

Effects of Whole-Season Training and Match-Play on Hip Adductor and Abductor Muscle Strength in Soccer Players: A Pilot Study

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Background: Previous investigations have associated weakness of hip muscles with a higher likelihood of developing hip groin injury. However, no previous investigation has examined the influence of soccer training and match-play during the season on maximal isometric hip adductor and abductor muscle strength.

Hypothesis: Maximal hip adductor and abductor muscle strength would increase after the preseason, maintaining relatively constant levels across the soccer season.

Design: Cross-sectional study.

Level of Evidence: Level 3.

Methods: A total of 26 semiprofessional male soccer players underwent measurements of maximal isometric hip adductor and abductor muscle strength at 3 time points of the soccer season: preseason, midseason, and end-season to investigate the longitudinal effect of soccer training and competition during a complete season on maximal isometric hip adductor and abductor muscle strength in the semiprofessional Spanish soccer player.

Results: Compared with preseason, hip abductor muscle strength increased in the midseason (14.2% and 17.1%, for dominant and nondominant limb, respectively; $P < 0.001$) and in the end-season (13.1%; $P = 0.005$, and 14.1%; $P < 0.005$). In contrast, hip adductor muscle strength remained unchanged across the season in both limbs. As a result, the adductor/abductor strength ratio in the nondominant limb was reduced at midseason and end-season time points (−14.6% and −18.4%, respectively; $P < 0.001$) with a corresponding tendency in the dominant limb (−9.3% and −15.0%, respectively; $P > 0.05$).

Conclusion: While maximal hip abductor muscle strength increased throughout the season, hip adductor muscle strength remained stable across the season. This produced a substantial deficit in hip adductor/abductor strength ratio at midseason and end-season.

Clinical Relevance: The progressive imbalance in adductor/abductor strength across the soccer season may be an indicator of increased risk of groin injury and may reinforce the need for preventive rehabilitation activities focused on enhancing adductor muscle strength.

Keywords: soccer; muscle overuse injury; fatigue; team sport; elite athlete

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Hip groin injuries are among the most frequent overuse injuries in soccer, accounting for 14% to 19% of all injuries reported in elite soccer teams.^{27,28} Groin injuries in sport are characterized by a difficulty of diagnosis,²⁹ long duration of recovery,^{15,17} and a high risk of reinjury.^{10,15} Approximately, one-third of players that suffered groin pain during the season reexperienced groin pain at the beginning of the subsequent season.²⁵ A recent study in male Qatar top-league soccer players reported an average of 6.6 groin injuries per team per season, resulting in an average of 85 days lost per team.¹⁷ Thus, preventing groin injuries is a top priority in elite soccer teams to reduce the negative impacts on performance associated with this type of injury.³⁰

The complexity involved in ascertaining the cause(s) of noncontact sport injuries is well-recognized⁴ because, in most cases, the mechanism of injury is multifactorial. However, the identification of a clinically meaningful risk factor remains an essential element of the injury prevention model with the aim of decreasing incidence and severity of various injury types in soccer.¹³ One of the most common modifiable risk factors for groin injury is hip adductor muscle weakness and/or the imbalance of the hip adductor/abductor strength ratio,^{7,8,12,16,22} Interestingly, side-to-side strength deficits of less than 10% when comparing injured and noninjured limbs for maximal hip adductor and abductor muscle strength may be a clinical threshold to return to play after groin injury.²⁴ Moreno-Pérez et al¹⁶ reported, in a sample of 71 soccer players, that those players with weaker isometric hip adductor muscles strength in the preseason were at a 72% higher risk of sustaining groin injury during the competitive season. Similarly, lower eccentric hip adduction strength during precompetition screening also was associated with an increased risk of groin injury during the competitive season.¹⁸ A recent investigation reported that hip adductor and abductor muscle strength increases from preseason throughout the remaining season,³¹ although this investigation only examined 15-year-old soccer players with much lower training and competitive match demands than among professional soccer players.⁵ Thus, there is an evolving body of evidence that hip adductor weakness in the preseason phase may predispose professional soccer players to groin injury during the subsequent season. Of note, no previous investigation has the natural time course of change in hip adductor and abductor muscle strength across the season in high-level soccer players. This information may be important as a progressive deconditioning of players and chronic fatigue developed during the competitive season may influence the risk of groin injury in professional soccer players.²¹

