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Original Research

Adductor squeeze test and groin injuries in elite football players: A prospective study

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ABSTRACT

Objective: To examining the relationship between hip adductor strength and groin injury incidence during the competitive season of professional football teams.
Design: Prospective Cohort study.
Setting: Controlled laboratory environment.
Participants: Seventy-one players volunteered to participate.
Main outcome measures: In the pre-season, maximal hip adductor strength was measured by means of the isometric adductor squeeze test. Hip adductor strength, normalized by body mass, was compared between players who suffered a groin injury ($n = 18$) vs uninjured players ($n = 53$). Risk ratios (RR) were used to evaluate the likelihood of players to suffer this type of injury.
Results: Most of the reported groin injuries occurred during competitive matches (5.5 per 1000 match hours). Maximal isometric hip adductor strength was lower in the groin-injured group compared with their uninjured counterparts (429.8 ± 100 vs 564 ± 58.7 N, $d = -1.58$ and 5.40 ± 1.27 vs 7.71 ± 0.89 N/kg, $d = -1.88$, respectively). Results revealed that values of maximal isometric adductor strength lower than 465.33 N increased the probability to suffer a groin injury by 72%. Furthermore, values of force relative to body mass lower than 6.971 N/kg increased the probability to suffer a groin injury by 83%.
Conclusion: The assessment of Hip adductor strength, in addition to other measurements, might help practitioners to determine the probability of suffering an overuse groin injuries in elite football players.

1. Introduction

Football (soccer) is an intermittent team sport with high physical, technical, and tactical demands (Arnason et al., 2004). Associated with the high physical demands of this team sport, previous studies have reported a relatively high injury incidence in football players, with 20–35 injuries per 1000 h of play (Waldén, Hägglund, & Ekstrand, 2005; Dvorak, Junge, Grimm, & Kirkendall, 2007; Ekstrand, Hägglund, & Ekstrand, 2011. Specifically, groin injuries represent one of the most common injuries in elite football with values ranging from 14% to 18% of the total number of injuries (Hägglund, Waldén, & Ekstrand, 2009; Werner, Hagglund, Walden, & Ekstrand, 2009), although these values can be lower in amateur football (Herrero, Salinero, & Del Coso, 2014). In addition, a recent study of male football players found that groin injuries accounted for 18% of all time-loss injuries (Mosler et al., 2018a). Furthermore, the available literature indicates that nearly 18% of overuse groin injuries will recur within 2 years, while 11% will recur in less than 2 months (Mosler et al., 2018a). Long-term symptoms in groin injuries are mainly the result of repetitive and sudden changes of direction and/or sprinting during football play, and during kicking actions during practices and competition (Machotka, Kumar, &

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Perraton, 2009; Delahunt, Kennelly, McEntee, Coughlan, & Green, 2011) while the incidence of acute groin injuries is lower in football (Hölmich, Thorborg, Dehlendorff, Krogsgaard, & Gluud, 2014). In order to implement preventive measures to minimize the risk of injury incidence, the identification of the risk factors associated with the occurrence of groin injury is crucial (Whittaker, Small, Maffey, & Emery, 2015).

Several non-modifiable internal risk factors such as previous injury (Engebretsen, Myklebust, Holme, & Engebretsen, 2010; Mosler et al., 2018b), older age (Arnason et al., 2004; O'Connor, 2004), higher level of competition (Tyler, Nicholas, Campbell, & McHugh, 2001), and modifiable risk factors such as decreased range of hip abduction and internal rotation motion (Arnason et al., 2004; Ibrahim, Murrell, & Knapman, 2007; Tak et al., 2016) have been related to an increased likelihood of suffering a groin injury in football players. In addition, isometric adductor muscle weakness and/or a lower ratio between adductor/abductor muscle strength have also been reported as possible physical risk factors for groin injury in football (Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2010; Esteve et al., 2018) and other sports (Tyler et al., 2001; Crow et al., 2010; Ryan, DeBurca, & Mc Creesh, 2014; Moreno-Pérez, Lopez-Valenciano, Barbado, Moreside, Elvira J, & Vera-Garcia, 2017). The combination of adductor muscle weakness and previous groin injury could further increase the probability of developing groin pain (Engebretsen et al., 2010; Esteve et al., 2018; Mosler et al., 2018b). Esteve et al. (2018) in a cross-sectional study of amateur football players identified that players who suffered from past-season groin pain for more than 6 weeks showed 13%–19% lower isometric adductor strength than the control players. This adds to the hypothesis that low values of isometric adductor strength might increase the risk of having a groin injury. Despite this evidence, few studies have examined the role that adductor strength plays in the aetiology of a groin injury in football and this warrants further prospective investigation (Mohammad, Abdelraouf, Elhafez, Abdel-Aziem, & Nassif, 2014).

