ISOKINETIC KNEE MUSCLE STRENGTH PROFILE IN BRAZILIAN MALE SOCCER, FUTSAL, AND BEACH SOCCER PLAYERS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Anterior cruciate ligament injury is higher in soccer athletes as compared to athletes of other sports. Risk factors for anterior cruciate ligament injury include low knee hamstring/quadriceps strength ratio and bilateral strength deficits.

Purpose: To investigate isokinetic thigh muscles strength, hamstring/quadriceps strength ratio, and bilateral strength comparisons in athletes who participate in professional soccer, futsal, and beach soccer.

Study Design: Cross-sectional study.

Methods: Brazilian professional soccer (n=70), futsal (n=30), and beach soccer (n=12) players were isokinetically assessed to examine strength of knee extensors and flexors at 60 degrees/second in concentric mode, to measure peak torque of dominant and non-dominant limbs.

Results: In the dominant limb, for extensors muscles, futsal players presented significantly lower peak torque values (223.9 ± 33.4 Nm) than soccer (250.9 ± 43.0 Nm; $p=0.02$) and beach soccer players (253.1 ± 32.4 Nm; $p=0.03$). Peak torque for extensor muscles in the non-dominant limb was significantly lower in futsal (224.0 ± 35.8 Nm) than in beach soccer players (256.8 ± 39.8 Nm; $p=0.03$). Hamstring/quadriceps strength ratio for dominant limbs for futsal ($57.6 \pm 10.1\%$), soccer ($53.5 \pm 8.8\%$), and beach soccer ($56.3 \pm 8.4\%$) players presented no significant differences between groups; however, the mean values were lower than recommended values found in the literature. There were no strength deficits for any of the evaluated groups when compared bilaterally.

Conclusions: Futsal athletes presented lower values for quadriceps strength than soccer and beach soccer athletes. Futsal, soccer, and beach soccer players presented no strength asymmetries, but they presented with strength imbalance in hamstring/quadriceps strength ratio.

Level of Evidence: 3

Key words: injury; isokinetic; muscle strength; performance; soccer

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INTRODUCTION

Soccer is the most popular sport in the world, with an estimated 265 million active players.¹ Performance depends upon a myriad of factors including technical, biomechanical, tactical, physiological,² and musculoskeletal health. Furthermore, a low incidence of injuries is highly desirable in order to improve the team success.³

Considering traditional soccer (hereafter referred to simply as soccer), beach soccer and futsal, the technical and skills principles used in all of the variations of the game remain the same as soccer. However, there are some differences between them, including: (a) futsal and beach soccer involve fewer players (four field players and a goalkeeper) and allow an unlimited number of substitutions, while soccer involves eleven players (ten field players and a goalkeeper) and a limited number of substitutions,⁴ giving futsal and beach soccer a more dynamic characteristic (players need to run more and faster); (b) futsal and beach soccer are played in a confined space within boards; in addition, each time the ball goes off to the side of the enclosure, a fault is marked, or a goal is scored, the timer is stopped. Together these characteristics make futsal and beach soccer a multiple-sprint sport (more high-intensity phases) that differs from soccer;⁵ (c) ball direction changes are faster in futsal and beach than soccer,⁶ which could impact knee joint demands; (d) match length differs between futsal (two periods of 20 minutes separated by a 10-min rest interval), beach (three periods of 12 minutes separated by 3-min rest intervals), and soccer (two periods of 45 minutes separated by a 15-min rest interval) and (e) there are differences in ball dimensions (~ 420g to beach and field soccer, and ~250g to futsal). In addition, there are major differences between beach soccer and futsal in terms of playing surface (unstable versus rigid), techniques (beach soccer requires more acrobatic actions), running speed (beach soccer players are unable to run at high speed) and jump height (lower maximum force and take-off velocity in beach soccer because of compliance and surface instability). Altogether, these differences can generate different physiological adaptations in athletes, especially in musculoskeletal system. Despite these different adaptations, the most frequent injuries in the three sports are those that affect the knees, ankles, and

thighs.⁷⁻¹⁰ However, there are particularities in injury incidence associated with the three variations of the sport.