Another potential risk for groin injury is hip adductor/abductor strength deficits. Strength imbalance between these 2 agonist/antagonist muscle groups may produce instabilities to the pelvis,² especially during acceleration/sprinting and in change of direction (CoD) activities.⁷ However, the evidence associating adductor/abductor strength deficits with groin injury in soccer players is scarce. A hip adductor/abductor strength ratio of 0.3 has been found in the affected limb of professional soccer players with previous groin injury, while an adductor/

abductor strength ratio close to 0.8 was observed in asymptomatic players.² In other team sports (Australian football), reduced isometric adductor strength has been reported in the weeks preceding onset of groin pain.⁶ Additionally, professional ice hockey players with isometric hip adduction strength levels >20% lower than hip abductor strength were 17 times more likely to sustain a groin injury.²⁶ Overall, weakness in hip adductor muscles by itself or in relation to a stronger hip abductor muscle appears to be associated with an elevated incidence of groin injury in soccer players. Nevertheless, with the current background, it is difficult to ascertain how soccer training and match-play during the season affect isometric hip muscle strength to estimate the fluctuation in groin injury risk across the season. Therefore, the aim of this study was to examine the longitudinal effect of soccer training and match-play during a complete season on maximal isometric hip adductor and abductor muscle strength in semiprofessional soccer players. We hypothesized that maximal hip adductor and abductor muscle strength would increase after the preseason, maintaining relatively constant levels across the season resulting in a stable adductor/abductor strength ratio throughout the playing season.

METHODS

Participants

A total of 31 healthy semiprofessional soccer players, from a team competing at the second-B Spanish league, volunteered to participate in this investigation. A total of 26 players (age, 20.05 ± 1.93 years; height, 176.94 ± 0.05 cm; body mass index, 22.35 ± 6.05 kg; body fat percentage, 10.65% ± 0.78%) completed the entire experimental protocol. The remaining participants (n = 5) were excluded because of leaving the team prior to completing the season (n = 3) or because of sustaining injuries that affected the measurements of the study (n = 2). Of the final sample of players, 9 were defenders, 10 were midfielders, and 7 were attackers. Players trained for an average of 13.0 ± 2.2 h/wk during the season and performed roughly 1 competitive match per week. The following exclusion criteria were adopted: (1) a history of adductor or abductor orthopaedic problems within the previous month prior to testing, (2) impossibility of being tested because of other types of lower limb injury, and (3) experiencing lower limb muscle soreness at time of the testing session. Goalkeepers were excluded because of the different nature of their activity during both training and match activities. Before taking part in the study, players were fully informed about the risk and benefits of the experimental protocol and provided their written informed consent. The experimental procedure of this study was in accordance with the latest version of the Declaration of Helsinki and was approved by the local university ethics committee (code: DPC.VMP.01.18).

Experimental Approach

The current investigation is a descriptive and longitudinal study designed to assess the fluctuations in maximal isometric hip adductor and abductor muscle strength in semiprofessional



Figure 1. Measurement of maximal isometric hip adductor strength.

male soccer players, by performing assessments at 3 separate time points during the season: (1) preseason (July; which started after 5 weeks of a transition period with cessation of training), (2) midseason (January; after a 1-week winter break in the season when players had competed in 17 official and competitive games), and (3) end-season (May; after completing the competitive season, which consisted of 38 official competitive games). At each time point (pre-, mid-, and end-season), players were evaluated for basic anthropometry and maximal isometric hip adductor and abductor muscle strength in their dominant (defined below) and nondominant limbs. Muscle strength testing was undertaken at the same time of the day before the first training session of the week in a physiotherapy assessment room at the training facility of the soccer club by the same researcher (>8 years of experience). Prior to each testing session, all players conducted a standardized warm-up consisting of 5 minutes of cycling on a stationary bike. All players were previously familiarized with the testing procedures because the muscle strength test employed in this investigation was part of an ongoing injury preventive program employed at the club, which had been initiated 5 years before this study. The dominant limb was determined as the preferred leg for kicking a ball.²⁴

