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ORIGINAL RESEARCH

A COMPARATIVE STUDY OF CORE MUSCULATURE ENDURANCE AND STRENGTH BETWEEN SOCCER PLAYERS WITH AND WITHOUT LOWER EXTREMITY SPRAIN AND STRAIN INJURY

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ABSTRACT

Background: Lower extremity sprain and strain injury constitutes a large percentage of lower extremity injuries experienced by soccer players. Yet, very limited data exists on the association between core strength and endurance and this injury.

Purpose: The purpose of this study was to compare core muscle endurance and hip muscle strength between soccer players who experienced non-contact lower extremity sprain and/or strain injury during their season and those who did not. Additionally, the frequency of injury was correlated with core muscle endurance and hip strength, and endurance was used for predicting the risk for injury.

Study Design: Prospective cohort

Methods: Twenty-one (35.59%) athletes experienced non-contact lower extremity sprain and/or strain injury during the season. Fifty-nine male athletes (mean age 20.92 ± 4.08 years, mass 77.34 ± 12.02 kg and height 1.79 ± 0.06m) were tested. Prior to the start of the season, prone-bridge, side-bridge, trunk flexion and horizontal back extension hold times were recorded for endurance assessment and peak hip abductor and external rotator isokinetic torques for strength assessment.

Results: Prone-bridge and side-bridge hold times were significantly longer in the non-injured players when compared with the times of the injured players ($p = 0.043$ & 0.008 for the prone-bridge and side-bridge, respectively). There were significant negative correlations between the frequency of injury and both prone-bridge ($r = -0.324$, $p = 0.007$) and side-bridge ($r = -0.385$, $p = 0.003$) hold times. Logistic regression analysis revealed that side-bridge hold time was a significant predictor of injury (OR = 0.956, CI = 0.925-0.989).

Conclusion: Soccer players with non-contact lower extremity sprain and/or strain have less core endurance than non-injured players. Reduced core endurance is associated with increased incidence of injury. Improving side-bridge hold time, specifically, may reduce the risk for injury.

Level of evidence: 1b

Keywords: Core endurance; hip strength, soccer; sprain and strain injuries

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INTRODUCTION

Soccer is a worldwide team sport that involves repetitive high-velocity activities including running, jumping, sprinting, ball-kicking, changing direction, acceleration, deceleration, and physical contact with the opponents. This imposes great technical, physical and physiological demands that increase the risk for injury.[1,2] Most soccer injuries occur in the lower extremities (61-82%) especially at the ankle (28%) and knee (19%)[3,4] with sprain and strain injuries constituting more than one-half of all collegiate injuries that require athletic trainer attention.[5] That is why clubs invest in time and resources for reducing injury incidences.[6]

A theoretical framework of the association between core muscle dysfunction and musculoskeletal injury became popularized over the past decade with limited scientific evidence.[7] Adequate core (lumbo-pelvic-hip) musculature neuromuscular control is required during lower limb dynamic activities to assure dynamic joint stability.[8,9] Improper control predisposes lower limb joints to uncontrolled displacements, and excessive loading.[9,10] Upon exceeding supporting soft tissue tensile threshold, these excessive stresses can cause mechanical failure.[11]

Imbalance in core musculature strength that controls pelvic-femoral alignment in the transverse and frontal planes causes lower limb misalignment that may increase the risk for injury.[12] Strong hip abductors and external rotators are necessary in unilateral limb support activities involved in soccer to avoid excessive hip adduction and internal rotation.[13] The position of hip adduction and internal rotation that is associated with knee valgus and tibial external rotation is referred to as the "position of no return" being responsible for many injuries including anterior cruciate ligament injury.[14] A negative correlation was previously reported between hip abductor peak torque (normalized to body mass) and dynamic knee valgus[15] with every 1% increase in peak torque showing a decrease of 0.216° in knee valgus.[16] Similarly, a negative correlation was reported between hip external rotator strength and knee valgus.[17] Athletes with weak hip abductors and/or external rotators have increased dynamic knee valgus.[17-19] In the same context, hip muscle activity affects the force production ability of the quadriceps and hamstrings together with affecting their ability to resist forces experienced by the lower limb during jumping.[20]