The incidence of knee injuries in soccer (18.8%)¹¹ and in futsal (15.8%)¹² is higher than in beach soccer (6.3%).⁷ On the other hand, thigh injury incidence in soccer (19.9%),¹² futsal (13.9%),¹² and beach soccer (24.3%)¹³ are similar. Risk factors, commonly perceived to be predictive of injury for knee or thigh injuries include: a decreased hamstring to quadriceps (H/Q) strength ratio, bilateral strength deficit, and muscular weakness,^{3, 14-21} although most authors agree that single variables were inconsistently identified as associated factors.^{21, 22}

H/Q strength ratio plays an important role in knee joint stability and it has been extensively used to examine functional ability, knee joint stability, and muscular balance between thigh muscles.²³ Additionally, it has been shown that an imbalance in H/Q peak torque strength balance ratio correlates with a greater incidence of lower extremity injury, including anterior cruciate ligament (ACL) injuries.¹⁹ In addition, it has been suggested that muscular weakness and bilateral lower limb muscular strength deficits affect posture,²⁴ sports performance,²⁵ and increases hamstring strain rate.^{17, 26} Thereby, in order to screen H/Q strength ratio and bilateral symmetry, it is common to assess athletes in the beginning of the season.^{26, 27}

Given the different physical requirements, incidence of lower limb injuries and muscle strength demands in lower limbs, the above cited risk factors for knee or thigh injuries (strength balance and bilateral symmetry) may differ somewhat among the soccer variations (futsal, soccer, and beach soccer). To assess muscular strength profile, isokinetic testing has been used by clinicians and physical therapists.^{23,28,29} Several studies have been carried out to establish strength profiles in soccer players.³⁰⁻³² However, only one study has investigated isokinetic strength in futsal players³³ while none have been conducted in beach soccer players.

Thus, the main objective of this study was to investigate isokinetic knee muscle strength, H/Q strength ratio, and bilateral strength comparisons in professional athletes who participate in soccer, futsal, and

beach soccer. It was hypothesized that athletes of different soccer variations would have a different isokinetic profile due to physiological, playing surface, biomechanical demands, and specificities.

METHODS

Participants

This study included 112 professional athletes who had been playing for at least five years, training regularly for five sessions per week and had no history of major lower limb injury or chronic disease. The sample of volunteers comprised soccer players (n=70), futsal players (n=30), and beach soccer players (n=12). Anthropometric characteristics (age, height, and body mass) of the groups are presented in Table 1.

The soccer players were selected from professional teams in the city of São Paulo (Brazil), during the 2012 competitive season. All players participated in respective Brazilian official league championships (First Division). Participants were informed of the potential risks and benefits of the study and signed an informed consent form to take part in this study. All experimental procedures were approved by the University Human Research Ethics Committee (Federal University of São Paulo, Brazil) and conformed to the principles outlined in the Declaration of Helsinki.

Procedure: Isokinetic test

Before isokinetic testing, the participants performed a five-minute warm-up on a cycle ergometer (Cybex Inc., Ronkonkoma, NY, USA) at a resistance of 25 Watts, followed by low-intensity dynamic stretching exercises for the hamstring and quadriceps. After this period, concentric isokinetic torque (strength) of both knees was assessed.

Knee dominance was determined by asking the participants which limb they preferred to use when

kicking a ball. The participants assumed a seated position on the isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) with their hips flexed at approximately 85 degrees, and standard stabilization strapping was placed around the trunk, waist, and the distal femur of the limb being tested in order to minimize additional movement and ensure the same conditions for all participants. The axis of the dynamometer was visually aligned with the lateral femoral condyle while the knees were flexed at 90 degrees.

