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Prediction of Knee Injury in Professional Soccer Players Using Core Endurance and Strength: A Cross-sectional Study

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Abstract

Although relationships between lower limb injury and core strength and endurance have been reported, limited research on the risk of knee injury specifically among soccer players exists. This study aimed to compare preseason trunk muscle endurance as well as trunk and hip muscle strength between soccer players who experienced knee injury during their season and those who did not. Dependent variables were also used to predict the risk for injury. This prospective cross-sectional study involved thirty-nine male soccer players (age 19.64±2.84 years, weight 73.94±15.66 kg and height 175.67±9.92 cm). By the end of the season, twelve (30.77%) reported knee injuries. Accordingly, two groups were identified and compared: injured and non-injured. Prone-bridge, side-bridge, trunk flexion and horizontal back extension hold times were used as trunk endurance measures, while peak isokinetic trunk flexor and extensor torques, as well as hip abductor and external rotator torques, were recorded as strength measures. MANOVA showed that only prone-bridge hold time was significantly higher in the non-injured players ($p<0.05$). Logistic regression showed that prone-bridge hold time and peak isokinetic hip abductor torque were significant predictors of injury (OR=0.97&0.03, respectively). Thus, soccer players with knee injuries have lesser core endurance. Reduced prone-bridge hold time and abductor torque, specifically, are associated with an increased risk of injury.

Keywords: *core endurance, trunk strength, hip strength, soccer, knee injury*

Introduction

Soccer is the most popular sport with more than 265 million players worldwide (FIFA, 2007). The game involves continuous running, jumping, cutting, acceleration, deceleration, and contact with other players. Thus, there is a massive technical, physiological, and structural demand, growing interest primarily on the lower limbs, making players more susceptible to injury (Dellal et al., 2011). Lower limb injuries account for 61-82% of soccer injuries (Emery & Meeuwisse, 2010). Ramathesele (1998) reported that knee injuries account for 12-26% of injuries in youth soccer players. Recently, Gebert et al. (2020) reported that knee injuries account for 24.8% of all injuries and 53.2% of the cost of injury in Swiss amateur soccer players. In addition to the monetary cost, knee injuries are most severe, resulting in the greatest time away from play compared to other injuries (Stubbe et al., 2015). There is also an emotional and psychological cost to injured players. Thus, reducing injury should be a top priority for everyone involved (Dellal et al., 2013).

There has been growing interest in the proximal control of the knee (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007), particularly that from the core (lumbopelvic-hip complex). Reduced core control would result in increased displacement of the centre of mass. Since the knee is the articulation at the distal end of the femur, the uncontrolled centre of mass displacements would result in excessive torques experienced at the knee (Zazulak et al., 2007). These excessive torques can

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strain different knee structures, causing injury (Zazulak et al., 2007). Weak hip abductors and external rotators specifically can lead to excessive knee valgus. Knee valgus has been termed the "position of no return" (Ireland, 2002) and is linked to many injuries, including those of the anterior cruciate ligament (ACL). Stickler, Finley and Gulgin (2015) reported that a 1% increase in hip abductor strength reduced knee valgus by 0.216°. Since soccer involves repetitive unilateral limb support situations, in our opinion, players with reduced core strength or endurance can be susceptible to experiencing dynamic knee valgus.

Few researchers have studied the influence of core related variables on lower limb injury in a limited number of sports. In these studies, the focus was on lower limb injury in general and not specifically the knee. For example, suboptimal core muscle endurance predicted lower limb sprain and strain injury in collegiate American football players (Wilkerson & Colston, 2015; Wilkerson, Giles, & Seibel, 2012), while reduced hip external rotator strength predicted lower limb injuries in collegiate basketball and track athletes (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). In addition, a recent study (Abdallah, Mohamed, & Hegazy, 2019) examined the relationship between reduced core endurance and lower limb sprain and strain injury in professional male soccer players. Specifically, players with reduced side-bridge hold times experienced more injuries throughout the season.

