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RESEARCH

Relationship between maximal strength and hamstring-to-quadriceps ratios in balanced and unbalanced legs in futsal athletes

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Abstract

Hamstring-to-quadriceps (H:Q) strength ratio has been used to estimate injury risk and readiness to return to sport. Previous studies have investigated if H:Q ratios are determined by the weakness of knee flexors (KF) or strength of knee extensors (KE) in soccer players. However, the results on H:Q ratio determinants are divergent. Moreover, studies with this proposal involving futsal athletes were not found. The present study aimed to verify: (a) the global correlation between KF (KF_{PT}) and KE peak torque (KE_{PT}) with conventional and functional H:Q ratios, (b) the correlation according to balanced and unbalanced H:Q ratio conditions and (c) the KF_{PT} and KE_{PT} between balanced and unbalanced legs. Male professional futsal players (46 athletes, 24.65 ± 6.78 years) participated in this study. Using a global analysis (balanced + unbalanced legs), H:Q ratios were significantly related to concentric KF_{PT} ($r = 0.36$–0.46), eccentric KF_{PT} ($r = 0.37$–0.63) and concentric KE_{PT} ($r = -0.31$ to -0.30). Balanced legs had a significant negative relationship between KE_{PT} and H:Q ratios ($r = -0.51$ to -0.35). In contrast, unbalanced legs presented significant positive associations between H:Q ratios with concentric KF_{PT} ($r = 0.39$–0.41) and eccentric KF_{PT} ($r = 0.52$–0.65) but not KE_{PT}. Finally, unbalanced legs showed lower KF_{PT} and higher KE_{PT} than balanced legs. In the global analysis, KF_{PT} and KE_{PT} were correlated with H:Q ratios. However, using specific analyses, KE_{PT} was negatively related to H:Q ratios in balanced legs but not unbalanced legs. In unbalanced legs, concentric KF_{PT} and eccentric KF_{PT} presented significant positive associations with H:Q ratios.

Keywords Team sports · Muscle strength · Injury risk · Hamstring strain injury · Anterior cruciate ligament

Abbreviations

KF	Knee flexion
KE	Knee extension
KF_{PT}	Knee flexion peak torque
KE_{PT}	Knee extension peak torque
H:Q	Hamstring-to-quadriceps ratio
$H:Q_{Conv}$	Conventional hamstring-to-quadriceps ratio
$H:Q_{Func}$	Functional hamstring-to-quadriceps ratio

Introduction

Futsal involves repeated executions of high-intensity and high-speed tasks such as sprints, changes of direction, accelerations, decelerations and kicks [1, 2]. This demand may increase the athletes' injury incidence in the lower limb, such as anterior cruciate ligament rupture and hamstring strain injury [3–5]. In a study involving 161 professional Spanish futsal players from 11 teams, López-Segovia et al. [6] observed that athletes are substantially harmed by lower-limb injuries (92%) during the preseason period. Additionally, the authors verified that thigh and knee joint injuries (37% of all lower-limb injuries) resulted in 403 days of missing players from matches and training

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[6]. Maximal strength and appropriate knee flexion–extension strength balance (i.e., hamstring-to-quadriceps relative strength ratio, H:Q are commonly suggested to protect athletes against anterior cruciate ligament rupture and hamstring strain injury [7–9]. According to the Croisier et al. [8] study, the hamstrings strain injury rate was 4.66 times higher in professional soccer players with untreated strength unbalances in the preseason. In this sense, maximal strength of knee flexors (KF), knee extensors (KE) and H:Q ratio assessments have been included in the preseason routine of professional futsal teams [10].