Even though several methods have been described to assess adductor muscle strength (Emery & Meeuwisse, 2001; Thorborg et al., 2011; Tyler et al., 2001), the popularity of the adductor squeeze test has increased in several sports like football (Hanna, Fulcher, Elley, & Moyes, 2010; Mosler et al., 2017; Esteve et al., 2018 and rugby (Coughlan, Delahunt, Caulfield, Forde, & Green, 2014) due to its simplicity, low-cost, good reliability and validity (Delahunt et al., 2011). In addition, this test is a popular screening tool used to identify changes in adductor strength in order to minimize the groin injury risk in several sports (Roe et al., 2016).

All this previous information suggests that reduced hip adductor strength in football players might be associated with a higher probability to suffer a groin injury. Only two recent studies have analysed pre-season strength in the adductor squeeze test to identify elite football players at risk of developing groin injury (Bakken et al., 2018; Mosler et al., 2018b) while their results are inconclusive. Therefore, the aim of the present study was to analyse the association between hip adductor strength, assessed with the adductor squeeze test, and groin injury incidence during a competitive season in elite football players.

2. Methods

2.1. Participants

From an initial sample of ninety healthy football players, seventy-one took part in this prospective study. The participants were recruited from a professional team of the Portuguese First Division League (Primeira Liga: n = 35; age = 24.8 ± 4.2 years; body mass = 79.9 ± 5.8 kg; height = 1.82 ± 5.52 m) and from the U-19 team of the same football club (First National League: n = 36; age = 17.4 ± 0.6 years; body mass = 70.7 ± 7.2 kg; height = 175.7 ± 7.6 m). Fifty-four participants were right-leg dominant and 17 were left-leg dominant. At the beginning of each season the players belonging to the respective squads were evaluated and injuries were reported. The exclusion criteria were: a) a history of hip and groin orthopaedic problems within the previous three months to the onset of the investigation (three senior players); b) inability to undertake testing due to other injuries (three senior players and one U-19 player); c) transfer to other club during the season (nine senior players and three U-19 players). A written informed consent was obtained from each participant, their parents (U-19 players) and the club, prior to testing. The experimental procedures used in this study were in accordance with the Declaration of Helsinki and the ethical standards of the local committee.

2.2. Data collection

Physical variables were obtained during the 2015–2016 and 2016–2017 pre-seasons always before football training. In the 2015–2016 season, data were obtained from 14 professional players and 16 U-19 players; in the 2016–2017 season, data were obtained from 21 professional players and 20 U-19 players. Participants performed a warm-up consisting in 5-min of jogging (light intensity [10–12 points of the Bog-scale]) and an 8-min protocol of standardised static stretching exercises in leg and trunk muscles (Cejudo, Sainz de Baranda, Ayala, & Santonja, 2015). Specifically, participants performed 2 repetitions of 7 different unassisted and static stretching exercises, holding the stretch position for 30 s. Thereafter, participants performed the hip adductor strength test, as previously described (Delahunt et al., 2011). One week before testing, all football players were familiarized with the procedures to reduce the influence of the learning effect. The measurements of the hip adductor strength were performed by the same two experienced members of the team's medical staff with previous skills in the tests employed in this investigation. Examiner 1 (>12 years' experience) conducted all measurements with the dynamometer while examiner 2 (5 years' experience) ensured a proper and reliable testing position to assure that all participants were tested in the same conditions.

During the competitive season, all injuries were meticulously diagnosed and recorded by the medical staff of the football team, following the recommendations of the Medical Assessment and Research Centre (F-MARC), sponsored by the Federation Internationale de Football Association (Fuller et al., 2006). In addition, the time devoted to football training and the match play were individually obtained by the physical trainer of each football team to calculate time of exposure for training and match.