The length of the lever arm was set individually based on the length of the participant's lower legs, and the resistance pad was placed proximal to the medial malleolus. Following direct measurement of the mass of the lower limb lever system at 30 degrees of knee extension, gravity correction procedures were applied according to the manufacturer's specifications to reduce the risk of inaccurate data. The knee was tested from 5 to 95 degrees of knee flexion, with full knee extension considered 0 degrees, as previously described.³⁴

This range of motion was chosen to prevent injury, although maximal torque output is not altered by variations in the range of motion during isokinetic activity testing.³⁵ For familiarization, the participants were given standard verbal instructions regarding the procedures and allowed several submaximal practice attempts. The participants then performed a maximum of five repetitions at an angular speed of 60 degrees/second and the results were stored for analysis. This angular speed was chosen as the lowest speed in order to avoid high joint pressure while producing the highest torque values, since there is an inverse relationship between isokinetic angular speed and load range.²³

Consistent verbal commands (e.g.: "As hard as possible" or "as hard and fast as possible") were given by the examiner before each test to ensure maximal

Table 1. Characteristics of subjects.			
Soccer variation	Age (years)	Height (cm)	Body mass (kg)
Futsal (n=30)	21.3±6.1	175.8±5.3	72.3±8.8
Soccer (n=70)	19.3±4.8	177.8±7.3	73.9±8.2
Beach soccer (n=12)	29.7±4.4*	177.1±6.1	74.7±6.5
p-Value	<0.0001	0.38	0.58
Data are expressed as mean±SD. *Significant difference versus soccer and futsal soccer players.			

effort and visual feedback of the recorded torque was provided during the test. The same examiner, who was trained and experienced in the use of isokinetic testing devices, tested all participants. The parameters evaluated (for concentric contractions expressed in Newton-meter - Nm) included isokinetic absolute hamstring and quadriceps muscle peak torque, H/Q concentric peak torque ratio in %, and bilateral strength deficit in %. Peak torque values were normalized by body mass (Nm/kg), as were absolute peak torque values, to enable comparison with values of other studies, eliminating the effects of subject heterogeneity as would occur if using absolute values of peak torque. The H/Q peak torque ratio was calculated by dividing the maximum torque values of the hamstring by the maximum torque values of the quadriceps at the same angular speed and multiplying by 100.³⁶ Those athletes that presented H/Q peak torque ratio below than 60% were classified with knee muscular imbalance. Muscular strength asymmetry was calculated by: [(dominant limb peak torque – non dominant limb peak torque) / dominant limb peak torque]*100. Those athletes that presented bilateral strength deficit higher than 15% were classified as asymmetrical.

Statistical methods

All variables presented normal distributions according to the Kolmogorov-Smirnov test. Data were expressed as mean and standard deviation (SD). To evaluate the anthropometric differences among the three groups, one-way analysis of variance (ANOVA) was used. Isokinetic concentric peak torque data

was collected for the quadriceps and hamstring muscles of both lower limbs. Based on concentric hamstring and quadriceps peak torque values, H/Q peak torque ratios were calculated for each participant. To evaluate the influence of soccer modality and side on isokinetic variables, a 2x3 design side (D versus ND) and sport (soccer versus futsal versus beach soccer) ANOVA was used. Newman-Keuls post-hoc procedures were used to identify specific differences when significant interactions were present on the ANOVA test. In the absence of interactions, only main effects were analyzed. Statistical significance was set at an alpha of 0.05 for all statistical procedures. All statistical analyses were performed using the Statistica (version 7.0, Statsoft Inc., Tulsa, OK, USA) software package.

