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ORIGINAL RESEARCH

ISOKINETIC ASSESSMENT OF MUSCULAR STRENGTH AND BALANCE IN BRAZILIAN ELITE FUTSAL PLAYERS

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ABSTRACT

Purpose/Background: Strength asymmetries are related to knee injuries in intermittent sports players. The purpose of this study was to examine whether elite futsal players demonstrate strength asymmetries during knee isokinetic testing applying the Croisier et al.[21] criteria.

***Methods*:** Forty male elite (27.9 ± 6.5 years) Brazilian futsal players participated in the study. The testing protocol required players to perform concentric contractions of both quadriceps and hamstring muscles at angular velocities of 60°·s^{-1} and 240°·s^{-1} and eccentric contractions of hamstring at 30°·s^{-1} and 120°·s^{-1}. Conventional (concentric:concentric) and mixed (eccentric:concentric) hamstrings/quadriceps (H/Q) ratios were calculated. Subjects were determined to have an imbalanced strength profile if an athlete had at least two parameters that were asymmetrical across speeds and conditions. Asymmetry was operationally defined as peak torque asymmetry greater than 15% in bilateral comparison, and H/Q ratio less than 0.47 for conventional and 0.80 for mixed conditions.

***Results*:** Significant differences were observed between preferred and nonpreferred limbs in the concentric contractions of flexors at 240°·s^{-1} and eccentric contractions of extensors and flexors at 30°·s^{-1} and 120°·s^{-1}. However, these asymmetries did not exceed 15%. The conventional and mixed H/Q ratios were greater in the preferred than in nonpreferred limbs, but only the mixed hamstrings$_{ecc}$/quadriceps$_{conc}$ in the nonpreferred limbs showed values lower than recommended (<0.80). In addition, 50% of elite futsal players had preseason strength imbalances per the developed criteria.

***Conclusion*:** The studied elite futsal players had preseason strength imbalances, which may increase the risk of hamstring injuries.

***Level of evidence*:** 3

***Key words*:** Asymmetry, injury risk, isokinetic, peak torque.

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INTRODUCTION

Futsal is currently sanctioned by soccer's international governing body, the Fédération Internationale de Football Association (FIFA), which has periodically organized futsal international competitions since 1989. This game started in South America in the 1930s as an indoor version of soccer/football, and it has rapidly expanded worldwide. Futsal is a very dynamic sport in which many goals are usually scored per match. Although futsal and soccer present similar technical characteristics,[1] the physical demands are somewhat different. Soccer is played on a 90-120 × 45-90 m pitch in two 45-minute periods. Players cover ~ 10,000 m per game, and only 0.5 to 3% of effective playing time is covered at high-intensity sprints[2]. Meanwhile, futsal players cover ~ 3300 m per match,[3,4] of which >7.5% are covered at high-intensity[3] and ~ 26 sprints are performed per match.[5] In contrast, futsal is played on a 40 × 20 m hard court surface in two 20-minute periods, with a 10-minute break between periods,[1] and the numbers of substitutions are unlimited, so high-intensity efforts are maintained throughout the matches.[1,6] As a consequence of the exposure to high-intensity actions, the requirement of concentric and eccentric muscular actions in the legs to sustain kicking, jumping, pulling up, tackling, turning, changing pace, decelerating and sprinting during a game is very high.[1,7]

Soccer and futsal are among the top ten injury-prone sports with incidence rate of 20.3 and 55.2 injuries per 10000 hours sport participation, respectively.[8] Most injuries affect the lower extremity (i.e., knee and thigh) in both soccer[9] and futsal.[10,11] For soccer, hamstrings injuries are the most common single injury subtype, representing 12% of all injuries,[12] and amounting 1.20 injuries per 1000 h exposure.[13] These high injury rates are associated with the short recovery (i.e., less than four days) periods between match and/or high match loads (matches sequence).[14] In futsal, prospective studies with hamstring injury rates are scarce, but Junge and Dvorak[10] demonstrated that thigh strain is among the most prevalent diagnoses of time-loss injuries in futsal players. In addition, recently Martinez-Rianza et al.[15] analyzed medical assistance to Spanish national futsal team over five seasons and showed that in 43.3% of the cases, injuries were sustained in the thigh, followed by the leg (12.6%) and knee (10%). Most assistance cases (52.6%) were due to muscle overload (i.e., when the individual did not have an anatomical injury but the muscle was painful and slightly tight when manually explored) and 14.4% were due to residual pain.