Measurements

Maximal Isometric Hip Adductor Strength

Maximal isometric hip adductor strength was assessed in both sides following the methodology previously described.¹⁴ The force produced by hip adductor muscles was measured by using a portable handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments). For this measurement, each participant was positioned supine on a bench with the hip in a neutral position and the arms extended with forearms supinated, while carefully instructed not to use the upper limbs for trunk stabilization during the measurements. Players' legs were abducted to the length of the tester forearm. On command, the



Figure 2. Measurement of maximal isometric hip abductor strength.

player exerted a 5-second maximal voluntary contraction against the dynamometer with the examiner applied corresponding external resistance (5 cm proximally to the proximal edge of the medial malleolus) to ensure static (isometric) contraction conditions (Figure 1). Players were encouraged to perform a maximal effort from the onset of muscle contraction and 3 attempts were performed per limb, with 30 seconds of rest between attempts and 2-minute pause between sides. The handheld dynamometer was calibrated before each testing according to the manufacturer's conditions. Standardized verbal encouragement was given during every repetition to promote a maximal voluntary effort. The best of the 3 trials (highest peak force) was used for the subsequent statistical analyses. In terms of intratester reliability, intraclass correlation coefficient (ICC) for the intratester-intraday measurements was 0.92, while intratester-interweek ICC for maximal isometric hip abductor strength was 0.96. ICC for intraday and interweek isometric hip adductor strength were 0.96 and 0.96, respectively.

Maximal Isometric Hip Abductor Strength

Maximal isometric hip abductor strength was assessed following a previously described method¹ and by using the same portable handheld dynamometer described above. For this measurement, the player was positioned on a physiotherapy table on the opposite side of the extremity to be tested. Both extremities were flexed to 45° at the hip and to 90° at the knee, with the tested limb on top of the opposite limb (Figure 2). Players were not allowed to use the upper extremities for trunk stabilization during the measurements. In this position, the weight of the

tested extremity was consistently assessed to allow correction of maximal voluntary contraction strength values by separating the knees, without the feet losing contact, and pushing against a dynamometer. The dynamometer was placed laterally 5 cm proximally to the knee joint, located exactly at the most prominent point of the lateral femoral condyle. Three maximal attempts were performed for each side, with a 30-second resting period between trials and 2-minute pause between sides. The attempt with the highest peak force of the 3 trials was used as the strength outcome measure for this test.

Quantification of Load

Workload was assessed using the session rate of perceived exertion (s-RPE). This method combines data from internal (effort) and external workload (session duration).⁹ The team's physical coach collected in each training session and in each competitive match the RPE reported by each player by using the modified 1- to 10-point Borg scale. In addition, the exercise times were collected to calculate the s-RPE. Week-long cumulative internal workload was calculated for each player by summing all s-RPE scores recorded for the week (including the competition, measured in arbitrary units [a.u.]).

Statistical Analysis

Statistical analysis was performed using SPSS (Version 25; IBM Corporation). Descriptive statistics (mean and standard deviation) were calculated for all variables obtained (descriptive characteristics and for the maximal isometric hip adductor and abductor muscle strength). Between-limb asymmetry in adductor and abductor muscle strength, respectively, was calculated as the percentage difference between limbs.³ Furthermore, the adductor/abductor ratio was calculated for each limb by dividing the force obtained in the maximal hip adductor strength test by the maximal hip abductor force. Normality of data distribution was verified using the Kolmogorov-Smirnov test. One-way repeated-measures analysis of variance (ANOVA) was used to identify differences among 3 time points of measurement (pre-, mid-, end-season); where sphericity was violated, a Greenhouse-Geisser correction was applied. When a statistical significance was identified in the ANOVA, Bonferroni post hoc tests were applied to detect pairwise differences. Statistical significance was set at $P < 0.05$. In addition, to determine the magnitude of differences, Cohen effect size (d) and 95% CIs were calculated with the former interpreted as <0.2 trivial, 0.2 to 0.6 small, 0.6 to 1.2 moderate, and >1.2 large.¹¹