Very few studies have examined the association between core stability measures and musculoskeletal injury[10,21-23] and none of them dealt with soccer athletes. In addition, several limitations were identified in these studies. Leetun et al.,[21] assessed hip muscles' strength, however they examined isometric forces not isokinetic torques. Torque measurement takes in consideration height differences. For instance, if the injured players were systematically taller than the non-injured players, the difference between both groups in torques might have been less significant than force measurements.[21] Their study used a hand-held dynamometer for strength (force) assessment not an isokinetic dynamometer (torque). Pre-season isokinetic strength testing has been identified as a useful tool for identifying soccer players that are potentially at risk for injury. Testing helped in detecting strength imbalances that increased the risk of hamstring injury.[24] Specifically, impairment in eccentric hamstring action required in high velocity acceleration and deceleration activities of soccer is associated with elevated risk for joint and muscle injury.[25]

In an attempt to identify the risk factors for injury, Wilkerson et al.[10] and Wilkerson and Colston[23] constructed a prediction model for core and lower extremity sprain and strain injury in football players. However, several limitations were identified that might have confounding effects on prediction power. They examined players with and without low back dysfunction. Low back dysfunction increases the susceptibility to lower extremity injury.[21,22,26] In addition, they examined a combination of risk factors including core endurance, level of low back dysfunction, and game exposure to predict sprain and strain injuries of both the core and lower extremities. Thus, the recorded and analyzed injuries were neither specific to core stability measures nor specific to the lower extremities. The intention of the current study was to examine the isolated contribution of core endurance and strength to lower extremity injury only.

Since there are very limited data on the association between core stability and injury in the literature, it was of interest to compare core muscle endurance and hip muscle strength in injured players with those of non-injured players. Rapid core musculature fatigue is reflected in poor core stability.[27,28] For instance, fatigue of hip and lumbar extensors, specifically, has been shown to contribute to forward trunk lean[29] as well as reduced trunk proprioception[28] and neural activation of lower limb muscles.[26] The time a player is able to maintain static postures during core endurance tests that load the core musculature is valuable for quantifying the risk for injury.[10] Thus, the purpose of this study was to compare core muscle endurance and hip muscle strength between soccer players who experienced non-contact lower extremity sprain and/or strain injury during their season and those who did not. Additionally, the frequency of injury was correlated with core muscle endurance and hip strength, and endurance was used for predicting the risk for injury.

Finally, core muscle endurance was used for predicting injury. Core endurance was the measure of interest as it is the most reliable measure of core stability followed by flexibility, strength, neuromuscular control and functional testing.[30] It was hypothesized that injured players would present with low core muscle endurance and diminished hip muscle strength. In addition, it was anticipated that low endurance would be associated with increased frequency of injury.

METHODS

Participants

Fifty-nine male professional soccer players (age 16-35 years and BMI 19.2-29.7 kg/m[2)] were tested after giving informed consent. They were recruited from four clubs. To participate in the study, players needed to have a manual muscle test score of five for back and abdominal muscles.[31] Other inclusion criteria included no history of sprain or strain injury during the previous season, no forms of lower limb or trunk trauma or back pain within the past year of testing,[32] and no tightness in the hamstrings or iliopsoas muscles. No limit was set for the number of participants, however, 82 players volunteered, out of which 59 met the inclusion criteria.

Instrumentation

McGill core endurance tests[33] were used for endurance assessment. These included the prone-bridge, side-bridge, trunk flexion and horizontal back extension tests. One's maximum ability to hold the test position was recorded in seconds.

The Biodex System 3 Pro multi joint testing and rehabilitation system (Biodex Medical System, Shirley, NY, USA) was used to assess peak hip abductor and external rotator isokinetic torques. The system is an objective, reliable, and safe method for strength assessment with an intraclass correlation coefficient (ICC) of 0.99.[34] It provides a valid measurement of angular position, torque and velocity. It is also used for training of different groups of muscles in the upper and lower limbs as well as the trunk.[35] Calibration of the Biodex dynamometer was performed according to the specifications outlined in the manufacturer's service manual. The Biodex Advantages Software v.3.33 corrected all torque values for the effect of gravity acting on the mass of lower leg and the mass of the dynamometer arm.