Although relationships between lower limb injury and core strength and endurance have been reported, to our knowledge, none of these studies was specific to knee injuries. In addition, only one study (Abdallah et al., 2019) established this relationship in soccer players; however, trunk muscle strength was not included as part of the assessment. Thus, the purpose of this study was to compare trunk muscle endurance as well as trunk and hip muscle strength between soccer players who experienced knee injuries during their season and those who did not. In addition, trunk muscle endurance, as well as trunk and hip muscle strength, were also used to predict the risk for injury. We hypothesized that players with lesser endurance and strength would experience more injuries. Furthermore, we would be able to predict injury from these reduced endurance and strength variables.

Methods

Design & participants

Eighty-two professional male soccer players from four clubs volunteered to participate in this prospective cross-sectional study. However, only 39 met the inclusion criteria. Inclusion criteria comprised age between 16 and 27 years, BMI between 18 and 30 kg/m², having no history of pain, injuries, or surgeries for at least one year. In addition, exclusion criteria included a manual muscle test score of less than five for trunk flexors and extensors, tightness of hamstrings or iliopsoas, and experiencing injury during the season in a non-practice or game setting.

Instrumentation

McGill core endurance tests were used for endurance assessment (McGill, Childs, & Liebenson, 1999), specifically, the prone-bridge, side-bridge, trunk flexion and horizontal back extension tests. Time (measured in seconds) recorded while holding a specific position was the variable of interest. McGill endurance tests have moderate to very high reliability (intraclass correlation coefficient (ICC)=0.66-0.96; Waldhelm & Li, 2012).

The Biodex System 3 Pro multi-joint testing and rehabilitation system (Biodex Medical System, Shirley, NY, USA) was used to assess trunk and hip muscle strengths. Peak trunk flexor and extensor, as well as hip abductor and external rotator isokinetic torques, were the variables of interest. The Biodex system is a safe, objective, and reliable assessment tool having an ICC of 0.99 (Alvares et al., 2015). All torque values were corrected for the effect of gravity using the Biodex Advantages Software v.3.33

Procedures

Prior to data collection, all procedures were approved by the Faculty of Physical Therapy, Cairo University Institutional Review Board. All procedures were carried out at an isokinetic laboratory. Players were then given a detailed orientation session on the purpose of the study and its procedures. All players or their legal guardians read and signed an informed consent form. All minors also provided verbal assent. Personal data were collected, and study inclusion and exclusion criteria were verified by the same examiner (a physical therapist with 10 years of experience). Each player's dominant foot (the preferred foot for kicking a ball) was specified.

Core endurance tests were performed first, followed by isokinetic hip and trunk muscle strength assessment. The prone-bridge test assesses anterior and posterior core muscle endurance. To perform this test, players supported their weight on their forearms and toes while keeping their pelvis in a neutral position. The total time they were able to do so before falling into hyper-lordosis was recorded. The side-bridge test assesses lateral core muscle endurance. To perform this test, players assumed a side-lying position and lifted their right

FIGURE 1. Core endurance tests; Side-bridge (a), Prone-bridge (b), Flexor endurance (c), and Horizontal extensor endurance (d)

FIGURE 2. Isokinetic strength assessment of hip abductors (a), hip external rotators (b), trunk flexors (c), and trunk extensors (d)

hip off the supporting table, thus, supporting their weight on both feet and right elbow. The left foot was placed in front of the right, and the left hand was placed on the right shoulder. The total time they were able to maintain this position without their pelvis dropping towards the supporting table was recorded. McGill et al. (1999) reported similar times for both sides; thus, the test was performed on the right side only. The flexor endurance test assesses anterior core muscle endurance. In this test, players sat on the supporting table while keeping their trunks flexed 60° and hips flexed 90°. The total time they were able to maintain these exact angles against gravity was recorded. Lastly, the horizontal back extension test was used to assess posterior core muscle endurance. In this test, players lied prone with their trunks off of the supporting table. Their pelvis and knees were stabilized by the examiner. The total time they were able to keep their trunk in a horizontal position without falling was recorded.