RESULTS

On average, players performed 17 ± 10 matches per season involving 1465 ± 964 minutes of match-play. For all players, the cumulated load assessed by total s-RPE score at preseason was 2659.38 ± 516.78 a.u., midseason 2055.52 ± 243.94 a.u., and the end-season 1693.22 ± 208.31 a.u. Values (mean \pm SD) for maximal hip adductor and abductor muscle strength, together

with the adductor/abductor strength ratio for both limbs throughout the pre-, mid-, and end-season are reported in Table 1. In comparison with preseason values, hip adductor muscle strength remained unchanged at mid- and end-season time points in both limbs. However, hip abductor muscle strength increased in the midseason for the dominant limb ($+14.18\%$; $P < 0.001$) and the nondominant limb ($+17.05\%$; $P < 0.001$). Similarly, comparing pre- and end-season revealed an increase in dominant ($+13.11\%$; $P = 0.005$) and nondominant hip abductor muscle strength ($+14.13\%$; $P < 0.001$) while no changes were observed from mid- to end-season. As a result, compared with preseason, adductor/abductor strength ratio in the nondominant limb was reduced at mid- and end-season time points (-14.6% and -18.4% , respectively; $P < 0.001$) with a corresponding tendency for the dominant limb (-9.3% and -15.0% , respectively; $P > 0.05$).

Statistical analysis reported no statistically significant changes in the bilateral differences for maximal hip adductor and abductor muscle strength throughout the pre-, mid-, and postseason (Table 2).

DISCUSSION

The aim of this study was to investigate the longitudinal effect of soccer training and match-play during a complete season on maximal hip adductor and abductor muscle strength in well-trained soccer players. This investigation is pertinent as several studies have indicated that adductor muscle weakness and/or low adductor/abductor ratios are present in soccer players with groin pain or diagnosed groin injury.^{2,16} However, it remains unknown to what extent these risk variables are modulated during an entire soccer season. The main finding of this present study was that hip adductor muscle strength remained stable at all 3 time points of assessment (pre-, mid-, end-season), whereas hip abductor muscle strength increased at midseason and was maintained high at end-season in both the dominant and the nondominant limbs. Consequently, the adductor/abductor strength ratio decreased by 15% to 18% at the mid- and end-season compared with preseason, potentially representing an elevated risk of groin injury in these phases of the season.

A similar increase in hip abductor muscle strength, from pre- to midseason, has previously been reported in young elite soccer players³¹ but the lack of a similar change in hip adductor muscle strength is a novel observation with the present investigation. A possible explanation for the observed increase in hip abductor muscle strength at mid- and end-season may be the players' physical adaptation to the daily and continuous demands of training and competition. Soccer-specific actions seem to be a strengthening activity for the hip abductor muscles, particularly because of the constant change of direction during match-play.²⁴ Another possible explanation for the observed in-season modulations in hip abductor muscle strength may be a variable enrollment of players in a preventive program to reduce the incidence of groin injuries. Although this

Table 1. Maximal isometric hip adductor and abductor strength and hip adductor/abductor strength ratio at pre-, mid-, and end-season in semiprofessional soccer players

