



Original Research

The association between the isokinetic muscle strength and lower extremity injuries in young male football players

Parisa Namazi ^a, Mostafa Zarei ^{a,*}, Fariborz Hovanloo ^a, Hamed Abbasi ^b^a Department of Sports Sciences and Health, University of Shahid Beheshti, Velenjak Square, Evin, Tehran, 1983963113, Iran^b Department of Sport Injuries and Corrective Exercises, Sport Sciences Research Institute, No. 3, 5th Alley, Miremad Street, Motahhari Street, 1587958711, Tehran, Iran

ARTICLE INFO

Article history:

Received 24 April 2019

Received in revised form

28 June 2019

Accepted 28 June 2019

Keywords:

Lower extremity injury

Isokinetic strength

Football

ABSTRACT

Background: Validating any screening test to predict and prevent football injuries is in need of identifying related risk factors through prospective designs. In spite of the extensive use of strength testing in football players, there are limited studies investigating the relationship between isokinetic muscle strength and injury risk in young football players. The present study aimed to evaluate the relationship between isokinetic strength and the risk of lower extremity injury among Iranian young football players.

Method: seventy three U-21 football players participated in this study. Isokinetic strength of hip, knee and ankle muscles were measured using the Isokinetic system pro 4. Injuries and exposure in training and matches were registered prospectively by club medical staff for one season.

Results: Significant relationships were revealed between the isokinetic strength of hip abductor and adductor muscles, and isokinetic strength ratio of hip abductor/adductor muscles at an angular speed of 30°/sec, the isokinetic strength of hip abductor muscles at 90°/sec, and isokinetic strength of knee flexor and extensor muscles at 60°/sec and knee flexor/extensor strength ratio at angular velocities of 60°/sec with the injury occurrence among football players.

Conclusion: lower extremity isokinetic strength indices are associated with injuries in young male football players.

© 2019 Elsevier Ltd. All rights reserved.

1. Introduction

The insight into musculoskeletal injury prevention continues to raise. Researchers have been to identify or develop clinical tools with the ability to determine an individual clinical of injury during athletic participation. Injury prediction and risk factor identification and risk reduction. Injury prevention tools in use; years. velocities of 60 Research on risk factors for injury is to find out why injuries occur and to predict athletes at risk of injury. Screening to identify players at a higher risk for injuries with the purpose of prescribing preventing measures is interested and monitored by periodic health evaluations (Bakken et al., 2018). To validate a screening test to predict and prevent sports injuries, three steps are required: (1) a strong relationship must be revealed in prospective studies between a marker from a screening test and injury risk; (2) the test properties of the

marker must be validated in relevant populations, using appropriate statistical tools; (3) an intervention programme targeting athletes identified as being at high risk using the marker must be more beneficial than the same intervention programme given to all athletes (Bahr, 2016).

Among the internal risk factors proposed for sport injuries, muscle strength deficiency and improper agonist/antagonist muscle strength ratios have been reflected as important factors predisposing a player to lower extremity injuries, and muscle strength testing is one of the most used screening tests in professional soccer to detect injury risk (Bakken et al., 2018). (McCall et al., 2015; Ryan, DeBurca, & Mc Creesh, 2014). However, contradictory reports on the relationship between muscle strength of different muscle groups and the risk of injury do not lead to a clear decision. In this regard, it has been shown that the isometric strength of quadriceps and isometric strength of hip adductor muscles had a weak correlation with the incidence of injury to professional football players (Bakken et al., 2018). Also, lower hip isometric strength is correlated with the increase of ankle sprains (De Ridder, Witvrouw, Dolphens, Roosen, & Van Ginckel, 2017). Quadriceps to

* Corresponding author. Velenjak Square, Evin, Tehran, 1983963113, Iran. Tel: +989132615259

E-mail addresses: M_zareei@sbu.ac.ir (M. Zarei), h.abbasi@ssrc.ac.ir (H. Abbasi).

hamstrings isokinetic strength ratio can predict the occurrence of hamstring injuries (Zvijac, Toricelli, Merrick, & Kiezbak, 2013). Also, weak eccentric strength of the hamstrings, especially at angular velocities less than 60°/sec has shown to cause injury to hamstring muscles (Sugiura, Saito, Sakuraba, Sakuma, & Suzuki, 2008). However, isokinetic strength of hip flexor, extensor, abductor, and adductor muscles at 60°/sec cannot predict lower extremity injuries (Verrelst, De, Willems, Roosen, & Witrouw, 2014). Also, the strength ratios of the hamstrings and quadriceps could not be considered clinically harmful to hamstrings (van Dyk et al., 2017).