Keeping in mind the high hamstring injury rates in soccer, Croisier et al.[16] created a protocol to assess bilateral asymmetries and hamstring/quadriceps (H/Q) ratios, which was shown to be useful for screening for hamstring injury risk in soccer players. It is known that soccer and futsal players have a preferred leg to perform specific skills (i.e., kicking and cutting), which may cause side-to-side asymmetry between legs.[17] Bilateral strength asymmetries have been frequently used during sport rehabilitation programs to quantify the functional deficit consequent of lower extremity injury or surgery.[18,19] Also, several authors have suggested that bilateral strength asymmetries can be a risk factor for musculoskeletal injuries.[20,21,22] For soccer and futsal players, some researchers have suggested that the presence of bilateral asymmetries is a risk for injuries.[21,23,24] However, bilateral asymmetries of peak torque (PT) production (as assessed through isokinetic testing) of up to 15% are considered acceptable.[20]

In intermittent sports, explosive muscular contractions play a significant role in athletes' performance due to the high number of sprints required in the match or competition.[25,26] Therefore, the necessary short phase of deceleration requires an aggressive eccentric hamstring activation, which can potentially harm or damage the muscle-tendon unit.[27] Futsal requires many sudden sprints and intense braking, during which the activation of quadriceps and hamstrings are maximally required. Furthermore, in soccer players it has been suggested that the hamstring muscles are vulnerable to injury during quick changes from eccentric to concentric action, mainly when the hamstrings become active extensors of the hip joint.[28] Thus, the H/Q ratio may be an important screen for injury risks if strength imbalances are detected in athletes of football.[21,23,29,30]

The purpose of this study was to examine whether elite futsal players demonstrate strength asymmetries during knee isokinetic testing applying the Croisier et al.[21] criteria. Based on technical similarities between soccer and futsal, the authors hypothesized that some isokinetic strength differences predisposing to lower limb injuries would be detected in this specific sample of athletes, which may inform prevention strategies.

METHODS

Participants

Forty male elite futsal players (27.9 ± 6.5 years; 75.1 ± 8.1 kg; 1.76 ± .03 m) from three different Brazilian professional teams volunteered to participate in the study. The players had at least five years of experience in futsal training and competition. Their respective futsal teams were ranked first, second, and fourth in the 2010 season of the Brazilian Futsal League, which is considered one of the best leagues in the world. Fifteen players evaluated in this study were regular athletes from the Brazilian futsal team, including the best goalkeeper and the best overall player of the FIFA Futsal World Cup.

The purpose, experimental procedures, possible risks and benefits of the study were explained to the athletes, who provided written informed consent before starting the participation. All procedures were approved by the Local Ethics Committee for Research with Humans (protocol number 5263.0.000.09110).

Experimental design

All study procedures were performed during the initial phase of the competitive season. In this phase, athletes were engaged in a training program one to two sessions per day (five to six days each week), including official futsal matches. Specifically, they performed four to five conditioning sessions (approximately 30-40 min per session) per week that were designed to develop sprinting abilities and explosive strength, as well as two to three resistance training sessions per week. Small-sided games were used to develop aerobic fitness and were included in the technical and/or tactical training sessions. Before starting the study, each athlete was instructed to refrain from heavy exercise, to avoid alcoholic or caffeinated products in the 48 hours preceding the tests and to present themselves at the experimental settings in a two-hour post-prandial state. Before the experiments the players were familiarized with the isokinetic test. The futsal players were assessed in isokinetic dynamometer during a single visit to the laboratory (familiarization and protocol test). The angular speeds used in the current study were chosen according to the protocol used in soccer players described by Croisier et al.[20] Accordingly, bilateral asymmetry and H/Q ratios were identified and compared to normative values.[20]

