



# **Low pre-season hamstring-to- quadriceps strength ratio identified in players who further sustained in- season hamstring strain injuries: a retrospective study from a Brazilian Serie A team**

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## **ABSTRACT**

A common pre-season injury prevention assessment conducted by professional football clubs is the hamstring-to-quadriceps (H:Q) strength ratio calculated by peak torque (PT). However, it is debatable whether players that present low pre-season H:Q ratios are more

susceptible to further sustaining in-season hamstrings strain injuries (HSI). Based upon retrospective data from a Brazilian Serie A football squad, a particular season came to our attention as ten out of 17 (~59%) elite male football players sustained HSI. Therefore, we examined the pre-season H:Q ratios of these players. H:Q conventional (CR) and functional (FR) ratios, and the respective knee extensor/flexor PT from the limbs of players further sustaining in-season HSI (injured players, IP) were compared to the proportional number of dominant/non-dominant limbs from uninjured players (UP) of the squad. FR and CR were ~18-22% lower ( $P < 0.01$ ), whereas quadriceps concentric PT was ~25% greater for IP than UP ( $P = 0.002$ ). Low scores of FR and CR were correlated ( $p < 0.01$ ) with high levels of quadriceps concentric PT ( $r = -0.66$  to  $-0.77$ ). In conclusion, players who sustained in-season HSI had lower pre-season FR and CR compared to UP, which appears to be associated with higher levels of quadriceps concentric torque than hamstrings concentric or eccentric torque.

## **INTRODUCTION**

It is well documented that the occurrence of hamstring strain injuries (HSI) in a professional football club is an issue that can compromise individual and team success during a season, result in early career retirement, and put financial hardships on clubs (Ekstrand, 2013; Hägglund et al., 2013; Eliakim et al., 2020). Despite significant effort made over the last years to identify risk factors and tests that can predict hamstring injuries, it remains debatable as to whether contemporary pre-season strength assessment methods can accurately inform coaches of those athletes that may be at greater risk of injury during the season.

Isokinetic strength assessment is commonly used in football club's medical departments during the pre-season. One of the most commonly calculated variables is the hamstring-to-quadriceps (H:Q) strength ratios calculated by peak torque (PT) because it may potentially detect the risk of players further sustaining HSI during the season (Kellis et al., 2022; Ruas et al., 2015a; Ruas et al., 2015b; Pinto et al., 2018; Baroni et al., 2020). However, the assessment of H:Q ratios has recently received much scrutiny regarding its potential to inform or predict HSIs (Dauty et al., 2018; van Dyk et al., 2017; Van Dyk., 2016), even though large-cohort prospective trials have shown that low pre-season H:Q ratios were associated with a greater risk of sustaining an acute HIS (Croisier et al., 2008; Lee et al., 2018)

Extensive focus to injury prevention-related research comes from European and Middle Eastern football leagues (Ekstrand et al., 2011; Grygorowicz et al., 2017; Dauty et al., 2020; Alizadeh et al., 2022; van Dyk et al., 2016; van Dyk et al., 2017; Read et al., 2022). However, a large

proportion of injuries occur in South American football leagues (Bengtsson et al., 2021; Drummond et al., 2021). A recent descriptive study performed in professional football teams from a southern state of Brazil showed that ~30% of players sustained an injury during the season and, 40% occurred in thigh muscles, with HSI representing 51.4% (Drummond et al., 2021), which is significantly more than previously reported in European football clubs (~17% per season (Ekstrand et al., 2011)). While differences in number of football match fixtures and competitions per season exist, the potential risk factors leading to HSI in Brazilian Serie A football players have been poorly explored, which is surprising given that Brazil is one of the largest countries in the world where football is practiced at multiple levels.

In the 2018 season, we were very intrigued by the high number of HSI (~59%) sustained in a squad of an elite football team playing the Brazilian Serie A league. Thus, we contacted the club to retrospectively investigate potential causes of the injuries. Specifically, we investigated whether the traditional H:Q ratios calculated by PT (assessed during pre-season) of players that further sustained in-season HSI (i.e., injured players - IP) was different than players that did not sustain any injury (i.e., uninjured players - UP). We also explored if individual quadriceps and hamstrings PT for each muscle action differed between those groups of players and were associated to the H:Q ratio scores. Given the experimental design and exploratory nature of the present study, no initial hypothesis was raised.