Regarding the first step on validating a screening test to predict and prevent sports injuries, which is finding related risk factors to football injuries through prospective designs (Bahr, 2016), the inconsistent results due to various research designs does not lead to a certain conclusion about the association between the muscle strength tests and incidence of football injuries. As a result, the purpose of this prospective study was to determine the relationship between isokinetic strength of hip, knee and ankle muscles and occurrence of injuries in young football players in Iran.

2. Methodology

This is a prospective, cohort design with the purpose of exploring the relationship between the measures of lower extremity isokinetic strength and the injuries in young soccer players through one season (9 months). The statistical population included the young soccer players from U-21 Iran premier league of which 73 young players (four teams) participated voluntarily. Inclusion criteria for the study were: at least three years of soccer playing experience, 18–21 years old, having an average of three training sessions per week (including matches and training), having no Severe injury (more than three weeks absence in exercise) during the last six months, having normal alignment of lower extremities. Discontinuity of more than three weeks of training and participation in the systematic and regular injury prevention program led to exclude the players.

In this research, to assess isokinetic muscle strength, The Biodex Isokinetic pro 4 system manufactured by the CMVAG Con-Trex company was used. All players attended Shahid Beheshti University Laboratory before the start of the 2017–2018 season. The measurements were taken between 8 a.m. and 12 p.m. by the same experimenter blinded to each subject's grouping. All tests were carried out just for the dominant leg. Leg dominance was determined by asking the players for their kicking leg. Before each testing session, the dynamometer was set in accordance with the manufacturer's recommendations. A standardized testing protocol was followed (De Noronha & Júnior, 2004; Fagher, Fritzon, & Drake, 2016). The subjects performed a general cardiovascular warm-up for at least 5 min on a Monark cycle ergometer at a moderate pace (50–100 W). Tests were conducted in the sitting position. And also a specific warm-up, consisting of three sub maximal contractions, followed by three maximum concentric contractions. To prevent extra movements, subjects were fixed with straps across the shoulders, chest, and hip. The cuff of the dynamometer's lever arm was also attached to proximal malleoli of the ankle. The rotational axis of the joint was aligned with the dynamometer rotational axis. The order of testing was randomized.

During isokinetic concentric tests, maximum torque was determined for all the tests. Every test was performed two sets, including three repetitions, with 60-s rest between the sets (Parcell, Sawyer, Tricoli, & Chinevere, 2002). 20 min rest was let between the joints. The best value observed from all repetitions was considered and normalized to body mass (MAXIMUM TQ/BM) for the final report and statistical analysis.

The angular speeds used for isokinetic tests were 30, 60 and 90°/sec/s for concentric strength of hip abductor and adductor muscles. 60, 180 and 300°/sec/s for concentric strength of knee extensor and flexor muscles. 60 and 120°/sec/s for concentric strength of ankle evtor and invertor muscles, 30, 60 and 120°/sec/s for concentric strength of ankle of dorsi and plantar flexor muscles. The knee was extended while testing the plantar flexion and dorsiflexion and in 30–40°/sec flexion while testing the inversion and eversion. The rationale for choosing these speeds was based on previous studies in which comparable speeds were used (De Noronha & Júnior, 2004; Fagher et al., 2016).

2.1. Injury and exposure time documentation

An injury is defined as any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities. An injury that results in a player receiving medical attention is referred to as a “medical attention” injury and an injury that results in a player being unable to take a full part in future football training or match play as a “time loss” injury (Fuller et al., 2006). Match exposure is defined as the play between teams from different clubs. Training exposure is defined as team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff that are aimed at maintaining or improving players' football skills or physical condition.

Injuries were recorded by the team's medical staff throughout one season (9 months) in injury forms, provided in the Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries (Fuller et al., 2006). Team instructors were requested to register their team's match and training hours in the Match and training exposure form which were collected weekly.

Injuries were recorded by the team's medical staff throughout one season (9 months) in injury forms, provided in the Consensus statement on injury definitions and data collection procedures in studies of football (football) injuries (Fuller et al., 2006). Team instructors were requested to register their team's match and training hours in the Match and training exposure form which were collected weekly.

2.2. Ethical considerations

Full consent was obtained from the participants prior to the study. Participants had rights to withdraw from the study at any stage if they wish to do so. The protection of the privacy of research participants, the confidentiality of the research data and the anonymity of individuals and organizations participating in the research while publishing the results were ensured. The study was approved by the local ethics committee [insert after review].