RESULTS

Table 2 shows the isokinetic muscular strength characteristics for the dominant (D) and non-dominant (ND) limbs with the mean values obtained for soccer, futsal, and beach soccer players. Regarding the D limb, absolute quadriceps concentric muscle peak torque values of futsal players were lower than those of soccer ($p=0.02$) and beach soccer ($p=0.03$) players, while there were no significant group differences in flexor muscle performance. Considering the peak torque values relative to body mass, the same differences can be seen. Futsal players values were lower than those of soccer ($p=0.01$) and beach soccer ($p=0.04$) players, while there were no significant group differences in flexor muscle strength.

Table 2. Knee isokinetic muscle strength in futsal, soccer, and beach soccer players in dominant limb.

Soccer variation	Futsal (n=30)		Soccer (n=70)		Beach soccer (n=12)	
	Dominant	Non-dominant	Dominant	Non-dominant	Dominant	Non-dominant
Extensor muscles						
Peak torque (Nm)	223.9±33.4 ^{*†} (169.2 – 284.7)	224.0±35.8 [†] (157.4 – 299.7)	250.9±43.0 (152.0–364.7)	241.9±47.1 (148.5 – 384.7)	253.1±32.4 (207.2–299.2)	256.8±39.8 (169.8– 316.6)
Peak torque/BM (Nm/kg)	3.1±0.3 ^{*†} (2.2–4.0)	3.1±0.3 [†] (2.4 – 3.9)	3.4±0.4 (2.5 – 4.4)	3.3±0.5 (2.1 – 4.7)	3.4±0.4 (2.9 – 3.9)	3.4±0.4 (2.5 – 4.3)
Flexor muscles						
Peak torque (Nm)	128.6±27.6 (79.4–191.0)	124.1±20.1 (88.7 – 161.4)	133.1±25.7 (59.6 – 187.7)	127.6±25.0 (77.4 – 184.4)	140.5±11.2 (117.8–156.6)	136.2±11.4 (116.2–153.1)
Peak torque/BM (Nm/kg)	1.8±0.3 (1.1 – 2.4)	1.7±0.2 (1.3 – 2.0)	1.8±0.3 (0.75 – 2.4)	1.7±0.3 (1.2 – 2.4)	1.9±0.2 (1.5 – 2.2)	1.8±0.1 (1.5 – 2.0)
H/Q ratio (%)	57.6±10.1 (37.9 – 90.4)	55.7±6.8 (46.9 – 77.9)	53.5±8.8 (27.4 – 76.5)	53.2±7.2 (36.8 – 71.2)	56.3±8.4 (42.3 – 67.7)	53.9±7.1 (46.1 – 68.9)
Data are expressed as mean±SD (min - max). BM= body mass; H/Q ratio= knee hamstring/quadriceps strength ratio						
*Significant difference relative to soccer ($p<0.05$). [†] Significant difference relative to beach soccer ($p<0.05$).						

Regarding ND limbs, absolute and relative quadriceps concentric peak torque values were significantly lower in futsal than in beach soccer ($p=0.03$ and $p=0.04$, respectively) players. In ND knee, there were also no significant intergroup differences in flexor muscle performance.

Table 2 also shows H/Q strength ratios for D and ND knees. There were no significant differences between groups for this measure. The percentage of athletes who presented knee imbalance, characterized by lower values than 60%, is presented in Table 3.

Regarding bilateral strength comparisons, no group presented significant difference, neither for extensor nor for flexors muscles. Futsal players had deficits of $-0.32 \pm 9.6\%$ and $1.7 \pm 14.5\%$ for extensors and flexors muscles, respectively. Soccer players had bilateral strength deficits of $3.3 \pm 11.2\%$ and $4.2 \pm 11.5\%$ for extensor and flexor muscles, respectively. Beach soccer players had strength asymmetry of $-1.7 \pm 12.3\%$ and $2.4 \pm 11.4\%$ for extensor and flexor muscles, respectively. Despite means values being lower than 15%, some athletes presented higher bilateral strength deficits. The percentage of athletes who presented bilateral strength deficit higher than 15% was presented in Table 4.