## **METHOD**

### *Overview*

One football club (including the players from the squad) from the Brazilian Serie A league agreed to provide the data related to the pre-season isokinetic assessment (quadriceps and hamstrings PT, CR and FR) and the prevalence of HSI in the squad during the 2018 season. This club participated of the most relevant national (i.e., Brazilian Cup, and Brazilian Serie A League) and international level leagues (e.g., Libertadores da America Cup and FIFA Club World Cup) during that particular season. The players completed a total 4-5 football training sessions (~ 90 minutes per session) and 1-2 matches per week during January to December - total of 73 matches and 6570 minutes of match in season. Given the season's highly congested fixture calendar, players only completed one resistance training session a week. The isokinetic assessments were performed during pre-season by an experienced evaluator (early January). All injury incidents were recorded throughout that season, being confirmed through clinical examinations by the medical and physiotherapy staff with the use of ultrasonography and/or magnetic resonance imaging. Ethical approval for this retrospective investigation was obtained from the Universidade Federal do Rio Grande do Sul, Brazil (Project n° 2.903.811).

### *Participants*

The squad originally consisted of thirty-eight male elite football players. However, to reduce the number of external factors influencing our analyses, the goalkeepers (n = 4) were excluded from analysis, and only players that had not sustained recent HSI (i.e., last 6 months) and/or played more than 8 matches (300 match/minutes) – ~11% of total matches and ~5% of match/min, respectively – during the season were included in the sample. This resulted in a total of 17 players included in the analyses of the present study. During the season, 10 out of those 17 (~59%) players of the squad sustained a HSI. The mean and standard deviation (SD) of the sample's characteristics, playing position, number and time of matches played during the season, injury grade classification, involved leg, and days of recovery until return to play are summarised in Table 1.

**Table 1.** Participant's characteristics

	Injured Players (n = 10)	Uninjured Players (n = 7)
Age, y	27.9 ± 4.9	26.4 ± 5.2
Body mass, kg	80.2 ± 8.4	77.3 ± 7.8
Height, cm	179.9 ± 4.3	108.9 ± 4.8
Player position, n	Defenders: 4 Midfielders: 2 Attackers: 4	Defenders: 3 Midfielders: 3 Attackers: 1
Total number of games played during the season, n	33.5 ± 13.0	37.7 ± 19.5
Total time of games played during the season, min	2199.3 ± 1000.1	3049.0 ± 1784.3
Games until HSI, n	18.3 ± 12.1	NA
Time of game until HSI, min	1175.8 ± 1025.6	NA
HSI grade, n	Grade 1: 2 Grade 2: 7 Grade 3: 1	NA
Limb dominance of HSI, n	Dominant: 4 Non-dominant: 6	NA
Days off due to HSI, n	28.1 ± 24.7	NA

The results are reported in mean ± SD. HSI, hamstring strain injury; NA, not applicable.

### *Injury definition, diagnosis, and classification*

The HSI was defined as an acute pain in the posterior thigh that occurred during training or matches, resulting in the immediate termination of play and inability to participate in the following commitment of the squad (i.e., training session or match) (Eirale et al., 2013). The HSI grades were classified as follows:

- Grade 1: Minimal muscle elongations identified (i.e., corresponding to less than 5% of the muscle volume or cross-sectional diameter).
- Grade 2: Partial muscle ruptures identified (i.e., corresponding from 5% to 50% of the muscle volume or cross-sectional diameter).
- Grade 3: Muscle tears with complete retraction. Usually, these lesions are clinically evident because the muscle belly forms a real mass and a gap can be palpated between the retracted ends of the muscle (Peetrons, 2002).

At the conclusion of the season, all data were stored into a central database with access to physicians and physical therapists of the club. These were further provided by the club by our request for retrospective analyses.