Variable (units)	Preseason	Midseason	End-season	Preseason vs Midseason <i>P</i> Mean Difference [95% CI] <i>d</i> [95% CI]	Preseason vs End-season <i>P</i> Mean Difference [95% CI] <i>d</i> [95% CI]	Midseason vs End-season <i>P</i> Mean Difference [95% CI] <i>d</i> [95% CI]
Adductor strength dominant limb (N)	312.58 ± 11.50	333.59 ± 15.27	303.82 ± 16.70	0.270 21.008 [-9.571, 51.566] 0.269 [-0.146, 0.669] Small	1.000 -8.763 [-56.890, 39.365] -0.102 [-0.501, 0.302] Trivial	0.368 -29.770 [-77.597, 18.056] -0.349 [-0.752, 0.074] Small
Adductor strength nondominant limb (N)	310.04 ± 9.62	316.70 ± 12.55	293.51 ± 17.55	1.000 0.662 [-20.845, 34.168] 0.104 [-0.301, 0.502] Trivial	0.733 -16.521 [-52.086, 19.043] -0.184 [-0.583, 0.225] Trivial	0.276 -23.183 [-57.115, 10.750] -0.259 [-0.658, 0.156] Small
Abductor strength dominant limb (N)	447.95 ± 18.42	522.00 ± 19.12	515.57 ± 25.00	0.0001 74.054 [49.840, 98.268] 0.759 [0.278, 1.194] Moderate	0.005 67.623 [17.911, 117.335] 0.530 [0.084, 0.943] Small	1.000 -6.431 [-55.141, 42.279] -0.050 [-0.449, 0.352] Trivial
Abductor strength nondominant limb (N)	427.17 ± 13.92	515.01 ± 19.03	497.50 ± 21.14	0.0001 87.842 [58.889, 116.796] 0.905 [0.398, 1.357] Moderate	0.0001 70.327 [31.099, 109.555] 0.652 [0.189, 1.076] Moderate	0.718 -17.515 [-54.797, 19.767] -0.162 [-0.561, 0.246] Trivial
Adductor/abductor strength ratio dominant limb	0.721 ± 0.03	0.654 ± 0.03	0.613 ± 0.03	0.080 -0.067 [-0.140, 0.006] -0.411 [-0.816, 0.019] Small	0.066 -0.108 [-0.222, 0.006] -0.549 [-0.964, -0.101] Small	1.000 -0.041 [-0.147, 0.066] -0.411 [-0.816, 0.019] Small
Adductor/abductor strength ratio nondominant limb	0.739 ± 0.02	0.631 ± 0.02	0.603 ± 0.03	0.0001 -0.107 [-0.167, -0.048] -0.729 [-1.160, -0.253] Moderate	0.0001 -0.136 [-0.197, -0.074] -0.764 [-1.199, -0.282] Moderate	0.852 -0.028 [-0.095, 0.038] -0.159 [-0.558, 0.248] Trivial

Table 2. Bilateral differences^a (dominant – nondominant limb) in isometric hip adductor and abductor muscle strength assessed at pre-, mid-, and end-season in semiprofessional soccer players

Variable (unit)	Preseason	Midseason	End-season	Preseason vs Midseason P Mean Difference [95% CI] d [95% CI]	Preseason vs End-season P Mean Difference [95% CI] d [95% CI]	Midseason vs End-season P Mean Difference [95% CI] d [95% CI]
Adductor strength (N)	2.54 ± 8.60	16.89 ± 7.19	10.30 ± 23.30	0.596 14.346 [-13.543, 42.236] 0.391 [-0.037, 0.795] Small	1.000 7.758 [-59.705, 75.222] 0.065 [-0.337, 0.464] Trivial	1.000 -6.588 [-70.446, 57.271] -0.055 [-0.454, 0.347] Trivial
Abductor strength (N)	20.77 ± 10.14	6.98 ± 8.36	18.06 ± 11.38	0.787 -13.788 [-44.645, 17.069] 0.323 [-0.098, 0.725] Small	1.000 -2.704 [-41.407, 35.999] 0.046 [-0.355, 0.446] Trivial	1.000 11.085 [-17.976, 40.145] -0.191 [-0.589, 0.219] Trivial

^aThe bilateral difference in these variables has been calculated by using the following formula: dominant – nondominant limb.

program was mainly aimed at detecting signs of lower limb muscle weakness based on simple muscle strength measurements, it is possible that the preventive program per se had an influence on the observed fluctuations in hip abductor muscle strength. Nonetheless, it seems that the increase in hip abductor muscle strength during the season was a result of intensified training routines rather than caused by increased match-play activities, as fluctuations were equally manifested when comparing players with >1500 minutes (n = 11) and those with ≤1500 minutes (n = 16) of match-play.

Contrary to our initial study hypothesis, a lack of seasonal changes in hip adductor muscle strength resulted in a reduced adductor/abductor strength ratio in the mid- and end-season, particularly for the nondominant limb. Reduced hip adductor/abductor strength ratios have previously been reported in professional soccer players with chronic groin pain,² and thus the present data suggest that high-level soccer players may be more prone to suffer groin injuries in the mid- to end-season phases. This hypothesis could not be empirically confirmed in this investigation, as only 3 groin injuries were observed during the season. Additionally, the strength data of these players were removed from the current analysis to avoid the potential influence of groin injury recovery on the in-season fluctuations of hip adductor and abductor muscle strength. From a practical perspective, the outcomes found in the current investigation

indicate a need to develop tailored strength-training protocols for the hip adductor muscles to compensate for (parallel) the enhancement in hip abductor muscle strength that appears to be caused by regular training and match-play. Additionally, future investigations with higher samples size should be carried out to determine if the in-season changes in hip adductor and abductor muscle strength and in the adductor/abductor strength ratio are associated with concurrent variations in groin injury risk.