Procedures

The purpose of the study and the testing procedure were fully explained to the participants. Participants' personal data were collected and the specified inclusion and exclusion criteria were verified. Leg dominance was specified for each participant; the preferred leg for kicking the ball.

Core muscle endurance was assessed first followed by isokinetic hip muscle strength assessment. The prone-bridge test assesses primarily the anterior and posterior core muscles. It was conducted with the participant supporting body weight between the forearms and toes. The participant was instructed to keep the pelvis in a neutral position and the body straight (Figure 1A). The total time the participant was able to lift his pelvis from the table was recorded using a stopwatch. Failure was defined as when the participant lost neutral pelvis position and fell into excessive lumbar lordosis with anterior pelvic rotation.[36]

The side-bridge test assesses lateral core muscle capacity, particularly the quadratus lumborum**.** It was conducted with the participant side-lying on the right side with the top foot being in front of the bottom and the hips at zero degrees of flexion. The participant was asked to lift his hips off the treatment

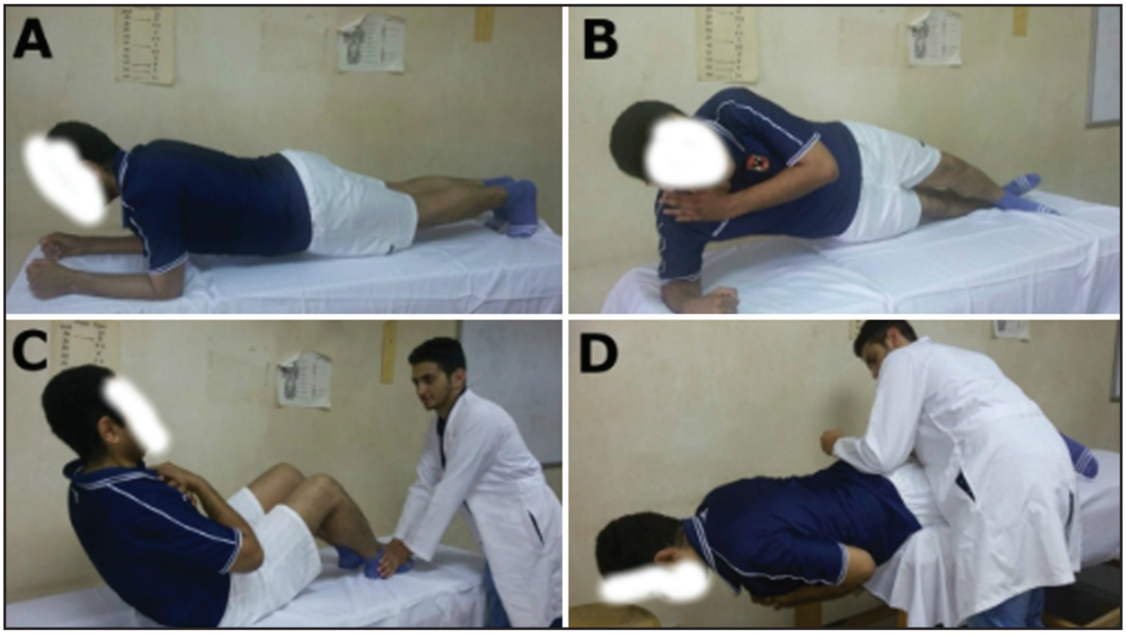

Figure 1. *Core endurance tests; prone-bridge (A), side-bridge (B), flexor endurance (C), and horizontal extensor endurance*

table, using only his feet and right elbow for support. The left arm was held across the chest with the hand placed on the right shoulder (Figure 1B). The total time the participant was able to lift his lower hip from the table was recorded using a stopwatch. Failure was defined as when the participant lost his straight posture and the hips fell towards the table. McGill et al.[34] previously documented no significant difference between right and left side-bridge endurance times. Therefore, the recorded time for the right lateral core muscles (dominant side) was used for data analysis.

The flexor endurance test assesses anterior core muscles. It was conducted through recording the time the participant held a seated torso flexion position against gravity. The torso was flexed at 60° and the knees and hips flexed at 90°. The toes were secured by the examiner (Figure 1C). Failure was defined as when the participant's torso fell below 60°.