Previous studies have investigated if H:Q ratios are determined by the weakness of KF or excessively strong KE in professional soccer players [11–14]. In this sense, concentric and eccentric KF peak torque (KF_{PT}) and KE peak torque (KE_{PT}) showed opposite correlations with H:Q ratios. A positive correlation between concentric KF_{PT} with conventional H:Q ratio (concentric KF_{PT}/concentric KE_{PT}, $H{:}Q_{Conv}$) ($r = 0.45$) was demonstrated [13]. Similarly, a positive relationship between eccentric KF_{PT} with functional H:Q ratio (eccentric KF_{PT}/concentric KE_{PT}, $H{:}Q_{Func}$) ($r = 0.66$) was verified [13]. In contrast, negative relationships between concentric KE_{PT} and $H{:}Q_{Func}$ ($r = -0.67$ to -0.30) were noted [11, 13]. Moreover, two studies reported that soccer athletes with unbalanced $H{:}Q_{Conv}$ ($H{:}Q_{Conv} < 0.60$) had weakened KF and stronger KE than balanced players [13, 14]. Contrariwise, another study found that soccer athletes with an unbalanced $H{:}Q_{Conv}$ had lower KF_{PT} but similar KE_{PT} compared to the balanced $H{:}Q_{Conv}$ group [12]. Regarding $H{:}Q_{Func}$, the unbalanced condition ($H{:}Q_{Func} < 0.80$) was verified in weakened eccentric KF_{PT} soccer athletes [12, 13]. However, conflicting results demonstrated that an unbalanced $H{:}Q_{Func}$ leg may have lower or similar KE_{PT} compared to a balanced $H{:}Q_{Func}$ leg [12, 13].

As mentioned above, there is divergence about the determinants of the H:Q ratios in professional soccer players. Importantly, studies investigating the relationship between KF_{PT} and KE_{PT} with H:Q ratios in professional futsal athletes were not found. Previous results showed that professional futsal players have lower H:Q ratio values than professional soccer athletes [15–19]. Thus, maximal strength and H:Q relationship findings in soccer players might not be directly applied to futsal athletes. Identifying the influence of KF and KE strength on the knee joint balance can contribute to informing interventions to increase athletic performance and help mitigate injuries in the futsal modality. Moreover, since balanced and unbalanced groups may have different muscle strength levels, it is possible that the impact of maximal strength on the H:Q ratio is distinct within each group, but this was not previously verified.

Thus, the present study aimed to verify: (a) the global correlation between KF_{PT} and KE_{PT} with $H{:}Q_{Conv}$ and $H{:}Q_{Func}$, (b) the correlation according to balanced and unbalanced H:Q ratio conditions and (c) the KF_{PT} and KE_{PT} between balanced and unbalanced legs in futsal athletes. Our general hypothesis was that concentric KE_{PT} would show a negative relationship with the H:Q ratios, while concentric and eccentric KF_{PT} would demonstrate positive associations. This hypothesis was based on the results of previous studies [11, 13].

Methods

Study design

The present study had a cross-sectional design to verify the relationship between KF and KE maximal strength with H:Q ratios in professional futsal players. Initially, a researcher contacted the technical staff involved with the athletes to explain the study aims. Assessments were performed in week 1 of the preseason, after the official presentation of the athletes. Participants did not perform physical training sessions 24 h before the tests. Moreover, physical tests were not conducted before the isokinetic test. Assessments took place in just 1 day. The sample size was determined by convenience as the present study is part of an umbrella project where evaluations of the neuromuscular performance of futsal players occur.

Participants

Forty-six male professional futsal players (24.65 ± 6.78 years; 175.30 ± 7.02 cm; 73.97 ± 8.63 kg; 24.05 ± 2.25 kg/m^2) from three different teams participated in this study. Participants were athletes from two professional seniors ($n = 31$) and one professional under-20 team ($n = 15$) from the Brazilian National Futsal League, who were free of musculoskeletal injuries requiring absence from training or matches for at least 6 months before the study. Participants played in the national and regional championships and represented the main category of their clubs. Additionally, the current evaluated teams use isokinetic evaluations in the preseason routine. Ninety-two legs were tested, with no adverse event identified during data collection. Participants were informed of the objectives, risks and benefits of the study before signing an informed consent form. The local Institutional Ethics Committee approved all procedures performed (Approval No. 2.903.811),conducted following the Declaration of Helsinki.