During preseason, there is a higher frequency of training sessions designed to improve players' general fitness levels.²³ Leading up to preseason testing, players arrived from a 5-week transition period, typically influenced by complete cessation of training,^{19,20} which probably contributed to the low levels of abductor muscle strength being recorded at preseason. Interestingly, if assuming that end-season values in the present study were similar to the previous season, it can be suggested that the transition period had only low or no negative impact on the maintenance of hip adductor muscle strength.

In the present study, the overall workload of the preseason period showed high ratings of perceived workload (+22.7% higher than midseason and +36.3% higher than end-season) likely because of the detrained status of players and because of a more congested training calendar caused by the lack of recovery sessions aimed at preparing athletes for official matches or to recover from a match. Therefore, the balance between hip

adductor/abductor muscle strength should be maintained by increasing hip adductor muscle force across the season by means of designated conditioning exercise (resistance training), as the enhancement of hip abductor strength will likely occur as a general adaptation to the soccer training and match-play performed in these seasonal phases. In any case, monitoring hip adduction and abduction muscle strength continuously during the season to detect weakness in these variables might also be considered a useful tool for the detection of hip muscle deficits and consequently for the ability to reduce the prevalence of future groin injuries in soccer players.

In terms of maximal hip adductor muscle strength, no changes could be detected across the season in any of the 2 lower limbs. These results differ from previous reports in elite male youth soccer players, where elevated strength values in adductor muscle strength were observed at several time points during the season when compared with preseason.³¹ This different finding could be related to the characteristics of the samples used in the studies. For instance, the current study had an average age of 19.8 ± 2.1 years, while Wollin et al³¹ examined youth players aged 15.1 ± 0.7 years, suggesting that part of the changes found in their study may be associated with the biological maturing of their players. Another possible explanation for the noted differences could result from the different demands of workload in the participants involved in this study (eg, intensity, duration, frequency, etc). While Wollin et al did not quantify the demands of their workload, the present study found an average of 2659.38 ± 516.78 a.u., 2055.52 ± 243.94 a.u., and 1693.22 ± 208.31 a.u. during pre-, mid-, and end-season, respectively.

A number of potential limitations may be recognized with the present study. First, the present study participants comprised a specific and limited sample size of male professional field soccer players, and the findings may therefore not be readily extended to, for example, goalkeepers, younger players, female soccer players, or to the general population as a whole. In addition, the results of this investigation are specific to the soccer training and competition conditions of the study sample, meaning that soccer players with higher or lower training/competitive workloads may present different results. Furthermore, the changes in hip muscle strength and in adductor/abductor strength ratio found in the present investigation were not directly compared against the actual incidence of groin injuries during the observation period. Although hip muscle weakness, especially for the hip adductors, has been a recurrent finding in previous investigations of the risk factors for groin injury in soccer players^{2,16} and other team-sport athletes,^{6,20} further information is needed to determine if in-season changes in hip muscle strength are directly linked to corresponding changes in the incidence of groin injury.

CONCLUSION

Maximal isometric hip abductor muscle strength increased in the present group of semiprofessional soccer players from pre- to mid- and end-season, while hip adductor muscle strength

remained stable across the season. This yielded a deficit in the hip adductor/abductor strength ratio at mid- and end-season, particularly for the nondominant limb. The progressive imbalance in adductor/abductor strength across the soccer season may indicate an increased risk of groin injury and may reinforce the need of designated prevention programs focused on enhancing maximal hip adductor strength. For this purpose, specific strength training exercises for the adductor muscles should be employed to prevent and rehabilitate imbalances between the abductor/adductor muscles of the hip joint in high-level soccer players.

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