Hip muscle strength assessment was carried out through a 0–30° range of motion at a 60°/sec (Boling et al., 2009) while that of the trunk through a 70° (20° extension-50° flexion) range of motion at a 60°/sec (Shirado, Ito, Kaneda, & Strax, 1995). All torque data were normalized to body mass (Nm/kg). Players performed five consecutive maximal muscle contractions for familiarization, followed by a one-minute break, followed by five recorded trials. Both endurance and strength assessments (Figures 1a-d and 2a-d) were conducted before the season.

Players were instructed to avoid any sports activity (including team practice) for 24 hours before testing. All knee injuries experienced by players during the season in game and practice settings were recorded. Players were excluded from the study if they experienced injuries in other settings. Team doctors were responsible for diagnosing and reporting injuries. Injury details, including mechanism, site, and whether it was contact or non-contact, were recorded. Injuries were operationally defined as those that led to time loss from games or practice (Leetun et al., 2004). Therefore, all injuries should have occurred during organized practices and/or games during the season.

Statistical analysis

Following the end of the season, players were subdivided into two groups; injured and non-injured. Initially, data exploration was conducted in which outliers and extreme scores were removed. Once assumptions for parametric testing were verified (normality and homogeneity of variance assumptions), MANOVA analysis was conducted to compare endurance times of the four tests, as well as the peak isokinetic torques of the four muscle groups between both groups. MANOVA was conducted with subsequent multiple pairwise comparison tests using Bonferroni adjustment of a 0.05-alpha level. To predict the risk of knee injury, each of the endurance and strength variables was used with logistic regression analysis. Hold times of the four endurance tests were used together as independent variables with injury occurrence as the dependent variable (injury presence=1, and injury absence=0).

Similarly, peak isokinetic torques of trunk flexors and extensors, as well as hip external rotators and abductors, were used together as predictors with injury occurrence as the dependent variable. Backward stepwise regression was conducted. SPSS version 17 (IBM, Inc, Armonk, NY) was used for statistical analysis.

Results

Descriptive statistics for player demographic data showed that the mean age was 17.92±1.93 vs 20.41±2.87 years, weight 77.83±19.52 vs 72.2±13.67 kg, height 1.76±0.1 vs 1.76±0.1 m, and BMI 24.83±3.75 vs 23.23±2.93 kg/m² for the injured vs non-injured groups, respectively. Injured players were significantly younger ($p=0.01$). No other demographic variables were significantly different ($p>0.05$).

Frequency distribution analysis revealed that twelve (30.77%) of the 39 players had at least one knee injury. A total of 25 knee injuries were recorded; 11 (44% of the total number of injuries) patellofemoral pain syndrome, 5 (20%) quadriceps strain, 3 (12%) knee lateral collateral ligament sprain, 2 (8%) iliotibial tract syndrome, 1 (4%) hamstrings strain, 1 (4%) hip adductors strain, 1 (4%) calf strain, and 1 (4%) knee medial collateral ligament sprain (Figure 3).

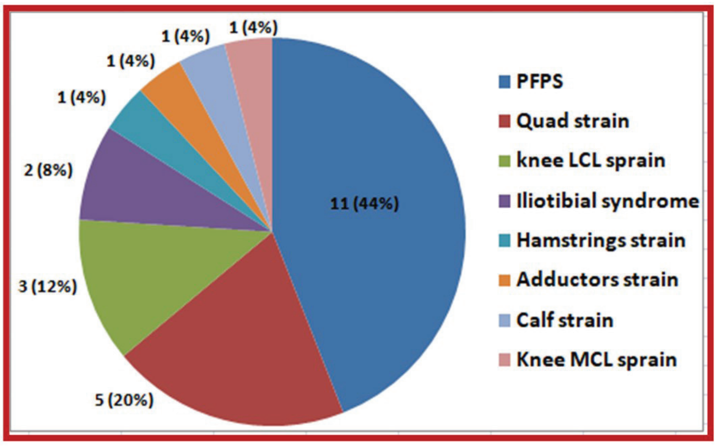

FIGURE 3. Knee injury distribution among injured soccer players

MANOVA analysis showed that prone-bridge hold time was significantly higher in non-injured players compared to injured (p=0.01), with no other significant differences for all other variables (Table 1).