Peak torque and H:Q ratios

Peak torque was evaluated using an isokinetic dynamometer (Cybex Norm; Ronkonkoma, NY, USA). First, a five-minute warm-up was performed at a self-reported low-to-moderate effort on a cycle ergometer (Movement Technology, BM2700, São Paulo, Brazil). Then, athletes were seated in the equipment with the trunk flexed at 85° and the knee joint (lateral epicondyle of the femur) aligned with the rotation axis of the dynamometer. In addition, the leg, thigh, torso, and pelvis were secured by straps to avoid compensatory movements [17, 20, 21]. Participants were instructed to perform all contractions with maximal effort (i.e., "as fast as hard as possible") [22]. Verbal encouragement was given, while visual feedback was provided in real-time on a screen placed in front of the participants. The right and left legs were evaluated.

Initially, a specific warm-up consisting of ten submaximal isokinetic contractions at 120°/s was conducted. Concentric KE$_{\text{PT}}$ and concentric KF$_{\text{PT}}$ were evaluated during five consecutive contractions using the concentric-concentric mode at 60°/s (range of motion: 0°–90°, 0° = full extension). Similarly, eccentric KF$_{\text{PT}}$ was assessed during five consecutive contractions performed at 60°/s [17, 20, 21]. Before each maximal test, three submaximal repetitions were performed as a pre-test to clear any further questions regarding the maximal tests. The pre-test and the maximal test were separated by a rest period of 30 s. After the maximal tests, there was an interval period of 60 s.

The equipment automatically informed the peak torque observed in each contraction (total of 5) of the maximal tests. The highest peak torque value observed in each maximal test was used for the analyses. Thus, H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ were calculated using the contraction with the highest peak torque. Cut points based on prior studies with professional soccer players were used. Cut points of 0.60 for H:Q$_{\text{Conv}}$ and 0.80 for H:Q$_{\text{Func}}$ were adopted [9, 12, 13, 23]. Thus, legs with KF$_{\text{PT}}$ lower than 60% or 80% compared to KE$_{\text{PT}}$ were considered unbalanced for H:Q$_{\text{Conv}}$ or H:Q$_{\text{Func}}$, respectively. Legs with KF$_{\text{PT}}$ values above 60% or 80% compared to KE$_{\text{PT}}$ were considered balanced for H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$, respectively [9, 12, 13, 23]. The global analysis involved unbalanced and balanced legs. The specific analyses involved only legs below the cut point (unbalanced legs) or above the cut point (balanced legs).

Statistical analysis

Data distribution was assessed using the Shapiro–Wilk test, and descriptive values are shown as mean ± SD and 95% confidence interval for effect size. Independent T or Mann–Whitney tests were used to compare the right and left leg parameters, with no statistical difference observed. Thus, the right and left legs' data were pooled in the analyses. Independent T or Mann–Whitney tests were also used to compare unbalanced and balanced legs. The correlations were verified with Pearson (r) and Spearman (r_s) tests, according to the distribution of the outcomes. For correlation value classification, trivial ($r = \leq 0.1$), small ($r = 0.1 < r \leq 0.3$), moderate ($r = 0.3 < r \leq 0.5$), large ($r = 0.5 < r \leq 0.7$), very large ($r = 0.7 < r \leq 0.9$), nearly perfect ($r = > 0.9$) and perfect ($r = 1$) were adopted [24]. Effect sizes [Δ (unbalanced leg—balanced leg//mean pooled SD)] were calculated using Cohens'd, assuming the results as a trivial ($d < 0.2$), small ($d < 0.5$), moderate ($d < 0.8$) or large ($d > 0.8$) [24]. The level of significance (α) was set at < 0.05. All statistical procedures were performed using the Statistical Package for Social Science (SPSS) version 23.0 (IBM SPSS Inc., Chicago, IL, USA).

Results

Concentric KE$_{\text{PT}}$, concentric KF$_{\text{PT}}$ and eccentric KF$_{\text{PT}}$ of 220.07 ± 39.38 Nm, 129.15 ± 24.68 Nm and 159.75 ± 35.90 Nm, respectively, were observed using global analysis (unbalanced + balanced legs, $n = 92$). H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ of 0.59 ± 0.10 and 0.73 ± 0.15 were verified. Parameters based on H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ cut points are presented in Table 1. Table 2 shows the results of the correlation analyses. Considering the global analysis, concentric KE$_{\text{PT}}$, concentric KF$_{\text{PT}}$ and eccentric KF$_{\text{PT}}$ were (weak to strong) correlated with H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ (Figs. 1, 2, 3). Moreover, H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ were positively related ($r = 0.73$, $p < 0.01$).