2.3. Measurements

2.3.1. Adductor squeeze strength test

For the measurement of maximal isometric hip adductor strength, each participant laid supine on a bench and, as explained elsewhere (Delahunt et al., 2011). Hips were positioned in a 45° flexion with knees flexed to 90° and hips in neutral rotation. The squeeze test was quantified using a handheld dynamometer (Smart Groin Trainer, Neuro Excellence, Portugal). The measurement of maximal isometric hip adductor strength with this same portable dynamometer is reliable and with low values of error (ICC = 0.94 (0.86–0.97); minimal detectable change (MDC) = 25.3 N; % MDC = 5.7% (Mesquita et al., 2018);). The dynamometer was placed between the knees (Fig. 1), specifically it was located at the most prominent point of the medial femoral condyles. Players were

Fig. 1. Example of a measurement with the adductor 45° squeeze test.

instructed to squeeze the cuff as hard as possible for 3 maximum contractions and held for 5 s with 3 min of passive recovery between contractions. The maximal pressure (squeeze) value displayed on the dynamometer dial was recorded during each of the three test trials. The best of the three trials was used for analysis.

2.3.2. Questionnaire

At the time of the hip adductor strength measurement, each participant's height and body mass were documented, as well as age, lower leg dominant side and a report of previous injuries (see Table 1). Any injury case included in the data analysis was defined as "*any physical complaint sustained by a player that results from a football match or training, irrespective of the need for the medical attention or time loss from football activities*" (Fuller et al., 2006). A groin injury was referred to any physical symptom located in the groin area (i.e., contact injuries were not included) which prevented a player from taking full part in training and match play activities to remaining for a period longer than 24 h (starting at the midnight of the day of the injury [Murphy Gissane, & Blake, 2012; Murphy, O'Malley E, Gissane C, & Blake, 2012];). Injury severity was defined as the number of days that have elapsed from the date of injury to the date of the player's return to full participation in team (Fuller et al., 2006). The following classification was used to describe injury severity: "minimal, 1–3 days; mild, 4–7 days; moderate, 8–28 days, and severe >28 days".

2.4. Data analysis

Force (N) and force relative to players' body mass values (N/kg) were used to individually assess maximal hip isometric adductor strength. Force relative to body mass was obtained through the calculation of the ratio of hip isometric adductor strength in relation to body mass of each player.

2.5. Statistical analysis

A descriptive analysis was performed using mean and standard deviations. Normality of the data distribution was verified using the Kolmogorov-Smirnov test. Groin injury incidence for the whole group of players was calculated as the number of groin injuries per 1000 h of match play and training. Groin-injured and uninjured players were compared via standardised mean differences, computed with pooled variance and respective 90% confidence intervals (CI). Thresholds for effect sizes (ES) were 0.2, trivial; 0.6, small; 1.2, moderate; 2.0, large and >2.0, very large (Hopkins, Marshall, Batterham, & Hanin, 2009). The probability of differences was reported with 90% confidence limits (CL). Magnitudes of clear effects were considered as the following scale: >5%, unclear; 25–75%, possibly; 75%–95%, likely; 95%–99%, very likely; >99%, most likely (Hopkins et al., 2009). In addition, binary logistic regression was used to assess the relationship between maximal isometric adductor strength, force relative to body mass and injury risk. The dependent variable was groin injury. The Odds Ratio (OR) and their 95% confidence intervals (CI), and the correspondent probabilities were determined. The threshold with the highest sensitivity and 1-specificity for maximal isometric adductor strength and force relative to body mass values was calculated using receiving operating characteristic (ROC) curves (Swets, 1988). All the statistical analyses were performed using IBM SPSS statistics for Windows (V22.0, Armonk, NY: IBM. Corp.) and the significance level was set at $p < 0.05$.

3. Results

Characteristics of the study participants are outlined in Table 1. Substantial differences were found in age, body mass, played games, time played and training time between groin-injured and uninjured players (Table 1). From the whole sample, fifty-three players (74.6%) did not suffer groin injuries during the competitive season, and the remaining (25.3% of players assessed) sustained 18 groin injuries in different players (12 adductor tendinopathies, 4 osteitis-pubis, and 2 femoral-acetabular impingement) during the same period. The number of groin injuries represented 10.5% of the total number of injuries. Specifically, 7% and 13.5% of all injuries that occurred during the first season and second season. In terms of severity, 10 were moderate injuries (8–28 days) and 8 severe (>28 days). The total groin injury incidence rate was 5.5 injuries per 1000 h played for matches and 0.3 per 1000 h for training sessions. There was significant difference between match-related and training-related groin injuries (5.2; 95% CL 3.82 to 6.80).

Very large effect sizes were observed in maximal isometric hip adductor strength when comparing groin-injured and uninjured players (429.8 ± 100 vs 564 ± 58.7 N, $d = -1.58$; 90% CL -2.08 to -1.07; Fig. 2). Similar results were found for the force relative to body mass (5.40 ± 1.27 vs 7.71 ± 0.89 N/kg, $d = -1.88$; 90% CL -2.37 to -1.39; Fig. 2).