Finally, the horizontal back extension test "modified Biering-Sorensen test" assesses the muscle capacity of the posterior core.[34] It was conducted with the participant lying prone with the upper body held straight over the end of the table, and the pelvis, hips, and knees secured on the table by the examiner (Figure 1D). The total time the participant was able to maintain the trunk in a horizontal position until he touched down on the bench in front of him with his hands was recorded in seconds using a stopwatch. Failure was defined as when the upper body fell from a horizontal into a flexed position.

Eccentric strength testing of the external rotators and hip abductors was performed through a range of 0-30 degrees at an angular velocity of 60 degrees.[37] Eccentric hip external rotator isokinetic testing was conducted with the participant seated with 90º of hip and knee flexion. The trunk and thigh of the tested lower limb were stabilized using straps. The dynamometer axis of rotation was aligned with the long axis of the femur and the resistance was applied proximal to the medial malleolus. The participant was instructed to exert maximum resistance against the dynamometer in the direction of hip external rotation (Figure 2A).

Hip abductors were assessed with the participant side-lying and the tested lower limb on top of the untested**.** The untested limb and trunk were stabilized with straps. The dynamometer's axis of rotation was aligned medial to the anterior superior iliac spine at the level of the greater trochanter of the tested lower limb and resistance was applied to the lateral aspect of the distal thigh, superior to the lateral femoral condyle. The participant was instructed to exert maximum resistance against the dynamometer in the direction of hip abduction (Figure 2B).

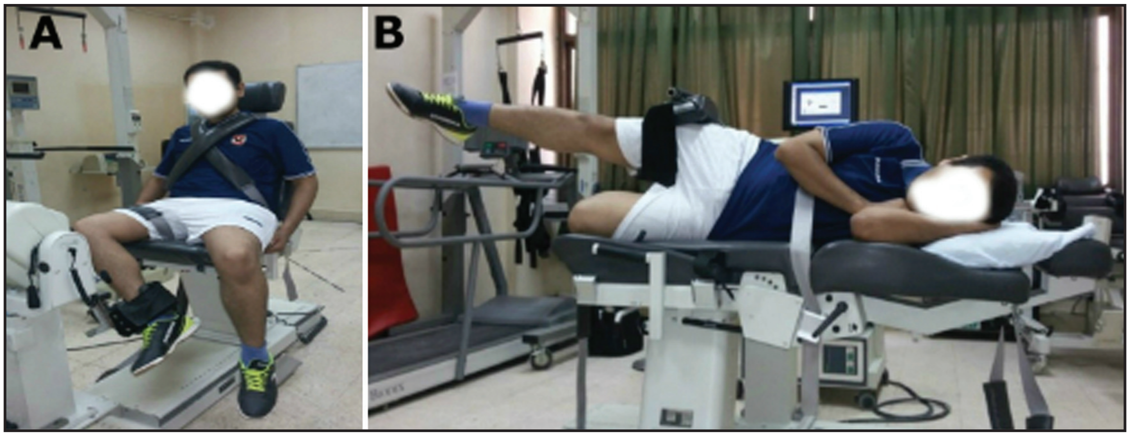

Figure 2. *Eccentric Isokinetic testing positions for the hip external rotators (A), and abductors (B)*

All torque data were normalized to body mass and expressed as Nm/kg.

Assessment of both endurance and strength was conducted once before the season. The number of non-contact sprain and strain injuries was reported by team doctors. Injuries were recorded when they resulted in time away from games or practice. All injuries including recurring injuries were recorded throughout the season. Multiple different injuries experienced by the same players were also documented.

Data analysis

Immediately after the end of the season, the players were dichotomously categorized into injured (group A) or non-injured (group B) for data analysis. Initially and as a pre-requisite for parametric analysis, data were screened for normality and homogeneity of variance assumptions. After removal of the outliers and assuring that data did not violate assumptions for parametric analysis, MANOVA was conducted. Core muscle endurance and hip muscle strength measures were compared between both groups using MANOVA with subsequent multiple pairwise comparison tests conducted using a Bonferroni adjustment of a family wise 0.05-alpha level (SPSS version 17, Chicago, IL). Core muscle endurance measures were the maximum times (in seconds) the player held his posture in the prone-bridge, side-bridge, trunk flexion and horizontal back extension tests while the hip muscle strength measures were the peak hip abductor and external rotator isokinetic torques.