Knee Maximal Strength Test

Isokinetic measurements were performed on hamstring and quadriceps muscles. All professionals conducting the isokinetic assessment received instructions to strictly apply a standardized testing procedure. Measurements were preceded by a 5 min warm-up consisting of pedaling on a cycle ergometer (75 to 100 watts).[20] Each player was placed in an upright seated position on the adjustable Cybex dynamometer chair (Cybex Norm, Lumex, Ronkonkoma, USA) and firmly stabilized by straps so that only the knee to be tested was movable with a single degree of freedom. The lateral epicondyle of the tested knee was aligned with the dynamometer's axis of rotation, and the machine's lever arm was attached to the lower leg 2 cm above the lateral malleolus.[31] The range of knee motion was fixed at 90° of flexion from the active maximum extension. The axis of rotation of the knee was then aligned with the axis of rotation of the dynamometer lever arm.

After a standard warm-up consisting of three to five submaximal and one maximal concentric (Conc) contraction efforts of the quadriceps and hamstring muscles at the angular speed of $120^\circ \cdot s^{-1}$.[20] The testing protocol required players to perform concentric contractions of both quadriceps and hamstring muscles at $60^\circ \cdot s^{-1}$ (three repetitions) and $240^\circ \cdot s^{-1}$ (five repetitions) angular velocities of movement. Athletes were then required to perform eccentric (Ecc) contractions of hamstring at $30^\circ \cdot s^{-1}$ (three repetitions) and $120^\circ \cdot s^{-1}$ (four repetitions) angular velocities of movement.[23] Verbal encouragement was continuously provided throughout the tests. A passive rest period of 90 seconds was allowed between limbs and each angular velocity, but the participant did not receive any visual feedback during the test.

The analyses of results were expressed in absolute (Nm) and relative (Nm/kg) concentric and eccentric peak torque (PT) of extensors and flexors of the knee, and the bilateral comparison (preferred and non-preferred limbs) led to the determination of asymmetries expressed in percentage form according to Equation 1.[32] Concentric H/Q peak torque ratio of flexors and extensors was established (at $60^\circ \cdot s^{-1}$ or $240^\circ \cdot s^{-1}$) and mixed H_{ecc}/Q_{conc} ratio was associated with eccentric performance of the hamstrings and the concentric action of the quadriceps muscles (hamstrings at $30^\circ \cdot s^{-1}$ versus quadriceps at $240^\circ \cdot s^{-1}$).[20] Regarding imbalance strength profile, this study followed the procedures described by Crosier et al.[20]: bilateral differences above 15% in concentric and/or eccentric on the hamstrings; concentric ratio (on at least one leg) of less than 0.47; and a mixed ratio of less than 0.80 (on at least one leg). Thus, at least two of the following parameters were used to characterize athletes with imbalances: concentric (at $60^\circ \cdot s^{-1}$ or $240^\circ \cdot s^{-1}$) and eccentric (at $30^\circ \cdot s^{-1}$ or $120^\circ \cdot s^{-1}$) bilateral asymmetries (>15%); conventional H_{conc}/Q_{conc} (at $60^\circ \cdot s^{-1}$ or $240^\circ \cdot s^{-1}$); and mixed H_{ecc}/Q_{conc} ratio. Data collection was performed in an acclimatized room. Temperature and relative humidity were maintained at 22-23°C and 50-60%, respectively. The tests were conducted in morning (9-11 a.m.) and afternoon (2-6 p.m.) periods during one week.

$$AI_{\%} = \left(\frac{P - NP}{P}\right) \cdot 100 \qquad (1)$$

AI equals the percent asymmetry index, calculated by using the outputs for PT measurements of the preferred (P) and non-preferred (NP) limbs.