The results from the binary logistic regression analysis showed a significant model for maximal isometric adductor strength ($X^2 = 6.319$; $p = 0.12$; $R^2 = 0.126$) and force relative to body mass ($X^2 = 41.613$; $p < 0.001$; $R^2 = 0.654$) (Table 2). Force relative to body mass (OR = 6.8 (2.699–17.129) revealed highest effectiveness on predicting groin-injuries in football players than maximal isometric hip adductor strength (OR = 1.005 (1.001–1.009). That is, the increase in 1 N in maximal isometric adductor strength decreases the chance to suffer a groin injury in 1.005, while the increase 1 N/kg in force relative to body mass decreases the chance to suffer a groin injury in 6.8 times.

The ROC curve analysis identified the threshold for the maximal isometric adductor strength as 465.33 N, with maximal sensitivity (0.887) and 1-specificity (0.278) between injured and non-injured players (C-statistic of 0.816, 95% CI 0.697 to 0.935 and, $p < 0.001$). Based on the results from binary logistic regression analysis, a threshold of 465.33 N correspond to a probability to not suffer a groin injury of 72%. The ROC curve analysis identified the threshold for the force relative to body mass as 6.971 N/kg, with maximal sensitivity (0.811) and 1-specificity (0.167) between injured and non-injured players (C-statistic of 0.936, 95% CI 0.80 to 0.993 and, $p < 0.001$). Based on the results from binary logistic regression analysis, a threshold of 6.971% correspond to a probability to not

Table 1
Descriptive characteristics of the football players who suffered a groin injury during the study or remained uninjured in this location during the competitive season.

	All	Uninjured (n = 53)	Groin-injured (n = 18)	Cohen's *d* (90% CL)	
Age (years)	22.0 ± 4.2	20.2 ± 4.7	23.5 ± 3.7	0.75 (0.32–1.78)	very likely ↑
Body mass (kg)	76.9 ± 7.5	73.7 ± 7.6	79.9 ± 7.1	0.83 (0.39–1.27)	very likely ↑
Body height (m)	1.79 ± 0.06	1.77 ± 0.07	1.82 ± 0.06	0.69 (0.27–1.11)	very likely ↑
Matches played (#)	32 ± 8	44 ± 10	21 ± 6	−2.51 (−3.06 to −1,95)	most likely ↓
Match exposure (min)	2715 ± 726	3960 ± 891	1471 ± 561	−3.03 (−3.63 to −2.42)	most likely ↓
Training exposure (min)	16891 ± 1151	18987 ± 1829	14795 ± 474	−2.63 (−3.20 to −2.06)	most likely ↓

Data are mean ± standard deviation for each group.

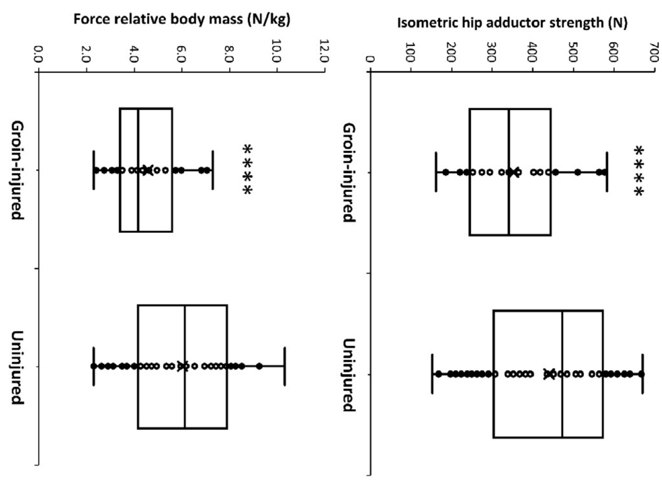

Fig. 2. Box-and-whisker plots for maximal isometric hip adductor strength (upper panel) and force relative to body mass (lower panel) in football players who suffered a groin injury or remained uninjured in this location during the competitive season. The lower, middle and upper lines of the box represent the 25, 50 and 75% percentile for each group. Whiskers represent lowest and highest values (range). **** denotes a very large effect size between groups.

suffer a groin injury of 83%.

The distribution of groin injuries over the entire season was not equal. As observed in Fig. 3 a higher percentage (44%) of groin injuries were reported during the first two months, (i.e., the pre-season and the first month of the competitive season) and January (22.2%) in while no groin-injuries were reported in December and in the last two months of the season.

