are encouraged to prioritize the development of hip external rotation endurance in their training programs. By doing so, they may help reduce the risk of injuries and enhance the overall performance and well-being of the players.

Acknowledgments

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Conflicts of interest

The authors report there are no competing interests to declare

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