Statistical Analyses

Data are reported as the mean, standard deviation (*SD*), and frequencies (absolute and relative) with a 95% confidence interval. Shapiro-Wilk tests were used to verify the normality of the data. Where the differences were not normally distributed, the values were calculated on the log transformation data. The differences between preferred and non-preferred lower limbs torque and H/Q ratios were compared using independent *t*-test. Paired t-tests were used to identify differences between angular velocities for AI%. Significance was assumed at 5% ($P \leq .05$) a priori. All statistical analyses were performed using SPSS 18.0 for Windows (SPSS Inc., Chicago, USA).

RESULTS

Table 1 shows the relative and absolute isokinetic concentric and eccentric knee PT of extensors and flexors at the P and NP limbs. The difference was analyzed according to the lower limbs (P vs NP). The knee flexor PT concentric at $240^\circ \cdot s^{-1}$ was significantly greater in the preferred limb. Regarding eccentric contractions, in both angular speeds ($30^\circ \cdot s^{-1}$ and $120^\circ \cdot s^{-1}$) of extensors and flexors, the preferred limb also showed higher values than the nonpreferred.

Table 2 shows the bilateral asymmetries for concentric and eccentric PT of knee extensors and flexors at all angular speeds. The differences were analyzed according to the angular speeds. Significant differences in the bilateral asymmetries were observed in the concentric contractions to extensors at $60^\circ \cdot s^{-1}$ compared to $240^\circ \cdot s^{-1}$ ($p = 0.011$) and eccentric extensors

Table 1. *Relative and absolute values of isokinetic concentric and eccentric peak torque (PT) of knee extensors and flexors in both lower limbs.*

	60°·s⁻¹ (Conc)			240°·s⁻¹ (Conc)		
	P	NP	p-value	P	NP	p-value
Extensors						
PT (Nm/kg)	2.85±0.58	2.88±0.59	0.67	2.37±0.67	2.35±0.64	0.71
PT (Nm)	214.7±49.6	216.5±51.6	0.62	178.1±53.1	176.8±52.0	0.71
Flexors						
PT (Nm/kg)	1.81±0.35	1.80±0.42	0.77	1.65±0.51	1.54±0.49	0.008*
PT (Nm)	136.6±31.7	135.8±36.3	0.81	124.3±40.3	115.9±38.1	0.007*
	30°·s⁻¹ (Ecc)			120°·s⁻¹ (Ecc)		
Extensors						
PT (Nm/kg)	3.95±0.99	3.70±0.95	.003*	3.98±0.75	3.70±0.80	.013*
PT (Nm)	296.0±75.7	277.2 ±73.0	.003*	299.3±66.4	277.3±66.1	.012*
Flexors						
PT (Nm/kg)	2.32±0.49	2.16±0.50	.006*	2.48±0.43	2.29±0.49	.008*
PT (Nm)	173.5±35.8	162.9±40.8	.099	185.7±34.1	172.7±58.0	.089

PT= peak torque; P = preferred limb; NP = nonpreferred limb; Conc = Concentric; Ecc = Eccentric. *significantly greater in P than NP (p<0.05).

Table 2. *Bilateral asymmetries for concentric and eccentric peak torque of extensors and flexors at the knee.*			
	$60°\cdot s^{-1}$ (CI 95%)	$240°\cdot s^{-1}$ (CI 95%)	p-value
Concentric			
Extensors (%)	2.5 (-1.35 – 6.35)	5.86 (.90 – 10.83)*	.011
Flexors (%)	-1.40 (-5.06 – 2.26)	.72 (-3.23 – 4.68)	.637
	$30°\cdot s^{-1}$ (CI95%)	$120°\cdot s^{-1}$ (CI95%)	
Eccentric			
Extensors (%)	7.92 (3.11 – 12.73)*	3.39 (-1.68 – 8.46)	.004
Flexors (%)	6.95 (3.11 – 10.78)	6.65 (1.69 – 11.6)	0.26

CI= confidence interval; * statistically significant differences between angular speeds (p<0.05).

at $30°\cdot s^{-1}$ compared with $120°\cdot s^{-1}$ (p = 0.004). Despite the differences in all angular speeds, the bilateral asymmetries were all deemed acceptable (<15 %).