Unbalanced versus balanced legs

Significant differences in peak torque and H:Q ratio between unbalanced and balanced legs were observed. Considering the H:Q$_{\text{Conv}}$ cut point (0.60), unbalanced legs had superior concentric KE$_{\text{PT}}$ (+ 9.07%, effect size: 0.54) than balanced legs. Contrary, balanced legs showed superior concentric KF$_{\text{PT}}$ (+ 14.52%, effect size: 0.91) and eccentric KF$_{\text{PT}}$ (+ 12.52%, effect size: 0.63). Considering the H:Q$_{\text{Func}}$ cut point (0.80), KE$_{\text{PT}}$ showed no significant differences between balanced and unbalanced legs (Table 1). Contrariwise, balanced legs demonstrated higher concentric KF$_{\text{PT}}$ (+ 11.12%, effect size: 0.66) and eccentric KF$_{\text{PT}}$ (+ 21.10%, effect size: 1.22) compared to unbalanced legs (Table 1).

Correlation analyses

Global analysis (unbalanced + balanced legs) showed that KE$_{\text{PT}}$ and KF$_{\text{PT}}$ had a significant (moderate to large) correlation with H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ (Table 2). Considering the H:Q$_{\text{Conv}}$ cut point (0.60), KE$_{\text{PT}}$ was negatively related (moderate to large) to H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ in balanced but not in unbalanced legs (Table 2). In contrast, KF$_{\text{PT}}$ was

Table 1 Knee extension (KE) and knee flexion (KF) peak torques (PT) and conventional and functional hamstrings-to-quadriceps (H:Q) ratios below (unbalanced legs) and above (balanced legs) the cut points

	Unbalanced (< 0.6), *n* = 54	Balanced (> 0.6), *n* = 38	Effect size (95% CI)	*Δ* %
Performance according conventional (concentric/concentric) ratio cut points				
Concentric KE PT (Nm)	228.63 ± 40.72[a]	207.89 ± 34.34	− 0.54 (− 0.96 to − 0.12)	− 9.07
Concentric KF PT (Nm)	120.69 ± 23.41[a]	141.18 ± 21.43	0.91 (0.47–1.34)	− 14.52
Eccentric KF PT (Nm)	150.83 ± 36.12[a]	172.42 ± 31.93	0.63 (0.20–1.05)	− 12.52
Conventional H:Q ratio	0.53 ± 0.04[a]	0.69 ± 0.09	2.40 (1.86–2.94)	− 22.99
Functional H:Q ratio	0.66 ± 0.12[a]	0.84 ± 0.14	1.40 (0.94–1.86)	− 20.96
	Unbalanced (< 0.8), *n* = 63	Balanced (> 0.8), *n* = 29	Effect size (95% CI)	*Δ* %
Performance according functional (eccentric/concentric) ratio cut points based				
Concentric KE PT (Nm)	225.21 ± 39.26	208.90 ± 37.92	− 0.42 (− 0.86–0.02)	− 7.24
Concentric KF PT (Nm)	124.25 ± 22.86[a]	139.79 ± 25.50	0.66 (0.21–1.11)	− 11.12
Eccentric KF PT (Nm)	147.33 ± 31.22[a]	186.72 ± 30.48	1.27 (0.79–1.75)	− 21.10
Conventional H:Q ratio	0.55 ± 0.07[a]	0.68 ± 0.11	1.47 (0.98–1.96)	− 18.25
Functional H:Q ratio	0.66 ± 0.11[a]	0.90 ± 0.11	2.47 (1.90–3.03)	− 27.24

[a]Statistical difference between unbalanced versus balanced legs ($p < 0.05$). *Δ* %: percentual difference between unbalanced versus balanced legs