Table 1. Descriptive statistics and multiple pairwise comparison tests for the core muscle hold time and peak hip and trunk muscle isokinetic torques between injured and non-injured soccer players

		Injured M±SD	Non-injured M±SD	p
Core muscle hold time (sec)	Prone- bridge	74.27±30.99	107.68±37.03	0.013*
	Side- bridge	64.36±31.23	73.28±29.86	0.42
	Trunk flexion	95±42.11	83.88±32.19	0.39
	Horizontal trunk extension	144.45±64.49	133.12±35.63	0.51
Normalized hip and trunk muscle isokinetic torque (Nm/kg)	Hip abductors	0.82±0.28	1.02±0.33	0.09
	Hip external rotators	0.63±0.2	0.61±0.22	0.85
	Trunk flexors	1.78±0.63	2.02±0.75	0.35
	Trunk extensors	2.73±1	3.3±1.1	0.15

Legend: * - Significant at p<0.05

Logistic regression revealed that prone-bridge hold time was the only significant predictor of knee injury (OR=0.97, p=0.02). The odds ratio indicated that with every unit (second) increase in the prone-bridge hold time, the odds of injury decreases to 0.97 times (i.e. decreases by 0.03 times (3%)). When only the constant was included in the model, the model correctly classified 70.3% of players into injured and non-injured categories. Adding prone-bridge hold time increased this percentage to 73% (Table 2).

Table 2. Knee injury logistic regression using core muscle hold times as predictors

		B	Wald	Sig.	Exp (B)
Step 1[a]	Prone-bridge	-0.04	4.856	0.028*	0.961
	Side-bridge	0.00	0.001	0.980	1.000
	Flexion Endurance test	0.009	0.588	0.443	1.009
	Extension Endurance test	0.011	0.973	0.324	1.011
	Constant	0.287	0.029	0.866	1.333
Step 2[a]	Prone-bridge	-0.040	5.607	0.018*	0.961
	Flexion Endurance test	0.009	0.591	0.442	1.009
	Extension Endurance test	0.012	1.266	0.260	1.012
	Constant	0.289	0.029	0.865	1.335
Step 3[a]	Prone-bridge	-0.039	5.776	0.016*	0.962
	Extension Endurance test	0.013	1.513	0.219	1.013
	Constant	0.823	0.285	0.593	2.277
Step 4[a]	Prone-bridge	-0.032	5.423	0.020*	0.968
	Constant	2.030	2.805	0.094	7.615

Legend:a - Variables entered in the corresponding step; B-coefficient of the predictor (slope values); Constant-value of the criterion when the predictor equals zero; *-Significant at p<0.05; Cox & Snell R^2=0.186; Nagelkerke R^2=0.264; Hosmer & Lemeshow test= $\chi^2(7)$=3.759; p=0.807 for step 4

When peak trunk and hip muscle isokinetic torques were used for prediction, hip abductor torque was the only significant predictor of knee injury (OR=0.03, p=0.03). The odds ratio indicated that with every unit (Nm/kg) increase in the abductor torque, the odds of injury decreases to 0.03 times (i.e. decreases by 0.97 times (97%)). When only the constant was included in the model, the model correctly classified 68.4% of players into injured and non-injured. Adding abductor torque increased this percentage to 78.9% (Table 3).