The conventional H_{conc}/Q_{conc} at $240°\cdot s^{-1}$ of the preferred limb was significantly greater than nonpreferred (p = 0.044) and the mixed H_{ecc}/Q_{conc} of the preferred limb was also significantly greater (p < 0.001). However, all values of the conventional and mixed H/Q ratios were acceptable, except the mixed H_{ecc}/Q_{conc} in the nonpreferred limb (Table 3).

Table 4 shows the number of futsal players with strength imbalances (bilateral asymmetries and H/Q ratio deficits) according to the Croisier et al.[20] criteria. Regarding the predefined cutoffs, there seems to be a high prevalence of futsal players with torque imbalances in at least two criteria (50%).

Table 3. *The relative peak torque values for conventional concentric and mixed hamstring/quadriceps ratios in both lower limbs.*			
	P Mean (CI95%)	NP Mean (CI95%)	p-value
Conventional concentric H_{conc}/Q_{conc} ratio			
$Conc60°\cdot s^{-1}/Conc60°\cdot s^{-1}$	0.64 (0.61 – 0.68)	0.64 (0.61 – 0.68)	.470
$Conc240°\cdot s^{-1}/Conc240°\cdot s^{-1}$	0.69 (0.66 – 0.73)*	0.65 (0.61 – 0.69)	.044
Mixed H_{ecc}/Q_{conc} ratio			
$Ecc30°\cdot s^{-1}/Conc240°\cdot s^{-1}$	1.05 (0.93 – 1.18)*	0.76 (0.71 – 0.82)	.000

Conc= concentric; Ecc= eccentric; H/Q = hamstring/quadríceps ratio; P = preferred limb; NP = nonpreferred limb; CI= confidence interval; *significantly greater for P than NP (p<0.05).

Table 4. *Number of futsal players with strength imbalances according to Croisier criteria.*	
	Rate of Players (%)
Bilateral difference	
Conc $60°\cdot s^{-1}$	7/40 (17.5)
Conc $240°\cdot s^{-1}$	14/40 (35.0)
Ecc $30°\cdot s^{-1}$	16/40 (40.0)
Ecc $120°\cdot s^{-1}$	13/40 (32.5)
H_{ecc}/Q_{conc} ratio (P)	
$Conc60°\cdot s^{-1}/Conc60°\cdot s^{-1}$	1/40 (2.5)
$Conc240°\cdot s^{-1}/Conc240°\cdot s^{-1}$	0/40 (0.0)
Mixed $Ecc30°\cdot s^{-1}/Conc240°\cdot s^{-1}$	11/40 (27.5)
H_{ecc}/Q_{conc} ratio (NP)	
$Conc60°\cdot s^{-1}/Conc60°\cdot s^{-1}$	2/40 (5.0)
$Conc240°\cdot s^{-1}/Conc240°\cdot s^{-1}$	3/40 (7.5)
Mixed $Ecc30°\cdot s^{-1}/Conc240°\cdot s^{-1}$	14/40 (35.0)
Injury criteria	
Deficiency in at least two parameters	20/40 (50.0)

Conc= concentric; Ecc= eccentric; H/Q = hamstring/quadríceps ratio; P = preferred limb; NP = nonpreferred limb.