Table 2 Correlations values between peak torque (PT) measures and hamstrings-to-quadriceps (H:Q) ratio (*n* = 46 futsal athletes, *n* = 92 legs tested)

	Concentric KE PT	Concentric KF PT	Eccentric KF PT
Global analysis (unbalanced + balanced legs), *n* = 92			
Conventional H:Q ratio	**− 0.31 ($p < 0.01$)**	**0.46 ($p < 0.01$)**	**0.37 ($p < 0.01$)**
Functional H:Q ratio	**− 0.30 ($p < 0.01$)**	**0.36 ($p < 0.01$)**	**0.63 ($p < 0.01$)**
Unbalanced conventional H:Q ratio (< 0.6), *n* = 54			
Conventional H:Q ratio	− 0.04 ($p = 0.78$)	**0.39 ($p < 0.01$)**	**0.35 ($p < 0.01$)**
Functional H:Q ratio	0.09 ($p = 0.50$)	0.14 ($p = 0.31$)	**0.65 ($p < 0.01$)**
Balanced conventional H:Q ratio (> 0.6), *n* = 38			
Conventional H:Q ratio	**− 0.51 ($p < 0.01$)**	0.15 ($p = 0.36$)	0.17 ($p = 0.30$)
Functional H:Q ratio	**− 0.35 ($p = 0.03$)**	0.21 ($p = 0.21$)	**0.53 ($p < 0.01$)**
Unbalanced funcional H:Q ratio (< 0.8), *n* = 63			
Conventional H:Q ratio	− 0.22 ($p = 0.08$)	**0.41 ($p < 0.01$)**	0.21 ($p = 0.10$)
Functional H:Q ratio	− 0.19 ($p = 0.14$)	0.19 ($p = 0.14$)	**0.52 ($p < 0.01$)**
Balanced functional H:Q ratio (> 0.8), *n* = 29			
Conventional H:Q ratio	**− 0.42 ($p = 0.02$)**	0.21 ($p = 0.27$)	0.26 ($p = 0.17$)
Functional H:Q ratio	**− 0.44 ($p = 0.02$)**	**0.43 ($p = 0.02$)**	0.02 ($p = 0.92$)

KE knee extension, *KF* knee flexion

Spearman (ρ) correlations were used to correlate global and balanced conventional ratios and unbalanced and balanced functional ratios. The level of significance (α) was set at < 0.05. Statistically significant correlations are highlighted in bold

positively related (moderate to large) to both H:Q$_{\text{Conv}}$ and H:Q$_{\text{Func}}$ only in unbalanced legs (Table 2). Analyses based on H:Q$_{\text{Func}}$ cut point (0.80) showed a significant negative moderate relationship between concentric KE$_{\text{PT}}$ and H:Q$_{\text{Func}}$ in balanced but not in unbalanced legs (Table 2). Eccentric KF$_{\text{PT}}$ significantly correlated with H:Q$_{\text{Func}}$ in unbalanced but not balanced legs (Table 2).

Discussion

The main findings of the present study were that: (a) using a global analysis (balanced + unbalanced legs), KF$_{\text{PT}}$ and KE$_{\text{PT}}$ were significantly correlated with H:Q ratios, (b) balanced legs had a negative relationship between KE$_{\text{PT}}$ and H:Q ratios, while (c) unbalanced legs presented positive associations between H:Q ratios with KF$_{\text{PT}}$ but not KE$_{\text{PT}}$, and (d) unbalanced legs showed lower KF$_{\text{PT}}$ and higher KE$_{\text{PT}}$ than balanced legs.