2.3. Statistical method

All data were analyzed using SPSS for windows version 20. Descriptive data are presented as mean \pm SD. Muscle strength measures are presented as absolute (for agonist/antagonist ratio tests) and body mass-normalized values for the other variables. To examine the relationship between lower extremity injuries with isokinetic strength indices of muscles, Cox regression analyses were used at 95% significance level with alpha equal or less than 0.05. In this study, only lower limb injuries were examined and the first recorded injury inflicted to each player was used in the assessments. Individual exposure data were calculated as the sum of the total number of hours of training and match play from the date of screening until the end of each season or until the date of the first

injury. On the basis of a previous similar study (Bakken et al., 2018).

3. Result

In this prospective study, data from 73 players were analyzed. Table 1 shows the subjects demographic information including age, body mass, height, and BMI (Table 1).

The total exposure of 10910 Playing hours was reported throughout the 36-week season. 22 players suffered lower extremity injuries during the season (injury incidence rate of 2.1 injuries per 1000 h of exposure). Table 2 presents the injury characteristics.

According to Table 3, there was a significant relationship between the isokinetic strength ratio of the hip abductor/adductor muscles at 30°/sec and lower extremity injuries, so that by increasing a unit of hip abductor strength, injury decreases by 10%. Also, there was a significant relationship between the maximal torque of adductor muscles in angular speed of 30°/sec/s and maximal torque of hip abductors in the angular speed of 90°/sec/s with the occurrence of injuries (Table 3).

Players who had a higher muscle isokinetic strength ratio of knee flexor/extensors at the angular speed of 60°/sec were significantly less injured. By increasing one unit in the ratio of the isokinetic strength of the knee flexor/extensor, the incidence of injury decreases by six percent. There was also a significant relationship between the maximum torque of the knee extensor muscles at 60°/sec and the maximum flexor torque of the knee at 60°/sec with the occurrence of injury. Therefore, increasing strength in knee flexors and knee extensors reduces the incidence of injury (Table 4).

There was no significant relationship among knee flexor/extensor strength ratio, knee extensor muscle maximum torque and knee flexor muscle maximum torque at the angular speed of 180 and 300°/sec. Also, the results of Cox regression test showed a significant relationship between the strength of the maximal torque of the ankle evertor muscles and the maximum torque of the invertor muscles at the angular speed of 60 and 120°/sec, and also the ratio of strength of the dorsi flexor/plantar flexor muscle of ankle, maximal torque of the dorsi flexor and maximal torque of the ankle plantar flexor muscles in angular speed of 30, 60 and 120°/sec with the occurrence of injury (Table 5).

4. Discussion

The aim of this prospective, cohort study was to determine the relationship between isokinetic strength of hip, knee and ankle muscles at different speeds and injuries in young football players through one season. The results indicated that the isokinetic strength indices of lower extremity muscles are associated with lower extremity injuries in football players.

A significant relationship was revealed between the ratio of the isokinetic strength of the abductor/adductor and lower extremity injuries. This is in line with some studies with similar reports (Kulig, Popovich Jr, Noceti-Dewit, Reischl, & Kim, 2011; Verrelst, Willems, et al., 2014). Verrelst et al., using a two-year review on the effect of hip muscle strength at 60°/sec on medial tibia pain,

Table 2
The Injury characteristics.

Number (Percentage)	Location
5 (23%)	Hip
2 (9%)	Thigh musceles
7 (32%)	Knee
1 (4%)	Foot
7 (32%)	Ankle

concluded that the hip abductor muscle strength can be considered a predictor of medial tibia pain (Verrelst, Willems, et al., 2014). Kulig, Popovich, Noceti-Dewit, Reischl, and Kim (2011). It has been shown that bilateral hip extensor/abductor muscle strength is significantly correlated with the incidence of injury. It is argued that reduced hip abductor muscle strength contributes to an increase in the foot pronation, thus increases the incidence of injury (Kulig et al., 2011). hip muscle deficit, especially hip abductor muscle deficit, can affect the musculoskeletal balance and coordination and leads to injury (Friel, McLean, Myers, & Caceres, 2006; Hubbard, Kramer, Denegar, & Hertel, 2007).

According to our findings players who had a higher muscle isokinetic strength ratio of knee flexor/extensors were significantly less injured. Lee et al. (2018) reported that hamstring strength deficit and poor hamstring-to-quadriceps ratio and previous hamstring injury is an intrinsic risk factor for acute hamstring injury (Lee, Mok, Chan, Yung, & Chan, 2018). Myer et al. (2009) in another study examined hamstring-to-quadriceps strength. They stated that women athletic with ACL injury had less hamstring muscle strength than men, but did not differ in quadriceps muscles. On the other hand, those with hamstring and quadriceps strength deficit are at risk of ACL injury, and increased hamstring muscle strength can reduce injury (Myer et al., 2009). By studying 221 female football players, Söderman, Alfredson, Pietilä, and Werner (2001) reported that increasing the strength ratio of hamstring to quadriceps could reduce lower limb injury and ACL injury (Söderman et al., 2001). Hamstring and quadriceps play an important role in controlling the movements of players when jumping and landing, changing directions, decreasing and increasing speed, and controlling knee movements (Van Beijsterveldt, van de Port, Vereijken, & Backx, 2013). The role of hamstring muscles at higher speeds is much more important than lower speeds. Therefore, hamstring muscle strength deficit at high speed causes injury (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; Lee et al., 2018).