Additionally, Spearman correlations were conducted to test the association between core muscle endurance and hip muscle strength measures and frequency of injury. Significant variables identified from the MANOVA and correlation analyses were used to predict the probability of injury using a logistic regression analysis. Significant variables were used as independent variables (predictors) and injury occurrence as the dependent variable (injury presence = 1, and injury absence = 0). The process began with simultaneous entry of the predictors into the model and was followed by backward stepwise elimination of the predictor that showed no significant contribution to the prediction power.

RESULTS

A total of 21 (35.59%) of the 59 players reported at least one non-contact lower extremity sprain or strain injury during the season. No between-group differences were found for all demographic variables ($p > 0.05$; table 1). The injured players sustained 43 injuries; 24(56%) ankle sprains, 9 (21%) knee lateral collateral ligament sprains, 1 (2%) knee medial collateral ligament sprain, 4 (9%) quadriceps strains, 2 (5%) hip adductor strains, 2(5%) calf strains and 1 (2%) hamstring strain (Figure. 3). The frequency distribution of soccer players according to the frequency of non-contact lower extremity sprain and/or strain injury is shown in Figure 4.

MANOVA analysis showed no significant difference between both groups for core muscle endurance and hip muscle strength measures ($F = 2.136$, $p = 0.067$). However, the subsequent pairwise comparison

Table 1. *Demographic data for the injured and non-injured soccer players.*				
	Descriptive statistics (Mean ± SD)		Unpaired t-tests	
	Group A (Injured)	Group B (Non-injured)	t-value	p-value
Age (years)	20.05 ± 4.2	21.39 ± 3.9	-1.22	0.28
Mass (kg)	77.24 ± 13.8	77.39 ± 11.1	-0.05	0.96
Height (m)	1.79 ± 0.06	1.79 ± 0.06	0.14	0.88
BMI (kg/m^2)	24.36 ± 3.5	24.23 ± 2.9	0.15	0.88
Level of significance set at p<0.05				

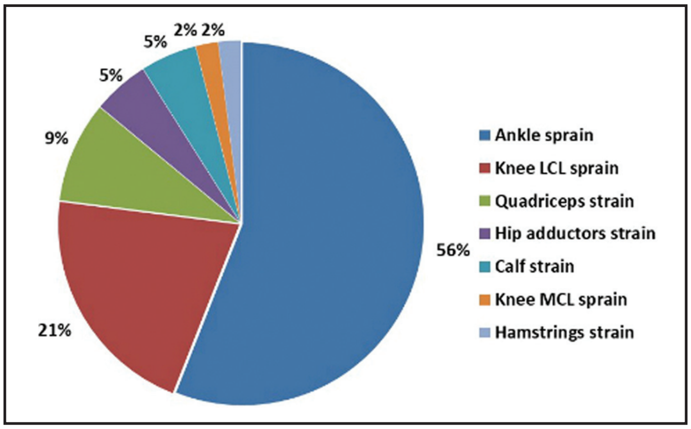

Figure 3. *Lower extremity sprain and strain injury distribution among injured soccer players*

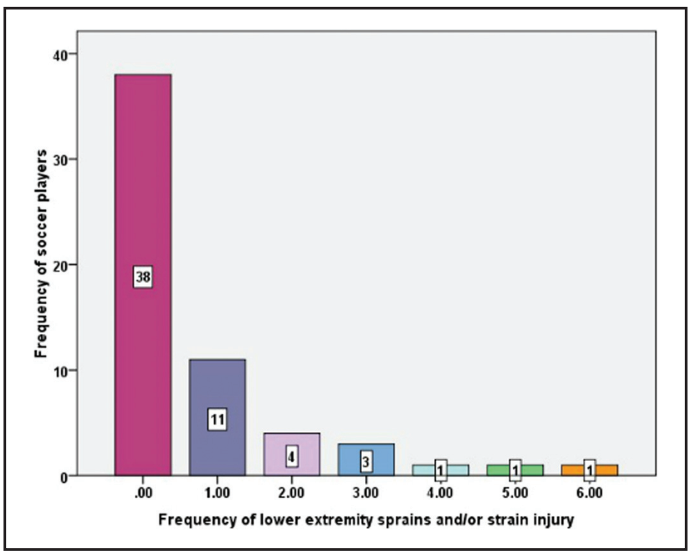

Figure 4. *Frequency distribution of lower extremity sprain and/or strain injury*