DISCUSSION

The aim of this study was to examine the strength and identify imbalances in elite futsal players using a protocol developed by Croisier et al.,[20] which established normative values for conventional and mixed H/Q ratio and bilateral asymmetries. Among the main findings of the present study, it can be highlighted that: a) Significant differences were observed between preferred and nonpreferred limbs in the concentric contractions of flexors at 240°·s⁻¹ and eccentric contractions of extensors and flexors at 30°·s⁻¹ and 120°·s⁻¹, but the group-average asymmetries did not exceed 15%; b) Conventional and mixed H/Q ratios were higher for preferred than nonpreferred limbs; however, only the mixed H_{ecc}/Q_{conc} in the nonpreferred limb showed values lower than those recommended (<0.80); c) Through strength imbalances (bilateral asymmetries, conventional and mixed H/Q ratios) criteria,[20] a high prevalence of players with hamstring injury risk was observed (50%). Some studies have already used this protocol in soccer players,[21,29,33] but not in futsal players.

Humans tend to use preferentially one side of the body in voluntary motor acts.[34] Lateral preference can be associated with task complexity,[35] gender[35] and developmental characteristics.[36] In sports scenarios, lateral preference can influence aspects related to force production due to long term adaptations from repeated use.[37] Accordingly, bilateral asymmetries have been reported in sports with predominant unilateral movements, such as soccer,[21,29,38] volleyball,[38,39] basketball[38,40] and handball.[41] Futsal also requires unilateral movements[17]; however, there is no previous evidence of isokinetic bilateral asymmetries in futsal players. During isokinetic tests the athlete cannot perform a functional movement specific to a futsal match, however, this objective test may be important to identify strength asymmetries, which can relate to muscle injury risk that are common in high-intensity team sports.[20,21,38,42] To date, studies that evaluated peak isokinetic knee torque in futsal players have assessed strength performance or fatigue,[43] but not bilateral asymmetries.

The present study reported higher PT concentric in flexors at 240°·s⁻¹ for preferred than nonpreferred limb. Regarding eccentric contractions, in both angular speeds (30°·s⁻¹ and 120°·s⁻¹) for flexors and extensors, the relative PT was greater in preferred than nonpreferred limb. Similarly, Ruas et al.[23] measured knee strength asymmetries in soccer players in different field positions, and their results indicated that in all players, the preferred leg's eccentric hamstring strength was greater than that of the nonpreferred leg. Bilateral asymmetry above 15% of maximum torque production has been associated with muscular injury risk.[20] Although the current findings reported higher values for preferred than nonpreferred lower limbs, these asymmetries, on average, did not exceed 15% (Table 2). Some authors have found that lack of bilateral asymmetry may be due to the importance of the nonpreferred limb's supportive strength to coordinate dominant knee actions,[44] and also due the idea of inter-hemispheric transfer of learning during practice.[45]

Some studies with soccer players have used knee extensor concentric actions during isokinetic tests[20,23,26,29] because the quadriceps muscles are devoted to explosive efforts such as propulsion jumps and pulls after quick changes in direction. Concentric muscular actions are primarily used during passing and kicking.[30] However, the eccentric phase of hamstrings also has a substantial influence on muscular performance.[46] When sprinting, a short phase of deceleration is required as a result of eccentric hamstring activation to compensate the forward moment, which can harm or damage the muscle-tendon unit, and consequently increases the injury risk to hamstrings.[47] During a futsal game, there is a greater proportion of high-intensity exercise such as sudden sprints (maximal or near-maximal single and multiple sprint bouts) compared to during a traditional soccer game.[3] Thus, the H/Q ratio may be a useful variable to help identify muscle imbalances in futsal players, since it was related to both hamstring strain injury[42] and anterior cruciate ligament rupture.[48]

The current study showed acceptable values for conventional concentric and mixed H/Q ratios in preferred leg. For nonpreferred leg, the conventional H/Q ratio presented acceptable values, while the mixed ratio presented average values lower than recommended (<0.80). Notably, the mixed H/Q ratio has been proposed to better reflect biomechanical conditions during sprints, passes and kicks.[33] The hamstring muscles play an important role in decelerating the extension of the lower limb on the thigh during ball-striking.[39] Also, normally, futsal players have one preferred leg for specific skills.[17] Thus, the authors hypothesized that because the nonpreferred limb performs fewer passes and kicks during a futsal match, muscle imbalances may have increased in the nonpreferred limb. On the other hand, studies of soccer players have produced similar values between preferred and nonpreferred limbs in the conventional concentric and mixed H_{ecc}/Q_{conc}.[20,33] For futsal players, there are no studies that used a similar protocol to determine conventional or mixed H/Q ratios in order for comparison to occur.