However, other studies contradicted the present study results (Hägglund, Waldén, & Ekstrand, 2013; Mosler et al., 2018; Verrelst, De, et al., 2014), may be due to the difference in muscle strength measurement tools. In the present study, muscle strength measurement method was performed in a sitting position, but the method was performed in a different position in many studies. Also, there are some differences in terms of statistical samples, device, and motor program. In addition to the existing differences, due to differences in the statistical samples and methodology of the previous research, some researchers argue that screening isokinetic strength of knee joint muscles is not an effective practical strategy to evaluate football players because lower extremity injury occurs at high speed, but this device fails to simulate motion speed effectively. Further, the highest strength recorded by the device is 85% of peak muscle strength, and the remaining 15% can be very effective in increasing the risk of injury among male players. On the other hand, the machine performs the measurement method irrespective of organ weight bearing, while all football motions are conducted in weight bearing situations. In addition, football movements are performed as a closed motor chain, while the

Table 1
Characteristics of all players (N = 73)^a.

	Value
Age (yrs)	17.7 ± 1.2
Height (cm)	176.4 ± 5.4
Body mass(kg)	67.8 ± 7
Body mass index(kg/m2)	21.7 ± 1.7

Data are presented as mean ± SD.

Table 3
Univariate comparison Cox Regression Analysis between Injured and Non-Injured Players (Hip).

P value	HR	Injured	Non-Injured	Isokinetic Test
0.01*	1.2	1.1 ± 0.5	1.1 ± 0.5	Maximum Isokinetic abduction in 30°/s
0.01*	0.9	0.8 ± 0.2	0.8 ± 0.3	Maximum Isokinetic adduction in 30°/s
0.02*	0.9	134 ± 45.1	144.1 ± 71.3	Maximum Isokinetic abduction/adduction in 30°/s
0.6	1	1.1 ± 0.5	1.1 ± 0.6	Maximum Isokinetic abduction 60°/s
0.9	0.9	0.9 ± 0.4	0.8 ± 0.3	Maximum Isokinetic adduction 60°/s
0.5	0.9	121.7 ± 45.3	140.8 ± 80.4	Maximum Isokinetic abduction/adduction 60°/s
0.03*	0.9	1.0 ± 0.5	1.1 ± 0.6	Maximum Isokinetic abduction 90°/s
0.6	1	1.0 ± 0.3	0.9 ± 0.4	Maximum Isokinetic adduction 90°/s
0.2	1	141.9 ± 65.5	139 ± 88.9	Maximum Isokinetic abduction/adduction 90°/s
0.02*	2.5	3.0 ± 0.3	2.8 ± 0.3	Maximum Isokinetic concentric extension 60°/s
0.03*	5.7	1.4 ± 0.3	1.5 ± 0.3	Maximum Isokinetic concentric flexion 60°/s
0.02*	0.4	47 ± 7.5	53.7 ± 10.7	Maximum Isokinetic concentric extension/flexion 60°/s
0.07	3011.9	2.1 ± 0.3	1.9 ± 0.3	Maximum Isokinetic concentric extension 180°/s
0.1	0	1 ± 0.1	1.0 ± 0.2	Maximum Isokinetic concentric flexion 180°/s
0.07	1.3	48.2 ± 6.5	53.8 ± 12.6	Maximum Isokinetic concentric extension/flexion 180°/s
0.1	2475.5	1.8 ± 0.2	1.6 ± 0.2	Maximum Isokinetic concentric extension 300°/s
0.4	0.0	0.9 ± 0.2	0.9 ± 0.2	Maximum Isokinetic concentric flexion 300°/s
0.4	0.1	51.9 ± 9.4	59.9 ± 12.8	Maximum Isokinetic concentric extension/flexion 300°/s

Data are presented as Mean ± SD for the injured and uninjured player. Hazard ratios (HRs), per 1 unit of change for variables, are presented with 95% CIs and P values from Cox regression analyses.

Table 4
Univariate comparison Cox Regression Analysis between Injured and Non-Injured Players (Knee).