Table 3. Knee injury logistic regression using the peak hip and trunk muscle isokinetic torques as predictors

		B	Wald	Sig.	Exp (B)
Step 1[a]	Trunk flexors	-0.459	0.202	0.653	0.632
	Trunk Extensors	-0.205	0.105	0.746	0.815
	Hip Abductors	-2.906	2.865	0.091	0.055
	Hip External Rotators	3.413	1.964	0.161	30.341
	Constant	1.218	0.639	0.424	3.379
Step 2[a]	Trunk flexors	-0.667	0.716	0.397	0.513
	Hip Abductors	-3.016	3.190	0.074	0.049
	Hip External Rotators	3.505	2.124	0.145	33.296
	Constant	1.039	0.548	0.459	2.826
Step 3[a]	Hip Abductors	-3.500	4.502	0.034*	0.030
	Hip External Rotators	2.674	1.546	0.214	14.502
	Constant	0.741	0.311	0.577	2.097
Step 4[a]	Hip Abductors	-2.513	3.443	0.064	0.081
	Constant	1.515	1.518	0.218	4.551

Legend: Cox & Snell R^2=0.138; Nagelkerke R2=0.193; Hosmer & Lemeshow test= $\chi^2(8)$=8.058; p=0.428 for step 3

Discussion

The purpose of this study was to compare trunk muscle endurance as well as trunk and hip muscle strength in soccer players that experience knee injury to those who did not throughout a season. The ability to predict knee injury from these variables was also assessed.

Prone-bridge hold time was the only variable that was significantly longer in players who did not experience knee injury than those who did. Therefore, it is likely that muscles active during the prone-bridge are of sufficient strength in all players. However, as games progress, muscles with less endurance are not able to sustain their force production. This reduction in force production reduces the body's ability to control centre of mass motion, thus, increasing the need for the lower limbs to compensate (Wilkerson et al., 2012). Considering that the knee lies between the two longest levers in the body, any minor centre of mass perturbations can lead to a huge amount of force experienced at the knee (Del Bel, Fairfax, Jones, Steele, & Landry, 2017). A reduction in core proprioception has also been shown to reduce lower limb neuromuscular control. Hart et al. (2006) reported a reduction in quadriceps activation following paraspinal fatigue when the quadriceps itself was not fatigued. Similarly, Park et al. (2008) reported a reduction in lower limb coordination following paraspinal muscle fatigue. Thus, it is reasonable to argue that core fatigue contributes to knee injury in soccer players directly by increasing the demand on lower limb muscles and indirectly by altering lower limb neuromuscular control.

The prone-bridge primarily assesses trunk flexor endurance as well as rectus femoris endurance (Escamilla, Lewis, Pecson, Imamura, & Andrews, 2016). The activation of both trunk flexor and rectus femoris is of key importance in reducing the load on the knee. During different tasks, such as walking and jump landing, the ground reaction force vector will pass in front of the hip and behind the knee, creating a flexion moment at both joints. How much flexion torque is experienced at each joint will depend on the distance between the force and joint centre. As trunk flexors become active, trunk flexion increases along with hip flexion, which leads the ground reaction force vector to pass close to the knee joint reducing the flexion moment at the knee, thus, reducing the level of quadriceps activation needed (Powers, 2010). In situations in which trunk flexors are not as active, the trunk will be more upright, causing the ground reaction force vector to be further away from the knee, resulting in greater knee flexion moment and a need for the quadriceps to increase its activation to control knee flexion. Similarly, a fatigued rectus femoris cannot control normal knee flexion moments sustained, even when the moment arm of the ground reaction force vector is close to the knee. Both situations can result in excessive loads on the quadriceps during its eccentric action, which is a common mechanism for quadriceps strain (Kary, 2010), which made up 20% of injuries suffered in our study.

Perhaps the reduced trunk flexor and rectus abdominis endurance combination differentiated the prone-bridge from both the side-bridge and trunk flexion tests. Our previous study (Abdallah et al., 2019) reported that both prone-bridge and side-bridge correlated with lower limb strain and strain injuries, with the side-bridge being the only predictor. We expected to have similar results in the present study; however, the side-bridge did not correlate or predict knee injury. Compared to the prone-bridge, the side-bridge requires greater activation of the gluteus medius (74% and 27% of MVC for the side-bridge and prone-bridge, respectively ;Ekstrom, Donatelli, & Carp, 2007). Our results suggest that knee injuries were more related to gluteus medius strength rather than its endurance.