## *Isokinetic Protocols*

All tests were conducted on an isokinetic dynamometer located in the club and the test procedures followed the same settings of previous studies (Ruas et al., 2015a; Ruas et al., 2015b; Pinto et al., 2018). Briefly, maximal knee extensor and flexor concentric peak torque (PT) and knee flexor eccentric PT were measured using a Biodex isokinetic dynamometer (Biodex, System 4 Pro™, Biodex Medical Systems, New York, USA). A 10-min warm-up was performed on a cycle ergometer at comfortable pace (Life Fitness, 95 Ci Upright Bike, Remanufactured, SP, Brazil). The athletes then sat on the chair of the machine with their hips positioned at 85° of the dynamometer, and had straps placed across their thighs, hips, and chest. The lateral epicondyle of the tested knee was aligned with the dynamometer's axis of rotation, and the machine's lever arm attached to the shank at 2 cm above the lateral malleolus of the ankle. Both the dominant (defined as preferred leg when kicking a ball) and the non-dominant knees were assessed through 90° range of motion (from 90° of knee flexion to 0° of full extension). The athletes performed a total of 5 maximal concentric knee extension-flexion contractions, followed by 5 eccentric knee flexion contractions at 60°.s<sup>-1</sup> (Ruas et al., 2015a) with 120-s of rest between the concentric and eccentric trials. The athletes were instructed to “push and pull as hard and as fast as possible” during each trial (Sahaly et al., 2001). Participants were already familiar with the testing procedures, as they were often tested as part of their screening routine before the start of every season.

Torque signals were recorded after gravity correction and sampled at 100 Hz using the dynamometer's software (Biodex Advantage Software, NY, USA). The highest PTs of each muscle action across all repetitions and trials were used for further analysis

## *Muscle strength imbalance measurements*

The conventional ratio (CR) and functional ratio (FR) were calculated by dividing knee flexion concentric PT by knee extension concentric PT, and knee flexion eccentric PT by knee extension concentric PT, respectively (Aagaard et al., 1998).

### *Statistical analysis*

Data normality was verified using the Shapiro-Wilk test. The dependent variables measured during pre-season (CR, FR, quadriceps and hamstrings concentric PT, and hamstrings eccentric PT) were compared between IP ( $n = 10$ ) and UP ( $n = 7$ ) limbs by independent t-tests. A Bonferroni correction was used to reduce the likelihood of type I error due to the multiple t-test comparisons. Since the IP had HSI diagnosed in four dominant (33%) and six non-dominant (66%) limbs, statistical analyses between groups were confounded by limb dominance and sample size inequality. To overcome this issue an approximately proportional number of dominant (33%) and non-dominant (66%) limbs of the UP was used to allow for an equivalent between-group comparison of the raw data. Therefore, two dominant and five non-dominant limbs of the UP group were randomly selected using the random function in the Excel software (Microsoft Excel, version 16.26). Moreover, Pearson product-moment ( $r$ ) correlation tests were used to examine the relationships between H:Q ratio (CR and FR) scores and the levels of quadriceps and hamstrings PT for each muscle action in all players. The level of significance ( $\alpha$ ) was set at 0.05, and all statistical procedures were performed using the Statistical Package for Social Science (SPSS) version 20.0 (IBM SPSS Inc., Version 28.0.1.0 IL, USA). The results are reported in means  $\pm$  standard deviation (SD).