P value	HR	Injured	Non-Injured	Isokinetic Test
0.02*	2.5	3.0 ± 0.3	2.8 ± 0.3	Maximum Isokinetic Concentric Extension 60°/S
0.03*	5.7	1.4 ± 0.3	1.5 ± 0.3	Maximum Isokinetic Concentric Flexion 60°/S
0.02*	0.4	47 ± 7.5	53.7 ± 10.7	Maximum Isokinetic Concentric Extension/Flexion 60°/S
0.07	3011.9	2.1 ± 0.3	1.9 ± 0.3	Maximum Isokinetic Concentric Extension 180°/S
0.1	0	1 ± 0.1	1.0 ± 0.2	Maximum Isokinetic Concentric Flexion 180°/S
0.07	1.3	48.2 ± 6.5	53.8 ± 12.6	Maximum Isokinetic Concentric Extension/Flexion 180°/S
0.1	2475.5	1.8 ± 0.2	1.6 ± 0.2	Maximum Isokinetic Concentric Extension 300°/S
0.4	0.0	0.9 ± 0.2	0.9 ± 0.2	Maximum Isokinetic Concentric Flexion 300°/S
0.4	0.1	51.9 ± 9.4	59.9 ± 12.8	Maximum Isokinetic Concentric Extension/Flexion 300°/S

Data are presented as Mean ± SD for the injured and uninjured player. Hazard ratios (HRs), per 1 unit of change for variables, are presented with 95% CIs and P values from Cox regression analyses.

Table 5
Univariate comparison Cox Regression Analysis between Injured and Non-Injured Players in (Ankle).

P value	HR	Injured	Non-Injured	Isokinetic Test
0.06	2.0	0.3 ± 0.06	0.3 ± 0.1	Maximum Isokinetic eversion 60°/s
0.5	0.01	0.4 ± 0.09	0.3 ± 0.1	Maximum Isokinetic inversion 60°/s
0.3	0.9	88.6 ± 21.5	91.1 ± 23.4	Maximum Isokinetic eversion/adduction in 60°/s
0.5	0.0	0.3 ± 0.06	0.2 ± 0.09	Maximum Isokinetic eversion 120°/s
1.5	19949.9	0.4 ± 0.1	0.3 ± 0.1	Maximum Isokinetic inversion 120°/s
0.9	1.0	83.8 ± 24.9	85.9 ± 16.2	Maximum Isokinetic eversion/inversion in 120°/s
0.4	5.6	1.2 ± 0.4	1.2 ± 0.4	Maximum Isokinetic concentric plantar-flexion 30°/s
0.08	5.2	0.3 ± 0.1	0.3 ± 0.1	Maximum Isokinetic concentric dorsiflexion 30°/s
0.1	1.2	28.0 ± 9.6	27.1 ± 8.3	Maximum Isokinetic concentric plantar-flexion/dorsiflexion in 30°/s
0.059	94584.5	1.1 ± 0.3	1.0 ± 0.3	Maximum Isokinetic concentric plantar-flexion 60°/s
0.4	2.6	0.2 ± 0.09	0.2 ± 0.1	Maximum Isokinetic concentric dorsiflexion 60°/s
0.1	1.3	25.1 ± 8.5	24.7 ± 6.5	Maximum Isokinetic concentric plantar-flexion/dorsiflexion 60°/s
0.3	0.0	0.8 ± 0.2	0.7 ± 0.3	Maximum Isokinetic concentric plantar-flexion 120°
0.9	0.2	0.2 ± 0.08	0.2 ± 0.1	Maximum Isokinetic concentric plantar-flexion 120°/s
0.7	0.9	25.9 ± 9.0	26.6 ± 9.9	Maximum Isokinetic concentric plantar-flexion/dorsiflexion 120°/s

Data are presented as Mean ± SD for the injured and uninjured player. Hazard ratios (HRs), per 1 unit of change for variables, are presented with 95% CIs and P values from Cox regression analyses.

machine operates as an open motor chain (S. Eustace, Page, & Greig, 2018; S. J. Eustace, Page, & Greig, 2017).

Additionally, the Cox Regression results indicated a significant relationship between strength ratios of ankle evverter to the invertor muscles. Willems et al. (2005) found that isokinetic strength of ankle evverter and invertor muscles among male athletes had significant relation with the occurrence of ankle injuries (T. M. Willems et al., 2005). Kaminski et al. (2002) measured the

isokinetic strength of ankle evverter-invertor muscles and concluded that the relevant muscle strength did not affect the incidence of ankle instability (Kaminski & Hartsell, 2002). The absence of an association between isokinetic strength of ankle evverter-invertor muscles and incidence of injury can be explained by the fact that the players have high speeds in football motions, and the lower limb is in contact with the ground while the players bear weight on their limbs. However, in this study, the assessment

was not conducted as such. In addition, some researchers stated that despite the importance of muscle strength in the incidence of injury, the size of these muscles and their productive power are not considerably high (Bernier, Perrin, & Rijke, 1997; Kaminski & Hartsell, 2002).