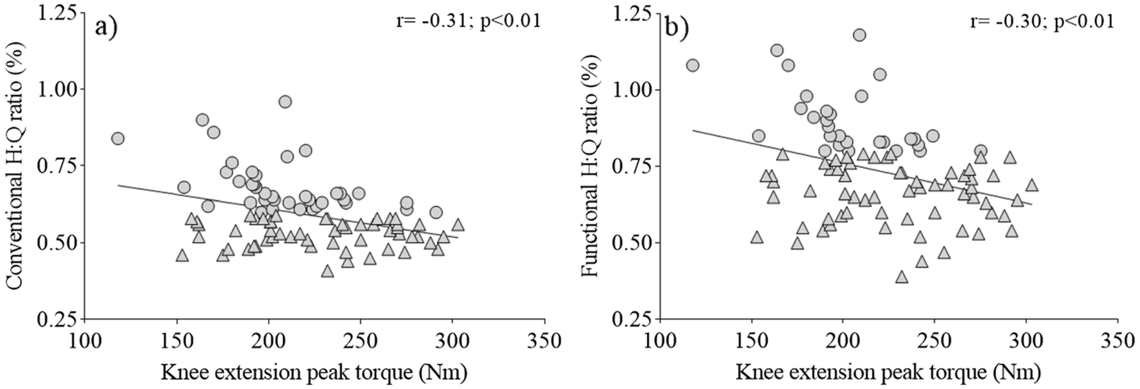

Fig. 1 Global (i.e., balanced + unbalanced, $n = 92$) relationships between conventional (concentric:concentric) and functional (eccentric:concentric) hamstring-to-quadriceps (H:Q) ratios with concentric knee extension peak torque. Triangles represent unbalanced legs and circle balanced legs

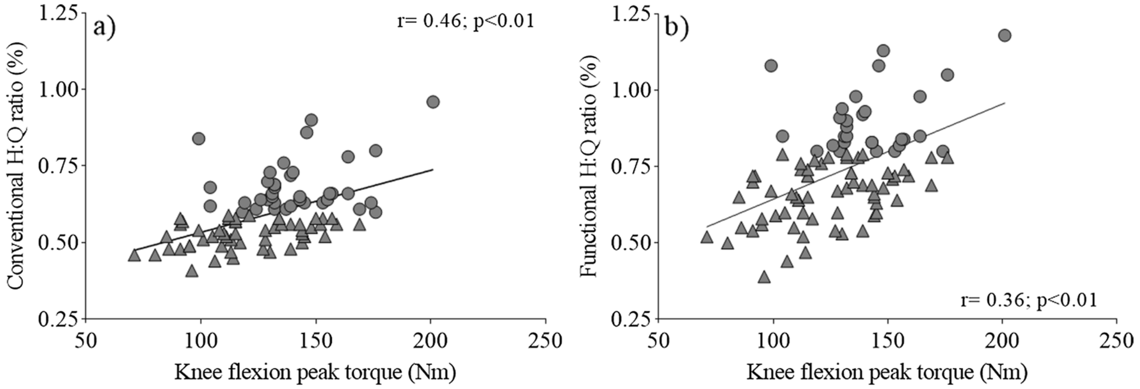

Fig. 2 Global (i.e., balanced + unbalanced, $n = 92$) relationships between conventional (concentric-concentric) and functional (eccentric-concentric) hamstring-to-quadriceps (H:Q) ratios with concentric knee flexion peak torque. Triangles represent unbalanced legs and circle balanced legs