DISCUSSION

The main purpose of the present study was to compare isokinetic muscular strength parameters in competitive soccer, futsal, and beach soccer players. Concentric extensors peak torque was found to be higher in soccer and beach athletes compared to futsal players while there were no significant differences between groups for peak torque of knee flexor muscles or for

H/Q ratio. Moreover, the three groups presented with symmetrical strength between dominant and non-dominant knee flexors and extensors muscles.

Lower concentric strength values for quadriceps muscles in futsal players could be expected because the match is played in a restricted space in which the kicks and passes are performed over shorter distances than in soccer. In the same way, Cheung et al³⁷ compared maximal isokinetic knee concentric flexion and concentric extension at 60 degrees/second and 300 degrees/second of field (soccer) and court sports players (basketball and volleyball) and found higher strength values for soccer players at both angular speeds. Comparing the current results with those of Cheung et al³⁷ higher peak torque relative to body mass values were found for the extensor muscles in soccer (present study: 3.4 ± 0.4 Nm/kg versus Cheung et al³⁷: 1.89 ± 0.25 Nm/kg) and court soccer players (present study: 3.1 ± 0.3 Nm/kg versus Cheung et al³⁷: 1.68 ± 0.24 Nm/kg). These results are expected since the soccer volunteers in the present study were professionals while those studied by Cheung et al³⁷ were drawn from college teams. On the other hand, the present results were similar to those reported in the study by Eniseler et al³⁸ in Turkish elite soccer players, Ardern et al²⁷ in Australian elite soccer players, and Ruas et al³⁹ in Brazilian south state soccer players comparing the peak torque of extensors and the flexors muscles.

In the present study, despite the lower quadriceps muscles peak torque observed in futsal versus soccer and beach soccer players and the absence of differences between flexor muscle strength for both limbs, there were no significant differences in H/Q ratio among the three groups studied. However, mean

Table 3. Number of athletes (percentage) who presented H/Q ratio lower than 0.6.

Soccer variation	Futsal (n=30)	Soccer (n=70)	Beach (n=12)
H/Q ratio ≤ 0.60 D	20 (67%)	56 (80%)	8 (67%)
H/Q ratio ≤ 0.60 ND	23 (77%)	58 (83%)	10 (83%)

H/Q ratio= knee hamstring/quadriceps strength ratio; D= dominant; ND= non dominant

Table 4. Number of athletes (percentage) who presented bilateral strength deficit higher than 15%.

Soccer variation	Futsal (n=30)	Soccer (n=70)	Beach (n=12)
Bilateral deficit for extensor muscles	2 (6%)	10 (14%)	3 (25%)
Bilateral deficit for flexor muscles	9 (30%)	13 (18%)	3 (25%)

H/Q ratios values for D and ND limbs in futsal, soccer, and beach players were lower than 0.6, which has been traditionally associated with a higher incidence of knee injuries.³⁹⁻⁴³ Croisier et al²⁶ showed that preseason thigh muscle strength imbalances put an athlete (football player) at 4.6 times increased risk of hamstring strain.

In this scenario, individual data analysis revealed lower values ($\leq 60\%$) for D limbs in 80% of soccer, 67% of futsal, and 67% of beach soccer players, which indicates muscle strength imbalance and a possible predisposing factor for injury.^{26,39,44} In this study, H/Q ratios present a large variation between the athletes; in soccer players ranging from 27.4 to 76.5%, futsal players from 37.9 to 90.5%, and beach soccer players from 42.3 to 67.7%. Eniseler et al,³⁸ Fousekis et al,³¹ Greco et al,⁴⁵ and Ruas et al³⁹ found higher H/Q ratio mean values for professional soccer players (range: 55 to 68%) than the values presented in the present study, however individual values were not reported. Previous authors have shown that introducing a specific hamstring strengthening program during soccer training is able to reduce the incidence of hamstring injuries.^{46, 47} Therefore, as the present study presented lower H/Q ratios for each of the three groups, the results highlight the need for hamstrings strength training programs for all the groups studied. Moreover, an individual evaluation should be conducted, before the injury risk reduction program is suggested because the H/Q ratios differed widely between the athletes in the same variation of soccer (e.g. the standard deviation was large).