No significant relationship was found between isokinetic strength ratios of ankle dorsi-to plantar flexor muscles. In line with the results of the present study, Gribble et al. (2009) suggested that ankle dorsi-flexor muscle strength was not different in those with ankle instability, compared to the group without ankle instability (Gribble & Robinson, 2009). Further, some researchers attribute the insignificance of ankle dorsi- and plantar flexor muscles to the fact that strength measurement method adopted by Biodex Isokinetic System (used in the present research) failed to provide a real-life simulation of ankle function. Analyzing the reason for this inefficiency, different studies focused on two problems including different positioning on the system seat and knee joint angle. In contrast, some research indicated that strength measurement of these muscles “in a smooth-knee state” can bring about better results and is closer to the football motions. However, some studies argue that knee flexion is more appropriate (Wennerberg, 1991).

On the other hand, unlike the results of the present study, some researchers such as Kobayashi, Tanaka, and Shida (2016) stated that ankle invertor muscle strength deficit affects the incidence of the ankle sprains (Kobayashi et al., 2016). Munn, Beard, Refshauge, and Lee (2003) concluded that muscle strength deficit in ankle invertors has a positive effect on functional instability. They recorded peak torque of evertor and invertor muscles at an angular speed of 60 and 120°/sec (Munn et al., 2003). Willems, Witvrouw, Verstuyft, Vaes, and De Clercq (2002) reported that the ankle evertor muscles were significantly associated with ankle chronic instability and in the case of ankle sprain, ankle lateral ligaments suffer from overextension if the ankle evertor muscles do not have sufficient strength to prevent this motion (T. Willems et al., 2002). Concerning the ankle dorsi- and plantar flexor muscles, Kobayashi et al. (2016) demonstrated that an increase in ankle dorsi-plantar flexor muscles have an effect on the incidence of ankle lateral sprain injury (Kobayashi et al., 2016). Negahban et al. (2013) suggested that people with ankle injury had weaker dorsi-flexor muscles than healthy people and even than their own healthy limbs (Negahban et al., 2013). Examining isokinetic strength of ankle dorsi- and plantar flexor muscles and its impact on the incidence of ankle ligament injury among male athletes, Willems et al. (2005) concluded that ankle dorsi-flexor muscle strength deficit can affect the incidence of this injury (T. M. Willems et al., 2005).

Based on the results, ankle lateral muscle strength, i.e. ankle invertor and evertor muscles, plays an important role in the ankle sprains, which can be due to the fact that, in case of ankle lateral sprain, if the muscles of opposite side of sprain are not strong, they fail to control motions and inhibit severity of injury, leading to injury or aggravation of injury (Baumhauer, Alosa, Renström, Trevino, & Beynnon, 1995). The effectiveness of ankle plantar muscles can be due to the fact that increased plantar muscle strength increases Achilles tendon tension and positioning of the leg in plantar flexion state and shortness of muscles contribute to ankle instability and consequently ankle sprain (Baumhauer et al., 1995; Kobayashi et al., 2016).

5. Limitations

To identify good associations in a prospective cohort study, 30 to 40 injury cases are required (11) whereas only 22 injuries occurred in this study. The limited number of participants and injured players represents a limitation in the current study.

We measured the dominant leg only and consequently, we did

not calculate ratios between the dominant and the non-dominant leg.

6. Conclusion

Based on the results, hip and knee muscle strength significantly impact the incidence of lower limb injury, and isokinetic strength of lower limb muscle is associated with the incidence of injury among football players. Furthermore, given the high rate of ankle injuries, knee and hip muscle strength affect the ankle function and injury. Therefore, findings regarding the isokinetic strength screening of hip abductor/adductor muscles, isokinetic strength ratio of hip adductor/abductor, knee flexor/extensor, and isokinetic strength ratio of knee flexor/extensor muscles, can raise awareness in identifying associated factors to football injuries and developing a screening test to predict and prevent sports injuries.

Disclosure of interest

The authors report no conflict of interest.

Conflicts of interest

The authors report no conflict of interest.

Ethical statements

This material has not been published in whole or in part elsewhere;

The manuscript is not currently being considered for publication in another journal.

All authors have been personally and actively involved in substantive work leading to the manuscript, and will hold themselves jointly and individually responsible for its content.

Funding

This research project was kindly supported by the Shahid Beheshti University. The funding source had no involvement in the conduct and reporting of the study.