4. Discussion

The aim of this study was to analyse the association between hip adductor strength, assessed with the adductor squeeze test, and groin injury incidence during a competitive season in elite football players. The main findings of the present study showed that football players who suffered a groin injury during the season had lower values of hip adductor strength, in absolute and relative to body mass terms, than their uninjured players. This information suggests that the measurement of hip adductor strength in elite football players might be a good tool to estimate the likelihood of suffering an overuse groin injury during the season. In addition, the investigation suggests that those players with low values of hip adductor strength should be engaged in specific training programs aimed to prevent overuse groin injuries.

According to the present findings, football players who sustained groin injuries during the competitive period showed weaker isometric adductor strength at the beginning of the season. These outcomes contrast with those recently obtained by Mosler et al. (2018b), who reported no association between bilateral isometric hip adduction strength, using the squeeze test, and the risk of groin injuries in professional football players. The different outcomes between investigations might be linked to the characteristics of the two cohorts under investigation. While the sample of professional football players in Mosler's investigation had values for body mass of ~72 kg and for body height of ~177 cm, the mean values of the professional players of this investigation were 80 kg and 182 cm, respectively. In fact, the characteristics of the football players in Mosler's investigation were comparable with our U19 squad (body mass ~71 kg and height ~176 cm). Moreover, training and playing exposure were rather different between the two cohorts: Mosler et al. (2018b) reported an average of 209 h of training and 25 h of match play while the uninjured group in the current investigation was exposed to ~316 h of training and ~66 h of match play. All this information, taken together, suggests that the players investigated the present study might be considered with a higher football level, in terms of both physicality (i.e., body mass and height) and training/playing exposure, than the ones investigated by Mosler et al. (2018b).

The contrasting findings, regarding the role of adductor strength in the risk of groin injuries in football players, is not a new issue in the literature on this topic. For example, Engebretsen et al. (2010) reported that adductor muscle weakness was associated with a 4-fold increase in risk of groin injury in players with otherwise normal strength values. On the contrary, having higher than normal eccentric adduction strength was associated with an increased risk of groin injuries (Mosler et al., 2018b). This overall lack of consensus between the role of adductor strength and the risk of groin injuries in football players might be related with the various potential mechanisms of the different categories of groin injuries and the differences in level and exposure of the samples studied (Mosler et al., 2018b). Further research with football players to elucidate the most appropriate tests to assess adductor strength and the potential risk of the different groin injuries is warranted. However, the present investigation adds to the literature important information to consider the assessment of hip adductor strength in the pre-season to discriminate those players with higher risk of overuse groin injuries.

Table 2
Results from binary logistic regression of maximal isometric adductor strength and force relative to body mass comparing groin-injured and uninjured football players.

	B	S.E.	Wald	df	Sig.	Exp(B)	95% CI	
Maximal isometric adductor strength	.005	.002	5.387	1	.020	1.005	1.001	1.009
Force relative to body mass	1.917	.471	16.536	1	.000	6.800	2.699	17.129

Abbreviations: B = changes probabilities; S.E. = Standart error; Wald = Wald test; df – degrees of freedom; Sig = satistical significance; Exp(B) = Odds ratio.

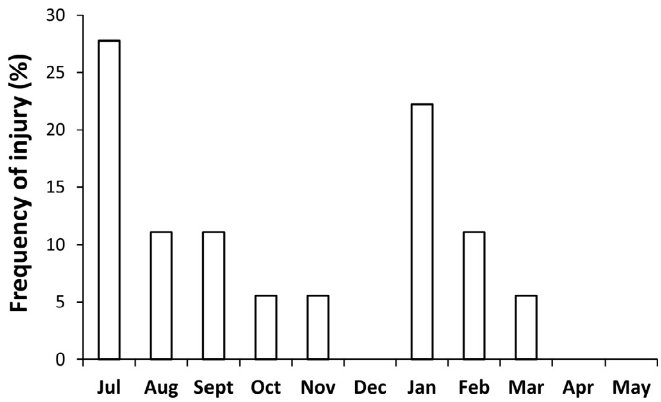

Fig. 3. Frequency of groin injuries in football players during the competitive season.