## **Results**

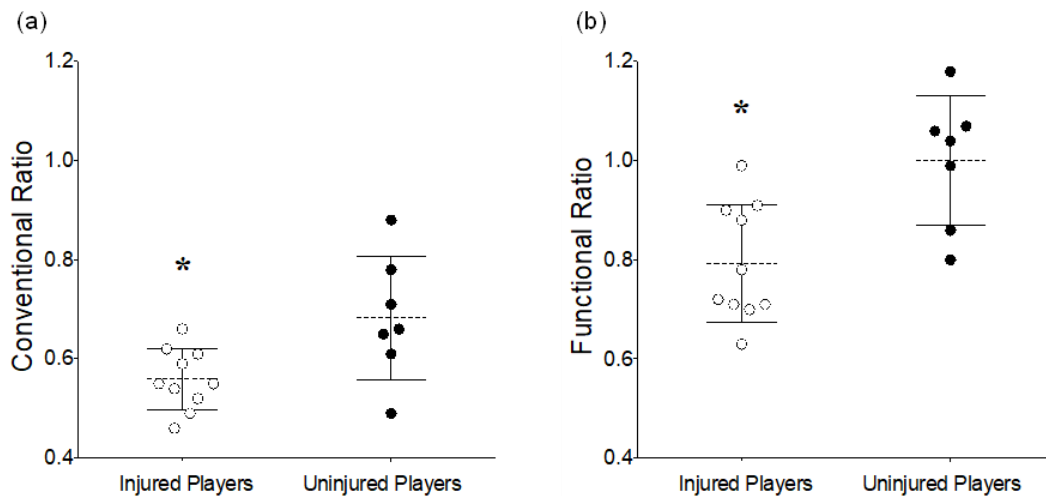
Significant differences between IP and UP were found for CR, FR and quadriceps PT. CR was lower for IP ( $0.56 \pm 0.06$ ; range: 0.46 to 0.66) than UP ( $0.68 \pm 0.12$ ; range: 0.49 to 0.88) [ $t(15) = -3.18$ ,  $p = 0.006$ ; Fig. 1a]. Similarly, FR was lower for IP ( $0.79 \pm 0.12$ ; range: 0.63 to 0.99) than UP ( $1.00 \pm 0.13$ ; range: 0.86 to 1.07) [ $t(15) = -3.72$ ,  $p = 0.002$ , Fig 1b]. However, quadriceps PT was greater for IP ( $207.8 \pm 22.6$  N·m; range: 166.0 to 235.1 N·m) than UP ( $156.9 \pm 40.8$  N·m; range: 87.7 to 207.9 N·m) [ $t(15) = 3.34$ ,  $p = 0.004$ ]. No significant differences between groups were found for hamstrings concentric [ $t(15) = 1.22$ ,  $p = 0.24$ ] and eccentric PT [ $t(15) = 0.65$ ,  $p = 0.52$ ] (Table 2).



**Table 2.** Quadriceps concentric, and hamstring concentric and eccentric peak torque (PT) between limbs of injured (n = 10) and uninjured (n = 7) football players.