Acknowledgments

We would like to thank the Shahid Beheshti University for their support which allowed the realization of this project. We would like to thank all clubs, coaches, and players for their participation and our study assistants for their valuable support during data collection.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pts.2019.06.013>.

References

- Amason, A., Andersen, T., Holme, I., Engebretsen, L., & Bahr, R. (2008). Prevention of hamstring strains in elite soccer: An intervention study. *Scandinavian Journal of Medicine & Science in Sports*, 18(1), 40–48.
- Bahr, R. (2016). Why screening tests to predict injury do not work—and probably never will...: A critical review. *British Journal of Sports Medicine*, 50(13), 776–780.
- Bakken, A., Targett, S., Bere, T., Eirale, C., Farooq, A., Mosler, A. B., ... Bahr, R. (2018). Muscle strength is a poor screening test for predicting lower extremity injuries in professional male soccer players: A 2-year prospective cohort study. *The American Journal of Sports Medicine*, 46(6), 1481–1491.
- Baumhauer, J. F., Alosa, D. M., Renström, P. A., Trevino, S., & Beynnon, B. (1995).

- A prospective study of ankle injury risk factors. *The American Journal of Sports Medicine*, 23(5), 564–570.
- Bernier, J. N., Perrin, D. H., & Rijke, A. (1997). Effect of unilateral functional instability of the ankle on postural sway and inversion and eversion strength. *Journal of Athletic Training*, 32(3), 226.
- De Noronha, M. A., & Júnior, N. G. B. (2004). Lateral ankle sprain: Isokinetic test reliability and comparison between invertors and evertors. *Clinical Biomechanics*, 19(8), 868–871.
- De Ridder, R., Witvrouw, E., Dolphens, M., Roosen, P., & Van Ginckel, A. (2017). Hip strength as an intrinsic risk factor for lateral ankle sprains in youth soccer players: A 3-season prospective study. *The American Journal of Sports Medicine*, 45(2), 410–416.
- Eustace, S. J., Page, R. M., & Greig, M. (2017). Contemporary approaches to isokinetic strength assessments in professional football players. *Science and Medicine in Football*, 1(3), 251–257.
- Eustace, S., Page, R., & Greig, M. (2018). Angle specific isokinetic metrics highlight strength training needs of elite youth soccer players. *The Journal of Strength & Conditioning Research*. <https://doi.org/10.1519/JSC.0000000000002612>.
- Fagher, K., Fritzon, A., & Drake, A. M. (2016). Test-retest reliability of isokinetic knee strength measurements in children aged 8 to 10 years. *Sport Health*, 8(3), 255–259. <https://doi.org/10.1177/1941738116632506>.
- Friel, K., McLean, N., Myers, C., & Caceres, M. (2006). Ipsilateral hip abductor weakness after inversion ankle sprain. *Journal of Athletic Training*, 41(1), 74.
- Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., & Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scandinavian Journal of Medicine & Science in Sports*, 16(2), 83–92.
- Gribble, P. A., & Robinson, R. H. (2009). An examination of ankle, knee, and hip torque production in individuals with chronic ankle instability. *The Journal of Strength & Conditioning Research*, 23(2), 395–400.
- Häggliund, M., Waldén, M., & Ekstrand, J. (2013). Risk factors for lower extremity muscle injury in professional soccer: The UEFA injury study. *The American Journal of Sports Medicine*, 41(2), 327–335.
- Hubbard, T. J., Kramer, L. C., Denegar, C. R., & Hertel, J. (2007). Contributing factors to chronic ankle instability. *Foot & Ankle International*, 28(3), 343–354.
- Kaminski, T. W., & Hartsell, H. D. (2002). Factors contributing to chronic ankle instability: A strength perspective. *Journal of Athletic Training*, 37(4), 394.
- Kobayashi, T., Tanaka, M., & Shida, M. (2016). Intrinsic risk factors of lateral ankle sprain: A systematic review and meta-analysis. *Sports health*, 8(2), 190–193.
- Kulig, K., Popovich, J. M., Jr., Noceti-Dewit, L. M., Reischl, S. F., & Kim, D. (2011). Women with posterior tibial tendon dysfunction have diminished ankle and hip muscle performance. *Journal of Orthopaedic & Sports Physical Therapy*, 41(9), 687–694.
- Lee, J. W., Mok, K.-M., Chan, H. C., Yung, P. S., & Chan, K.-M. (2018). Eccentric hamstring strength deficit and poor hamstring-to-quadriceps ratio are risk factors for hamstring strain injury in football: A prospective study of 146 professional players. *Journal of Science and Medicine in Sport*, 21(8), 789–793.