Because hamstring strains are frequent in soccer and futsal players[10,29] and muscle weakness and strength imbalance are considered to be their main causes,[20] a standard protocol to screen for hamstring injury risk is necessary. Croisier et al.[21] developed an isokinetic protocol for detecting strength imbalances during the preseason in soccer players based on cutoffs related to bilateral hamstring asymmetries and H/Q ratios. The criteria for being allocated to the groups of players with strength imbalances corresponded to a significant deficiency in at least two parameters as previously described. Croisier et al.[21] observed that one in two players had isokinetic strength disorders (47%), and players who performed soccer activities performed with untreated strength imbalances had an increased four-fold increased risk of hamstring injury compared to players with normal strength balance profile.

Nevertheless, the use of isokinetic dynamometry for screening hamstrings for injury risk has demonstrated contradictory results. Dauty et al.[42] showed that the isokinetic test in the beginning season was able to predict a third of soccer players who would get injured during the season. Conversely, in a large cohort study of professional soccer players Van Dyk et al.[49] observed that the use of isokinetic testing to determine the association between strength differences and hamstring strain injury was not supported. Likewise, the meta-analysis by Freckleton and Pizzari[50] showed that H/Q ratio was not associated with hamstring strain injury. These literature inconsistencies can be related to methodological aspects, including different angular velocities and types of muscle contraction (i.e., concentric and/or eccentric).

Considering strength imbalances, Lehance et al.[33] reported that approximately one in three uninjured Belgian soccer players had strength imbalances in the preseason, including concentric or eccentric bilateral asymmetries and conventional or functional H/Q ratio deficits, while in Australian soccer players' strength imbalances were observed in approximately one in four players.[29] In the present study one in two Brazilian futsal players possessed strength imbalances, which related to hamstring injury risk criteria established by Croisier et al.[20] The current study used the isokinetic test as a tool to identify strength imbalances in futsal players. Therefore, when imbalances are identified, exercise programs such as Fédération Internationale de Football Association's "the 11+"[51] Nordic hamstrings exercise[52] and isoinertial eccentric-overload[53] may be useful to increase the quadriceps concentric and hamstring concentric and eccentric peak torque, and improved mixed H/Q ratio in futsal players.

Among the limitations of this study, it is well documented that the isokinetic dynamometer assessment does not reflect the functional aspects of the practice of futsal. However, it is a useful tool for the objective evaluation of strength, and it can be used to identify strength imbalances in futsal players. In addition, the study did not include a prospective observation for hamstring injuries of futsal players during the full competitive season. To the authors knowledge, the present study is the first to test an isokinetic protocol for strength imbalances[20] in elite futsal players. Future studies looking for development of specific isokinetic screening protocols for futsal players, and the development of prevention strategies for hamstring injuries through prospective studies are needed.

CONCLUSION

Although the current study showed significant differences between preferred and nonpreferred limbs peak torque outputs, elite futsal players did not have, as a group, bilateral asymmetries (>15%). In addition, conventional and mixed H/Q ratios showed acceptable average values; however, the mixed H_{ecc}/Q_{conc} in the nonpreferred limb showed values lower than those recommended (< 0.80). In contrast, when analyzing the individual results, one in two elite futsal players had preseason strength imbalances per the developed criteria, which may be impact the risk of hamstring injuries. Therefore, coaches, physiotherapists, athletic trainers, and sport physiologists could use isokinetic tests to identify strength imbalances and consider the use of a preventive training program to reach a strength balance in lower limbs before the competitive season begins.

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