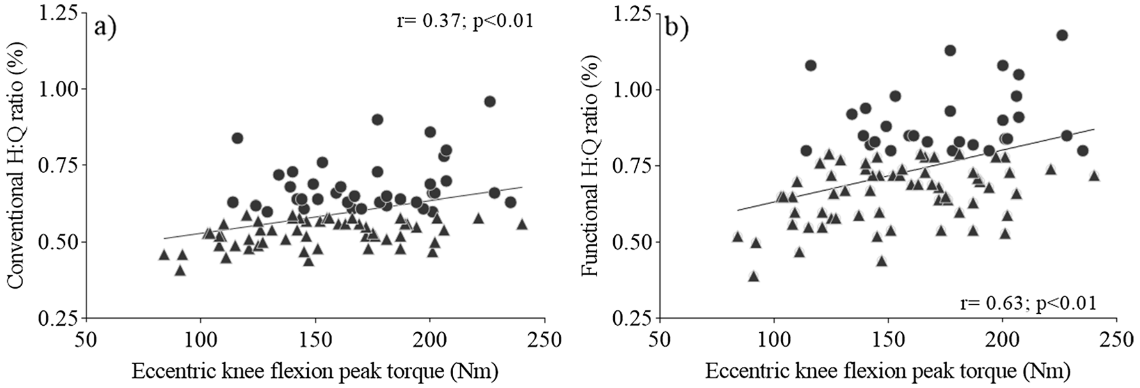

Fig. 3 Global (i.e., balanced + unbalanced, $n = 92$) relationships between conventional (concentric:concentric) and functional (eccentric:concentric) hamstring-to-quadriceps (H:Q) ratios with eccentric knee flexion peak torque. Triangles represent unbalanced legs and circle balanced legs

Balanced H:Q ratio is suggested to protect athletes against lower-limb injuries such as anterior cruciate ligament rupture and hamstring strain injury [7–9]. Thus, previous studies investigated H:Q ratio determinants [11–14]. Fritsch et al. [13] demonstrated a negative relationship between concentric KE_{PT} with $H:Q_{Conv}$ ($r = -0.37$) and $H:Q_{Func}$ ($r = -0.30$)

in professional soccer players. In contrast, concentric KF_{PT} presented a positive association with $H:Q_{Conv}$ ($r = 0.45$) [13]. Also, a significant positive relationship between eccentric KF_{PT} and $H:Q_{Func}$ ($r = 0.66$) was verified [13]. In another study, Bogdanis and Kalapotharakos [11] observed a negative association between concentric KE_{PT} and $H:Q_{Conv}$ ($r = -0.67$). However, there was no significant correlation between $H:Q_{Conv}$ and concentric KF_{PT}. In the present study, global analysis findings demonstrated a significant relationship between KF_{PT} and KE_{PT} with H:Q ratios (Table 2). Notably, the studies by Fritsch et al. [13] and Bogdanis and Kalapotharakos [11] verified KF and KE strength correlations involving pooled unbalanced and balanced legs. In the current study, KE_{PT} demonstrated a negative association with $H:Q_{Conv}$ and $H:Q_{Func}$ in analysis involving balanced but not unbalanced legs (Table 2). In contrast, unbalanced legs showed positive relationships between H:Q ratios with concentric KF_{PT} and eccentric KF_{PT} (Table 2). These results revealed that the associations between KF_{PT} and KE_{PT} with H:Q ratio change according to balanced or unbalanced leg condition.

Another interesting way of investigating the determinants of the H:Q ratio is the possible strength differences between balanced and unbalanced legs. In the present study, unbalanced (0.60) $H:Q_{Conv}$ legs had superior KE_{PT} but lower concentric KF_{PT} than balanced legs (Table 1). Considering the $H:Q_{Func}$ cut point (0.80), unbalanced legs showed lower eccentric KF_{PT} than balanced legs. KE_{PT} was not statistically different between $H:Q_{Func}$ unbalanced and balanced legs. Previous studies verified that unbalanced legs present a weakened concentric and eccentric KF_{PT} but superior [13, 14] or similar concentric KE_{PT} [12] compared to balanced counterparts. Contrariwise, Bogdanis and Kalapotharakos [11] found that unbalanced legs had stronger KE but similar KF strength compared to balanced legs. Corroborating most studies with a similar proposal, the present results reinforce that KF weakness can be the main determinant of unbalanced H:Q ratios in team sports, such as soccer and futsal.