- McCall, A., Carling, C., Davison, M., Nedelec, M., Le Gall, F., Berthoin, S., et al. (2015). Injury risk factors, screening tests and preventative strategies: A systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. *British Journal of Sports Medicine*, 49(9), 583–589.
- Mosler, A. B., Weir, A., Serner, A., Agrícola, R., Eirale, C., Farooq, A., ... Hölmich, P. (2018). Musculoskeletal screening tests and bony hip morphology cannot identify male professional soccer players at risk of groin injuries: A 2-year prospective cohort study. *The American Journal of Sports Medicine*, 46(6), 1294–1305.
- Munn, J., Beard, D. J., Refshauge, K. M., & Lee, R. (2003). Eccentric muscle strength in functional ankle instability. *Medicine & Science in Sports & Exercise*, 35(2), 245–250.
- Myer, G. D., Ford, K. R., Foss, K. D. B., Liu, C., Nick, T. G., & Hewett, T. E. (2009). The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clinical Journal of Sport Medicine*, 19(1), 3–8.
- Negahban, H., Moradi-Bousari, A., Naghibi, S., Sarrafzadeh, J., Shaterzadeh-Yazdi, M.-J., Goharpey, S., et al. (2013). The eccentric torque production capacity of the ankle, knee, and hip muscle groups in patients with unilateral chronic ankle instability. *Asian Journal of Sports Medicine*, 4(2), 144.
- Parcell, A. C., Sawyer, R. D., Tricoli, V. A., & Chinesever, T. D. (2002). Minimum rest period for strength recovery during a common isokinetic testing protocol. *Medicine & Science in Sports & Exercise*, 34(6), 1018–1022.
- Ryan, J., DeBurca, N., & Mc Creesh, K. (2014). Risk factors for groin/hip injuries in field-based sports: A systematic review. *British Journal of Sports Medicine*, 48(14), 1089–1096.
- Söderman, K., Alfredson, H., Pietilä, T., & Werner, S. (2001). Risk factors for leg injuries in female soccer players: A prospective investigation during one out-door season. *Knee Surgery, Sports Traumatology, Arthroscopy*, 9(5), 313–321.
- Sugiura, Y., Saito, T., Sakuraba, K., Sakuma, K., & Suzuki, E. (2008). Strength deficits identified with concentric action of the hip extensors and eccentric action of the hamstrings predispose to hamstring injury in elite sprinters. *Journal of Orthopaedic & Sports Physical Therapy*, 38(8), 457–464.
- Van Beijsterveldt, A., van de Port, I. G., Vereijken, A., & Backx, F. (2013). Risk factors for hamstring injuries in male soccer players: A systematic review of prospective studies. *Scandinavian Journal of Medicine & Science in Sports*, 23(3), 253–262.
- van Dyk, N., Bahr, R., Burnett, A. F., Whiteley, R., Bakken, A., Mosler, A., ... Witvrouw, E. (2017). A comprehensive strength testing protocol offers no clinical value in predicting risk of hamstring injury: A prospective cohort study of 413 professional football players. *British Journal of Sports Medicine*, 51(23), 1695–1702. [bjsports-2017-097754](https://doi.org/10.1136/bjsports-2017-097754).
- Verrelst, R., De, D. C., Willems, T. M., Roosen, P., & Witrouw, E. (2014). Contralateral risk factors associated with exertional medial tibial pain in women. *Medicine & Science in Sports & Exercise*, 46(8), 1546–1553.
- Verrelst, R., Willems, T. M., De Clercq, D., Roosen, P., Goossens, L., & Witvrouw, E. (2014). The role of hip abductor and external rotator muscle strength in the development of exertional medial tibial pain: A prospective study. *British Journal of Sports Medicine*, 48(21), 1564–1569.
- Wennerberg, D. (1991). Reliability of an isokinetic dorsiflexion and plantar flexion apparatus. *The American Journal of Sports Medicine*, 19(5), 519–522.
- Willems, T. M., Witvrouw, E., Delbaere, K., Mahieu, N., De Bourdeaudhuij, L., & De Clercq, D. (2005). Intrinsic risk factors for inversion ankle sprains in male subjects: A prospective study. *The American Journal of Sports Medicine*, 33(3), 415–423.
- Willems, T., Witvrouw, E., Verstuyft, J., Vaes, P., & De Clercq, D. (2002). Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. *Journal of Athletic Training*, 37(4), 487.
- Zvijac, J. E., Toriscelli, T. A., Merrick, S., & Kiebzak, G. M. (2013). Isokinetic concentric quadriceps and hamstring strength variables from the NFL Scouting Combine are not predictive of hamstring injury in first-year professional football players. *The American Journal of Sports Medicine*, 41(7), 1511–1518.