On the other hand, it is important to note that the association between H/Q strength imbalance and hamstrings injury is not universally agreed upon in the literature. Dyk et al²¹ demonstrated only a small associations between lower hamstring eccentric strength and lower quadriceps concentric strength with hamstrings injury. However, lower limb muscle strength demands are sport-specific, which may indicate that H/Q ratio may differ somewhat between athletes from different sports modalities and competitive levels.⁴⁸ In a previous study, a significant H/Q ratio difference has been demonstrated between judokas, handball players, and soccer players.²³ In the study, male soccer players presented a mean H/Q ratio of 66%. However, the volunteers

involved were not professional athletes. Those results suggested that younger athletes, or those not competing at elite levels, do not present with stronger quadriceps relative to the hamstring muscles, which is observed in elite athletes. Therefore H/Q ratio may be not only sport-specific, but also to each competitive level within that sport.

In addition to H/Q ratio, muscular bilateral asymmetry also has been considered a risk factors for lower limb injuries,^{26,39} and it also may affect sport performance.²⁵ Specific motor demands of sports and training methods are a possible cause of muscular asymmetries and most soccer athletes had a preference for use of one lower limb over the other. Therefore, an analysis of bilateral strength asymmetry has been considered important to control and reduce injury risk.²⁶ However, in the present study, athletes had no lower limb asymmetry, since bilateral strength deficit was lower than 10%. In a study of elite professional soccer players, Menzel et al¹⁵ also found low mean values for bilateral peak torque deficit ($9.14 \pm 8.65\%$). Despite the low mean values of bilateral strength deficit found in volunteers of the present study ($< 10\%$), individual values ranged from -37% to 34%. Therefore, the fact that elite soccer, futsal, and beach soccer players presented symmetrical strength for the lower limbs does not preclude the need to conduct individual evaluations to identify this potential injury risk factor.

One potential limitation of this study was the age of the athletes. Beach soccer players were older than the other athletes. Nevertheless, this difference in age is expected since, generally, beach soccer teams are made up of former athletes from futsal and soccer and by players that have not turned professional in futsal or soccer. Another limitation of the study, is the lack of eccentric strength evaluation. Although H/Q concentric strength ratio measures may give an indication of muscle function and knee stability, they do not include the eccentric contractions involved in the kicking action, and so do not fully reflect muscle function during activity. During soccer actions, the agonist (quadriceps) muscles produce concentric movement to accelerate the limb forward, whereas the antagonist muscles (hamstrings) generate eccentric work to control (decelerate) this concentric movement, maintaining the joint dynamic stability. Finally, beach soccer ($n=12$) and futsal ($n=30$)

groups presented lower sample sizes than the soccer player group (n=70), which can be considered a potential weakness of the study. Therefore, the authors suggest that future studies, conducted with bigger sample sizes, could investigate the eccentric strength measure of hamstrings muscles and the functional strength ratio assessed by eccentric action of hamstrings and concentric action of quadriceps.

CONCLUSIONS

H/Q ratio did not differ significantly among soccer, futsal, and beach soccer players, while extensors muscles were stronger in soccer and beach soccer players than in futsal players. In the three soccer variations, mean values for H/Q ratio were lower than the recommended literature values. Injury risk reduction programs that utilize strength training for hamstring muscles can be useful to improve H/Q ratio. An individual strength evaluation to identify bilateral strength deficits or deficits in the H/Q ratio in the different soccer variations could help identify injury risk factors and establish injury risk reduction programs, resulting in less interruption of soccer training and competition. In addition, beach soccer is a relatively new sport for which no national professional leagues exist in many countries. Thus, future studies investigating other characteristics of beach soccer players are warranted.

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