tests showed significantly longer hold times for the prone-bridge and side-bridge tests in the non-injured players ($p < 0.05$; Table 2). Similarly, Spearman correlations revealed significant moderate negative correlations between the frequency of injury and each of the prone-bridge (r = -0.324, p = 0.007) and side-bridge (r = -0.385, p = 0.003) hold times with no other significant correlations (Table 3).

Regarding the logistic regression results, the proposed model was found to fit the data well. A test of the full model (2-factor model) versus an intercept-only model was statistically significant, $\chi^2_{(2)} = 10.133$, p = 0.006 indicating that the predictors as a set reliably distinguishes between injured and non-injured soccer players. Similarly, a test of the 1-factor model versus an intercept-only model was statistically significant, $\chi^2_{(1)} = 8.906$, p = 0.003. Both models were able to correctly classify the players into injured and non-injured with an overall accuracy of 72.7%. Side-bridge hold time accounted for the majority of variability in the model and represented the only factor that made significant contribution to prediction (OR = 0.956, 95% CI = 0.925-0.989). The odds ratio indicated that with a unit increase in side-bridge hold time, the odds of non-contact sprain and/or strain injury occurrence decreases 0.956 times (Table 4). When only the constant was included in the model, the model correctly classified 65.5% of players into injured and non-injured. After including the predictors (side-bridge and prone-bridge hold time), this percentage rose to 72.7%.

DISCUSSION

The purposes of this study were to compare prone-bridge, side-bridge, flexor endurance, and horizontal extensor endurance test hold times and peak hip abductor and external rotator eccentric torques of injured soccer players with those of non-injured players. The association between core muscle endurance and non-contact lower limb strain and sprain injury as well as the ability to predict injury from core muscle endurance were also tested.

Table 2. *Descriptive statistics and multiple pairwise comparison tests for the core muscle hold time and peak hip muscle isokinetic torques between the injured and non-injured soccer players.*

		Descriptive statistics (Mean ± SD)		Multiple pairwise comparison tests	95% confidence interval for difference	
		Group A (Injured)	Group B (Non-injured)	(p-value)	Lower bound	Upper bound
Core muscles' hold time (s)	Prone-bridge	80.21±29	100.26±36	0.043*	-39.43	-0.68
	Side-bridge	54±18.7	69.94±21	0.008†	-27.57	-4.31
	Trunk flexion	75.84±40	91.15±43	0.208	-39.42	8.81
	Horizontal back extension	122.79±27.5	125.18±34.5	0.797	-20.92	16.14
Normalized hip muscles' peak torque (Nm/kg)	Hip abductors	90.05±30.7	89.14±35.1	0.925	-18.42	20.24
	Hip external rotators	62.55±19.3	56.93±21.2	0.345	-6.2	17.45

*significance at p<0.05, † significant at p<0.01

Table 3. *Spearman correlation between the core muscle endurance hold time and peak isokinetic hip abductor and external rotator torques and the frequency of lower extremity sprain and/or strain injury.*

		Frequency of lower extremity sprain and/or strain injury
Core muscle endurance hold time (s) for the conducted McGill endurance tests	Prone-bridge	r = -0.324 p = 0.007†
	Side-bridge	r = -0.385 p = 0.003†
	Trunk flexion	r = -0.173 p = 0.095
	Horizontal back extension	r = -0.036 p = 0.395
Peak hip muscle torques (in Nm/kg)	Abductors	r = -0.053 p = 0.344
	External rotators	r = 0.135 p = 0.158

† significant at p<0.01

Table 4. *Logistic regression of sprain and strain injury in soccer players using the side bridge and prone-bridge hold times as predictors.*

		B	Wald	Sig.	Exp(B) (odds ratio)	95% CI for Exp(B)	
						Lower	Upper
Step 1[a]	Prone-bridge	-0.01	1.17	0.279	0.99	0.97	1.009
	Side-bridge	-0.04	4.06	0.044*	0.96	0.93	0.999
	Constant	2.71	4.91	0.027*	14.98		
Step 2	Side-bridge	-0.04	6.79	0.009*	0.96	0.93	0.99
	Constant	2.15	4	0.049*	8.54		