In contrast, the prone-bridge requires greater trunk flexor activation (21% and 40% of MVC for the side-bridge and prone-bridge, respectively ;Escamilla et al., 2016). Although other mechanisms may be involved, the effect of lower trunk flexor endurance is described above. Similar to the prone-bridge, the trunk flexion test assesses trunk flexor endurance; however, the prone-bridge requires greater rectus femoris activation (6% and 20% of MVC for the trunk flexion and prone-bridge, respectively; Escamilla et al., 2016). Thus, it is likely that a combined reduction in both rectus abdominis and rectus femoris endurance is related to injury and not just one muscle on its own.

Hip abductor strength was the other significant knee injury predictor. Although it was not statistically different between groups, it did approach significance (p=0.09). Weaker hip abductors are unable to resist knee valgus tendency. Specifically, hip abductor weakness leads to femoral adduction, resulting in the knee joint centre moving medially as the tibia moves to a more abducted position relative to the femur (Powers, 2010). This pattern is linked to different knee injuries, including ACL, patellofemoral pain syndrome, and iliotibial band syndrome (Fredericson et al., 2000; Powers, 2010). Although there were no ACL injuries in the current study, the most prevalent injury experienced was patellofemoral pain syndrome, with 11 (44%) injuries occurring throughout the season. Patellofemoral pain syndrome has been consistently linked to decreased hip abduction and external rotation (Bolgla, Malone, Umberger, & Uhl, 2008). Although we measured hip abductor group strength, our data suggest patellofemoral pain syndrome is most likely linked to weakness of the gluteus medius rather than tensor fasciae latae considering the gluteus medius is an external rotator whereas the tensor fasciae latae is an internal rotator. In addition, one participant (4%) experienced iliotibial band syndrome. Weaker hip abductors and greater hip adduction have been observed in runners with the iliotibial band syndrome (Fredericson et al., 2000). The hip adduction position stretches the iliotibial band, thus, leading to its strain.

Weak hip abductors have also been linked to lateral collateral ligament (LCL) strain, which was experienced by three players accounting for 12% of knee injuries. During single-limb support situations, such as running, the ground reaction force vector passes medial to the knee, thus increasing varus stress, which is resisted by the LCL. Weak hip abductors can result in the trunk falling away from the support leg, thus increasing the moment arm of the ground reaction force vector, and increasing the strain on the LCL (Powers, 2010). This force can be greatly increased in situations, such as cutting and changing direction, commonly seen in soccer (Besier, Lloyd, Cochrane, & Ackland, 2001).

Our previous study (Abdallah et al., 2019) found no relationship between hip abduction strength and lower limb sprain and strain injuries. However, that study was not specific to the knee, and 56% of injuries were ankle sprains. Thus, a knee-specific analysis for our previous study data could have revealed hip abductor strength involvement in knee injury; however, it was not conducted.

The current study findings support that lower core endurance and hip muscle strength are related to and can be used to predict knee injuries. Specifically, reduced prone-bridge time and reduced hip abductor strength increase the probability of injuries. Our first hypothesis was partially supported, as prone-bridge hold time (a trunk endurance variable) was the only variable that differentiated between injured and uninjured players. Our second hypothesis was supported as both prone-bridge hold time (a trunk endurance variable) and hip abductor strength (a hip strength variable) predicted injury. Thus, core training can be an effective injury prevention strategy for soccer players (Vasileiadis, 2020), particularly those identified as susceptible to injury by preseason screening.

The findings of the current study should be considered in light of few limitations. First, our findings are limited to professional male soccer players. Thus, our findings cannot be generalized to female soccer players or athletes involved in different sports. In addition, training load (hours of exposure) was not considered in our study, which may have impacted injury incidences. Furthermore, despite isokinetic trunk extensor and hip abductor torques showing moderate effect size, there was no significant difference between groups. We attribute this to our small sample size; however, we were limited to players who volunteered from the four clubs that met our inclusion criteria.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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