The values of KE_{PT} observed in the present study (220.07 ± 39.38 Nm) are similar to those reported by previous studies investigating futsal players. KE_{PT} values of 207.81 ± 36.63 Nm [17], 223.9 ± 33.4 Nm [16] and 214.7 ± 49.6 Nm [18] were demonstrated. Similarly, the current values of concentric KF_{PT} (129.15 ± 24.68 Nm) agree with the findings by Machado et al. [17] (122.75 ± 22.90 Nm), de Lira et al. [16] (128.6 ± 27.6 Nm) and Nunes et al. [18] (136.6 ± 31.7 Nm) studies. Moreover, a similar eccentric KF_{PT} compared to the verified by Machado et al. [17] (159.75 ± 35.90 Nm vs. 157.19 ± 34.84 Nm) was observed. Regarding H:Q ratios, there were similarities between the present findings and the mean $H:Q_{Conv}$ values reported by previous studies (0.59 vs. 0.59, 0.58 and 0.64) [16–18]. Additionally, the current $H:Q_{Func}$ value was similar to that demonstrated by Machado et al. [17] (0.73 vs. 0.76). In summary, the current findings corroborated the prior results verified in the futsal modality. However, these futsal studies did not investigate the relationship between KF and KE strength and H:Q ratios. This analysis was previously demonstrated only in professional soccer athletes [11, 13], which may have different levels of KE_{PT}, KF_{PT} and H:Q ratios compared to professional futsal players [15, 16, 18, 19].

The current findings showed that the hamstrings muscle group had lower strength than the quadriceps muscle group (Table 1). This condition agreed with a few legs demonstrating balanced values of $H:Q_{Conv}$ ($n = 38$) and $H:Q_{Func}$ ($n = 29$). In the current study, approximately 59% and 69% of the legs showed unbalanced conditions of $H:Q_{Conv}$ and $H:Q_{Func}$, respectively. A superior resistance training focus for the KE muscle group than KF may be the main reason for strength unbalances between KF and KE. Notably, KF performance seems to be the primary determinant of a balanced H:Q ratio, mainly among unbalanced legs (Table 2). In this way, the present results reinforce the need for resistance training focused on concentric and eccentric KF in futsal athletes.

As a practical application, unbalanced legs need training programs emphasizing concentric and eccentric KF strength. Exercise recommendations for increasing concentric and eccentric KF performance include Nordic hamstring exercise, prone leg curl, slide leg curl, upright hip extension, straight-knee bridge and deadlifts [25–27]. On the other hand, it is important to note that balanced legs showed lower KE_{PT} values, which may harm sports tasks such as jumping and sprinting [28, 29]. Thus, interventions for balanced legs involve increasing KE strength without impairing the H:Q ratio. Therefore, KF needs training programs that accompany the increase in KE capacity.

Some limitations of the present study must be considered. First, only three teams were investigated, limiting the current sample size. Still, it is noteworthy that the current players evaluated have relevance in the futsal modality (regional, national and continental titles). Second, the transversal design does not allow us to infer the predictive capacity of H:Q ratio measures. This analysis would contribute to unbalanced and balanced conditions' impact on injuries. Third, the results of the present study refer to a velocity of 60°/s used in the isokinetic evaluation and should not be extrapolated to other angular velocities. Moreover, analyses with different cut points were not performed due to the low number of legs in more subdivisions. Importantly, the present study used cut points previously adopted in professional soccer players [9, 12, 13, 23]. Finally, the impact of the athletes' strength level on the relationships between KF_{PT} and KE_{PT} with the H:Q ratio was not verified. Two athletes may have H:Q ratios considered balanced but be in different strength level categories (e.g., low vs. high strength level). Despite the limitations above, the current findings broaden the view of verifying the performance of KF and KE and risk factors for injuries as H:Q ratios in the sports scenario.

Conclusions

In the present study, the global analysis demonstrated a relationship between KF_{PT} and KE_{PT} with H:Q ratios. On the other hand, the specific analyses presented some particularities of the relationship between KF and KE performance with H:Q ratios. A negative relationship between KE_{PT} and H:Q ratios was observed in balanced legs but not in unbalanced legs. Moreover, unbalanced legs presented positive associations between concentric KF_{PT} and eccentric KF_{PT} with H:Q ratios. Finally, unbalanced legs demonstrated inferior KF_{PT} and superior KE_{PT} than balanced legs, which helps to explain the low H:Q values.

Author contributions C.L.F.M., R.P.F and R.S.P. contributed to the study conception and design. C.L.F.M. and R.P.F. performed data collection and analysis. The first draft of the manuscript was written by R.P.F. and C.L.F.M. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interest The authors report no conflict of interest.

Consent to participate All participants provided written informed consent to participate in the study.

Ethics approval The study was approved by the local Human Research Ethics Committee.

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