In the current analysis, the force relative to body mass showed a greater magnitude effect than absolute values of isometric hip adductor strength when comparing injured and uninjured players. Specifically, the results of the analysis of force relative to body mass revealed that a decrease in 1 N/kg increased the chance to suffer a groin injury in 6.8 times. Furthermore, values of force relative to body mass lowert han 6.971 N/kg increased the probability to suffer a groin injury in 83%. Regarding maximal isometric adductor strength in absolute terms, the results revealed that a decrease in 1 N increased the chance to suffer a groin injury in 1%. Also, values of maximal isometric adductor strength lower than 465.33 N increased the probability to suffer a groin injury in 72%. According to other researchers (Kloskowska, Morrissey, Small, Malliaras, & Barton, 2016), factors such as strength and muscle activation may clearly depend on the individual athlete's fitness and muscle morphology and could explain the best values obtained in force relative to body mass. These results of are in agreement with the results obtained in previous studies conducted with athletes of other sports that also entail repeated sudden changes of direction and/or repetitive kicking actions such as Australian and Gaelic football players (Crow et al., 2010; Delahunt, Fitzpatrick, & Blake, 2017) also assessed with the isometric adductor squeeze test. Specifically, in a prospective cohort study on 113 Australian football players Crow et al. (2010) found that hip adductor muscle strength was decreased by 5.83% the week that preceded or the actual week of the onset of a groin injury in elite under-age Australian footballers. Furthermore, Delahunt et al. (2017) reported that in 55 male elite Gaelic football players a pre-season test score below 225 mmHg (as determined by the use of a sphygmomanometer recording during the adductor squeeze test) predicted a groin injury with a sensitivity of 0.70 and a specificity of 0.78. Based on the above data, force relative to body mass could be considered as an interesting individual measurement that increases the sensitivity to detect strength deficits related with groin pain in football players.

The current study showed that a 7% and 13.5% of all injuries that occurred during the first season and second season, respectively, were groin injuries. Furthermore, match-related groin injuries occurred more frequently than training-related groin injuries (5.2; 95% CI 3.82 to 6.80). These findings are similar to previous football epidemiological studies that show a similar percentage (4%–21%) of groin injuries in professional football players per season (Hägglund et al., 2009; Mosler et al., 2018b; Noya, Gómez-Carmona, Gracia-Marco, Moliner-Urdiales, & Sillero-Quintana, 2014; Werner et al., 2009) and reported higher percentage of injuries during matches 3.5 per 1000 h (95% CI, 2.7–4.3) than training, with 0.7 per 1000 h (95% CI, 0.6–0.8 (Mosler et al., 2018b);).

Another interesting finding of the present study was the groin injury distribution during the season (Fig. 3). The present data showed that the majority of groin injuries were reported to occur in July and August (38.8%) (i.e., pre-season) and January (22.2%), while the lowest number of groin injuries was reported in November and December (5.5%). These results are in line with previous reports with professional male football players (Woods et al., 2004). A previous study (Walden, Hagglund, Orchard, Kristenson, & Ekstrand, 2013) found regional differences in injury incidence in European professional football due to differences in tactics, playing style, playing intensity, and climate-related differences in ground hardness. In Portugal, professional soccer players start the pre-season and season at the end of July and August, respectively. Thus, the highest incidence of groin injuries in those months might be related by the excessive and/or inappropriate accumulation of training load and associated lack of recovery during the pre-season period. Therefore, based on the present results, an extra care could be placed during the preseason with those players with relatively weaker adductors.

While the results of this study have provided information regarding the relationship between the isometric adductor hip strength and force relative to body mass in pre-season using the adductor squeeze test and the incidence of suffering groin injury over season in professional football players, limitations to the study must be acknowledged. Firstly, as the current study has been performed in a specific sample of football players, these findings may not be extended to another athletes' population. Additionally, other potential weakness is that the current information is related to the beginning of the season (pre-season screening programme) and do not provide information on how these scores may vary during the season or from season to season. We have calculated cutoff point to determine the likelihood of suffering a groin injury, in both absolute and relative terms, but these thresholds should be used with caution because they might vary in terms intra and interindividual variability of the measurement and/or with the use of other models of handheld dynamometers. Finally, we set a 3-month exclusion criterion from any previous groin/hip injury in our study sample while the strength deficit produced by a previous groin/hip injury might last more than this established period. Despite these limitations, the authors believe that the manuscript adds valuable information to provide an easy and useful screening test to increase the likelihood of preventing groin injuries in football players.

5. Conclusion

The results of the present study revealed a significantly lower isometric adductor strength, and strength relative to body mass, in groin-injured elite football players during a competition season. The measurement of normalized force values in relation to body mass (force relative to body mass) for each player seems to constitute an interesting individual variable that might help to identify the risk of groin injuries in football players.

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