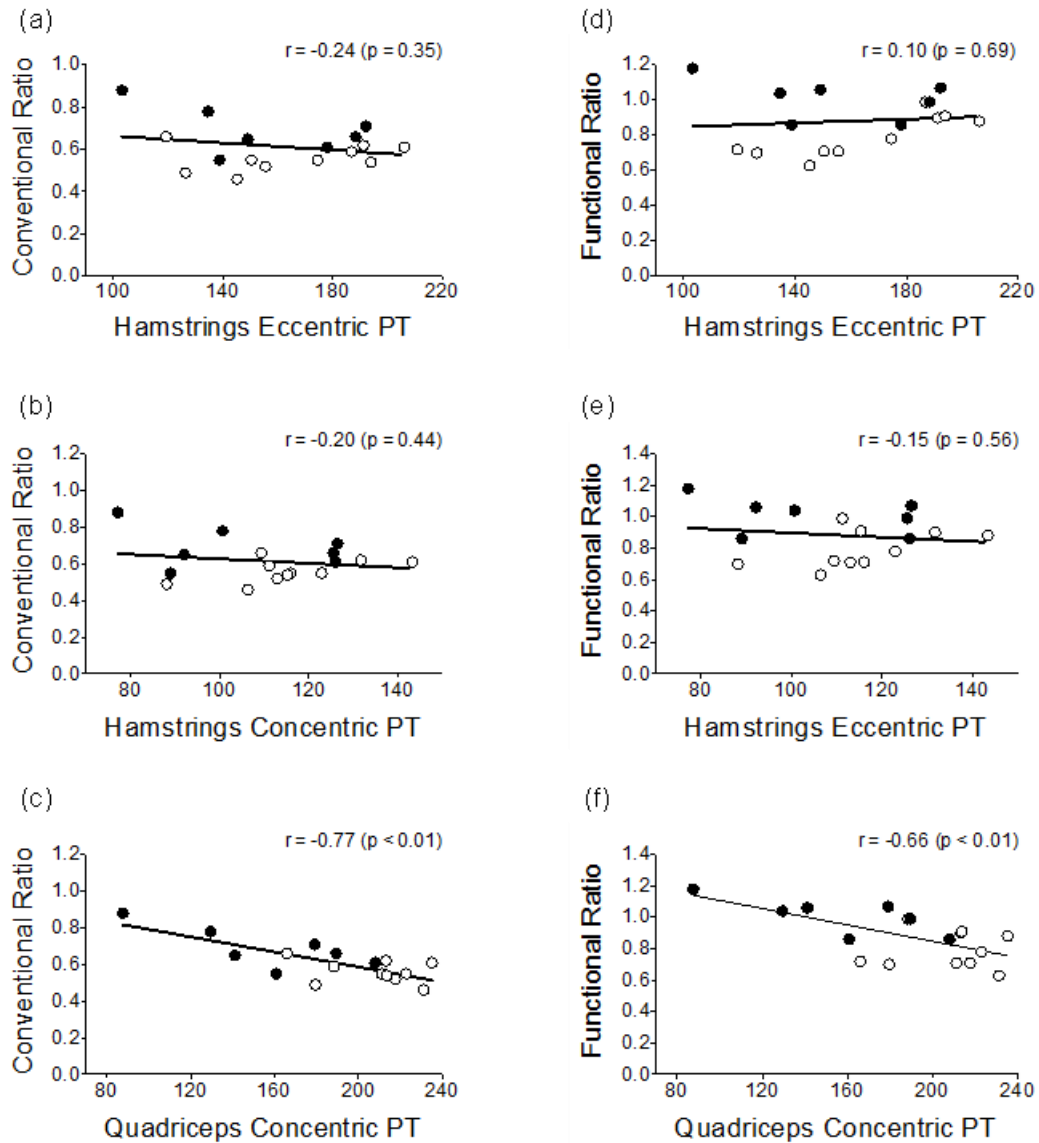
Isokinetic strength measures	Injured Players (n = 10) [95% CI]	Uninjured Players (n = 7) [95% CI]	P Value
Quadriceps concentric PT (Nm)	207.8 ± 22.6* [166.0 to 235.1]	156.9 ± 40.8 [87.7 to 207.9]	0.004
Hamstring concentric PT (Nm)	115.7 ± 14.8 [88.2 to 143.3]	104.1 ± 21.9 [77.2 to 126.5]	0.241
Hamstring eccentric PT (Nm)	164.9 ± 29.9 [119.3 to 206.1]	153.8 ± 33.5 [103.2 to 192.2]	0.522

Data are presented as means ± SD. \* Indicates significant difference from uninjured players (P < 0.05).



**Figure 1.** Conventional (CR; **a**) and functional (FR; **b**) hamstring-to-quadriceps ratios between limbs of injured (n = 10) and uninjured (n = 7) football players. Data are presented as means ± SD, and circles represent individual players from each group.\* Indicates significant difference from uninjured players (P < 0.05).

Low scores of FR and CR were significantly correlated with high levels of quadriceps concentric PT ( $r = -0.66$  to  $-0.77$ , all  $p < 0.01$ ). Visual inspection to the individual data plots revealed that those associations were more pronounced for the IP than UP (Fig. 2c and 2f). However, no significant correlations ( $p > 0.05$ ) were evident for CR or FR and quadriceps concentric and eccentric PT, and hamstrings eccentric PT (Figs. 2a, b, d and e).



**Figure 2.** Correlations between conventional and functional ratios in relation to quadriceps concentric peak torque (PT), hamstring concentric PT, and hamstring eccentric PT of football players. Data of limbs of uninjured players are shown in black circles ( $n = 7$ ), and data of limbs of injured players are shown in white circles ( $n = 10$ ).