[a]Variable(s) entered in step 1: prone-bridge and side-bridge hold times
B=coefficient of the predictor variables (slope values)
Constant = value of the criterion when the predictor is equal to zero
* $p < 0.05$
Note: Cox & Snell R^2= 0.168 (for step 1) and 0.149 (for step 2), Nagelkerke R^2= 0.232 (for step 1) and 0.206 (for step 2). Hosmer and Lemeshow test= $\chi^2_{(7)}$= 5.867, p=0.555 (for step 1) and $\chi^2_{(7)}$= 7.537, p=0.375 (for step 2)

In this study, prone-bridge and side-bridge hold times were significantly shorter in players that sustained non-contact lower limb sprain and/or strain injury during the season. In addition, shorter hold time was significantly correlated with the frequency a player was injured. Low endurance of core muscles can lead to non-contact injury directly through the inability to produce sufficient force to maintain trunk stability once the muscles fatigue. This limits the body's ability to control its center of mass forcing the lower limbs to compensate.[10] Compensation is achieved through greater lower limb force production and joint displacements that are transmitted through the kinetic chain making the whole system susceptible to injury.[9] Fatigue also causes several sensory changes that alter motor output. These sensory changes include reduction in perception of core motion with delay in subcortical motor response interfering with the normal corrective response, which may make it too late to maintain stability and prevent injury.[9,38] Core muscle fatigue has also been shown to alter landing mechanics in different tasks such as stop jumps and cutting maneuvers,[39] thus, contributing to altered lower limb movements during soccer performance.[40] Furthermore, the current findings are consistent with those reported by Moore et al.[41] who reported an increase in number of injuries that occur as time passes during a soccer game, thus, linking fatigue to injuries sustained.

Indirectly, core muscle fatigue can affect activation patterns of one or more lower limb muscles, altering their ability to provide proper compensatory response to perturbations. Hart et al.[26,42] reported reduced activation of the quadriceps muscle after fatigue of the paraspinal muscles even though the quadriceps was not fatigued. Park et al.[43] reported reduction in lower limb muscle coordination following a paraspinal fatigue protocol. Poor leg coordination is a recognized risk factor for injury.[44] These effects on lower limb muscles support the possibility of indirect involvement of core muscles. However, the effect of these alterations on joint stability during physical activity have never been tested.

Results of the current study support that core muscle endurance is an important factor influencing the possibilities of non-contact lower limb sprains and strains. The question remains as to which specific muscles are most important. In this study, muscle activity was not measured, however, different EMG studies shed some light on the matter. Both the side-bridge and prone-bridge have shown similar muscle activation patterns for the internal oblique, upper rectus abdominis, latissimus dorsi, rectus femoris, gluteus maximus, vastus medialis obliquus, and hamstrings muscles.[45,46] However, the side-bridge showed greater gluteus medius (74% and 27% of MVC for the side-bridge and prone-bridge, respectively) and paraspinal muscle activity (29-42% and 5-6% of MVC for the side-bridge and prone-bridge, respectively) with the lower rectus abdominis being more active during the prone-bridge (21% and 42% of MVC for the side-bridge and prone-bridge, respectively). Although its activity has never been measured during the prone-bridge, it is unlikely that the quadratus lumborum is as active during the prone-bridge as it is during the side-bridge. In the side-bridge, it plays a key role in trunk stability and is highly active, showing more than 50% of maximum voluntary contraction (MVC).[47,48] Both side-bridge and prone-bridge times correlated to injury. However, based on this study's regression analysis, side-bridge time only can be used to predict injury, which highlights the overlap between muscles contributing to maintaining both positions and suggests greater contribution to stability from muscles that are more active during the side-bridge test such as the gluteus medius and paraspinal muscles.

Compared to trunk flexion and horizontal back extension, the side-bridge requires activation of multiple muscles (discussed above) whereas trunk flexion primarily focuses on activation of the rectus abdominis with little activation from other core muscles.[46] During horizontal back extension, the paraspinal muscles produce greater than 40% of MVC.[49] No studies that investigated other core muscle activation during horizontal back extension were found. However, it can be speculated that other core muscles would have little activation as compared to what is seen with trunk flexion. Findings of this study are in line with previous studies that stressed no specific muscle can be singled out as most important contributor to core strength, endurance, and stability[38] and exercises that include a wide variation of core muscles should be conducted. Thus, in agreement with Ekstrom et al.,[45] both the side-bridge and prone-bridge exercises should be used to improve core strength, endurance, and stability, however, emphasis would be placed on the side-bridge based upon results of the current regression analysis. In addition, since side-bridge hold time was identified as an injury risk factor, it may be a better test when conducting pre-participation screening.

Contrary to the findings reported by Leetun et al.,[21] no relationship between injury and eccentric hip muscle strength measured isokinetically (eccentrically) was identified. Weak hip abductors and external rotators have been reported to lead to the inability to control hip adduction and internal rotation forcing the knee into a dynamic valgus position.[21] Dynamic valgus has been termed "the position of no return" by Ireland[14] as it is the position seen right before ACL injury and has also been linked to patellofemoral pain syndrome,[50] both of which are more common in females than males.[51-53] Weakness of hip abductors and external rotators as well as excessive knee valgus are also more common in female athletes compared with their male counterpart.[54-57] In the study by Leetun et al.,[21] participants were basketball (males = 44, females = 60) and cross-country athletes (males = 16, females = 20). Considering more than half the participants in their study were female athletes, it is likely that gender played a role in the relationship between hip muscle strength and injury. Nikolaidis[58] reported that female soccer players have greater horizontal back extension times than their male counterpart. Thus, endurance may be less likely to be a contributor to injuries in female athletes. This is not the case when examining strength as it is well established that male athletes have grater muscle strength than female athletes.[57] Nadler et al.[59] found a relationship between hip muscle strength and injury in females and not males. Since a reduction (reflected in the increased trunk displacement following a force release) in lateral trunk control has been shown to predict knee injury,[22] the reason for the loss of control may be endurance and/or strength related. It is possible that hip abductor and external rotator endurance is more important for male athletes as compared to eccentric strength. However, this possibility cannot be confirmed since hip muscle endurance was not measured in this study. Furthermore, lateral trunk control in male athletes may be related to trunk muscle endurance rather than that of hip muscles.

LIMITATIONS

This study included only male soccer players, while the study conducted by Leetun et al.[21] included male and female basketball and cross-country athletes. Thus, results of the current study cannot be generalized to female players or players of other sports. The differences in playing surfaces between these sports are enough to affect the types and rates of injuries experienced. In fact, within soccer itself, playing on natural grass vs artificial turf changes the nature of injuries experienced.[60] In addition, the demands of these sports are different leading players develop different neuromuscular control strategies specific to the sport they play. Basketball players tend to experience greater ground reaction forces when landing from a jump compared with soccer players, whereas the opposite is true during cutting maneuvers.[61] Piasecki et al.[62] reported that most ACL injuries in basketball occur during jump landing whereas those from soccer occur during other noncontact mechanism such as cutting. Other sport specific differences such as differences in static and dynamic balance have also been reported in the literature.[63]

In this study maximum eccentric torque created by hip abductors and external rotators were measured, whereas, in the study by Leetun et al.,[21] they used maximum isometric force. Eccentric torque is the muscle action needed during the deceleration phase of many activities including running, thus, is likely a better measure in the case of soccer players. However, all findings related to strength measures in the current study are limited to eccentric torques.

Based on the current study findings, the hypothesis that injured players would present with low core muscle endurance and hip muscle strength was accepted regarding the side-bridge and prone-bridge hold times only. Similarly, the hypothesis that low core muscle endurance would be associated with increased frequency of injury was accepted for the side-bridge and prone-bridge times only.

CONCLUSIONS

The current study findings support that low core muscle endurance is an important factor contributing to non-contact injury of the lower extremities in male soccer players. Both prone- and side-bridge times were significantly negatively correlated with non-contact lower limb sprain and strain injuries in male soccer players. However, only side-bridge time can be used as a pre-participation screening tool based upon the results of the regression analysis. These findings cannot be generalized to female soccer players or other athletes.

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