## Discussion

In the present study, we examined whether the pre-season hamstring-to-quadriceps (H:Q) strength ratios and knee extensor/flexor peak torque (PT) were different between injured and uninjured players (IP and UP, respectively) of an elite football club from the Brazilian Serie A league. The results showed that that pre-season H:Q ratios (conventional and functional ratios; CR and FR) were lower and concentric PT was higher for IP than UP. Furthermore, low scores of FR and CR were correlated with high levels of quadriceps concentric PT ( $r=-0.66$  to  $-0.77$ ), and analysis of individual data indicated this association was more evident in the IP than UP. Therefore, players that sustained in-season HSI showed lower pre-season FR and CR, and greater quadriceps concentric PT prior to sustaining an injury compared to UP. These findings suggest that players exhibiting higher quadriceps concentric torque levels without equivalent hamstrings torque during pre-season assessment may be at greater risk of sustaining in-season HSI.

Assessments involving traditional H:Q ratios or hamstring eccentric PT have been often included during pre-season routines of professional football clubs to monitor the potential risk of players sustaining in-season HSI (Kellis et al. 2022; Ruas et al. 2019; Pinto et al. 2018). The dissemination of H:Q strength ratio assessment comes from early research showing that lower extremity injuries, such as HSI and anterior cruciate ligament (ACL), are likely to occur when the hamstrings are not capable of generating equivalent torque to decelerate the high levels of quadriceps torque needed during knee extension anterior tibial shear or rotation movements (Aagaard et al., 1998; Coombs & Garbutt, 2002; Croisier et al., 2008; Ruas et al., 2015a). The classic study from Croisier et al. 2008 showed that professional football players with low pre-season imbalances (including H:Q ratios) were 4 to 5 times more likely to sustain HSI. In line with this, our findings revealed that the 59% of players of the squad that sustained in-season HSI also presented lower pre-season FR and CR compared to their uninjured counterparts.

It is generally accepted that low levels of hamstring PT are the main contributor to lower H:Q ratio levels, and thus potential increased HSI risk (Aagaard et al., 1995; Aagaard et al., 1998; Croisier et al., 2008; Fritsch et al. 2020). In the present cohort, low H:Q ratios in the IP were mainly mediated by high levels quadriceps concentric PT. A closer look at the individual data revealed that injured individuals had overall greater levels of quadriceps PT ( $> 160$  N.m), thus resulting in low CR ( $< 0.7$ ) and FR ( $< 1.0$ ) scores (Fig. 2c and 2f). Interestingly, the IP group had approximately similar levels of hamstring strength to UP. This may support the idea shown by a recent study demonstrated that pre-season hamstrings eccentric strength by itself was not

associated to a greater risk of in-season HSI in 326 collegiate athletes (including football players), after controlling for known risk factors (e.g., age, prior HSI and sex differences) (Wille et al., 2022). Taken together, these findings seem to support the idea that special care should be taken during pre-season to monitor whether the quadriceps concentric torque is unproportionally higher than the hamstrings. In circumstances where hamstrings are not proportionally stronger to quadriceps (i.e., low H:Q ratios) it may be interesting to strengthen the hamstrings using isokinetic or traditional resistance training to correct for such imbalance.

We acknowledge that this study had some limitations. First, we limited our retrospective analysis to only one elite, professional football team. However, it would be interesting to examine whether similar differences in the pre-season H:Q ratios between IP and UP groups are present in larger samples of South American professional football squads, leagues and players in future studies. It is also important to emphasize the exploratory character of the present study; thus, no causal relationship was determined.

## **Conclusion**

The present study revealed that in a top elite South-American football squad that presented a very high rate of HSI during one season, the players who sustained HSI during the course of the season were also the ones that previously showed lower pre-season FR and CR. The low H:Q ratios of these players were particularly associated with high levels of quadriceps concentric PT without equivalent hamstrings eccentric PT. Therefore, despite the inconsistent findings in the literature, our results suggest that H:Q ratio may still be an important measure to be monitored during the pre-season of professional football players as it may identify muscle strength imbalances that can potentially lead to future injury. Furthermore, exercise and sport scientists and strength and conditioning coaches from Brazilian Serie A football clubs should prescribe resistance training programs that allow an equivalent hamstring to quadriceps strength balance and proportional muscle activation patterns for dynamic knee joint stability, which in turn may reduce the occurrence of in-season HSI in the squad.

## **DECLARATION OF INTEREST STATEMENT**

Nil.

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