Sport Sci Health (2017) 13:315–321
DOI 10.1007/s11332-017-0360-y

ORIGINAL ARTICLE

Isokinetic performance of knee extensors and flexors in adolescent male soccer athletes

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Received: 17 January 2017 / Accepted: 3 April 2017 / Published online: 18 April 2017

Abstract
Background Soccer is one of the most popular sports in the world and thigh muscle strain and knee injuries are two of the most common injuries. Asymmetrical muscle strength between the dominant limb (DL) and the non-dominant limb (NDL), asymmetries between the extensor and flexor muscles of the knee and between the different roles can explain the high injury incidence.
Aims This study aimed to analyze the knee extensor and flexor muscular contralateral strength, the flexors'/extensors' function, and the muscular strength differences according to different playing positions of adolescent male soccer athletes.
Methods The information provided by the database concerning the isokinetic evaluation of knee muscles from 32 male soccer athletes under 17 years of age was analyzed. The isokinetic dynamometer was used in a concentric-concentric mode for the knee extensor and flexor muscles at angular velocities of 60°/s, 120°/s, 180°/s and 240°/s.
Results Two significant differences were observed between the DL and the NDL; just at an angular velocity of 60°/s, the flexor muscles and the flexor/extensor ratio mean values were significantly smaller for the NDL. When averaged separately, the DL and NDL values of the defenders, midfielders, and forwarders demonstrated no differences in the peak torque and flexor/extensor analysis.
Conclusions Muscular demands of adolescent soccer players do not cause large asymmetries and imbalances in the extensors and flexor muscles of the knee. In addition, different soccer playing positions do not significantly affect peak torque and flexor/extensor ratio results.

Keywords Soccer · Knee · Muscle strength

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Introduction

Soccer is one of the most popular sports in the world [1] with more than 265 million registered players; 69.6% of the players are males and 56.3% are 18 years and younger [2]. This sport is associated with a high risk of lower limb injuries, which may result in long-term disabilities and negatively affect the physical performance [3, 4]. Thigh muscle strain is the most common injury in male professional soccer [5–10] and one of the most common injuries in male collegiate soccer players together with knee and ankle sprains [11]. Besides being critical for good performance while playing soccer, the thigh muscles are essential to protect, support, stabilize, and absorb mechanical loads on the knee during physical activity [12].

Most thigh and knee soccer injuries are related to different unilateral and flexors/extensors demands. Playing soccer puts uneven demands on the DL and NDL, which can result in bilateral strength difference [13–15]. Regular training and frequent kicking can further promote disproportionate extensor muscle development and imbalances in flexors/extensors function [16, 17]. The imbalances between extensors and flexors increase the risk of hamstring strains [14, 16, 17] and are a determining factor of non-contact knee injuries [16, 18].

Isokinetic dynamometer is the most common, validated, and reliable [19] tool used to assess muscle strength and strength imbalances [20]. Several studies have previously used isokinetic dynamometry to define normative data and to understand the acquired muscle adaptations and imbalances of the athletes; however, the results have been divergent [12, 14–17, 21–32]. However, there are not many studies comparing isokinetic variables among players of different playing positions [33–35] or determining adaptations and imbalances in adolescent soccer athletes [33, 36–38]. Therefore, the purposes of this study were to analyze, using information from a database, the knee extensor and flexor muscular contralateral strength, the flexors'/extensors' function, and the muscular strength differences according to different playing positions of adolescent male soccer athletes.

Methods

Design

This quantitative, cross-sectional and retrospective study was conducted at the Instituto de Medicina do Esporte e Ciências Aplicadas ao Movimento Humano da Universidade de Caxias do Sul (IME-UCS) in the city of Caxias do Sul, Rio Grande do Sul, Brazil. It was approved (protocol number 967.527) by the Ethical Research Committee of the Faculdade Cenecista Bento Gonçalves (Bento Gonçalves, Rio Grande do Sul, Brazil), and conducted according to the 2012 Law No. 466 of the National Health Council, which approves the guidelines and rules for research involving human beings.

Participants

The information provided by the IME-UCS database concerning the concentric isokinetic evaluation of the knee extensor and flexor muscles from 32 male soccer athletes under 17 years of age from the Universidade de Caxias do Sul team occurred in the pre-season was part of this study sample. The number of participants was conveniently established and, therefore, determined intentionally and not by probability according to the number of available evaluations in the IME-UCS's database. Athletes, who self-reported not receiving rehabilitation or any history of injury, were included in the study. Athletes, who had not consented either by themselves or their guardians in the IME-UCS database, were excluded from the study. The mean age of the athletes was 16.34 (±0.70) years, mean height was 1.73 (±0.06) m, the mean weight was 65.37 (±7.66) kg, and the mean body mass index (BMI) was 20.86 (±4.24) kg/m^2, which is considered normal [39]. Nine of the selected athletes were defenders, 14 midfielders, and 9 forwards. Three goalkeepers were excluded due to their different specific movements. Twenty-five athletes reported dominance of the right limb and seven of the left limb while playing.

Procedures

These evaluations were made with the IME-UCS' isokinetic dynamometer (Biodex System 4®, Biodex Medical Systems, Shieley, New York, USA). The athletes first underwent warmup exercises on a stationary bicycle for 8 min with no resistance at moderate velocity (70–80 rounds per minute). The athletes were then led through the isokinetic dynamometer. The athletes sat on the dynamometer chair with their torsos at positioned at 85° with the motor axis aligned to the knee joint axis. They were also stabilized with belts around the torso, pelvis, and thigh (1/3 distal) to avoid compensatory movements. Tests were first performed on the DL and then on NDL. The athletes performed three sub-maximal repetitions (50% of their maximum effort) and a previous maximal for each test on all four velocities to familiarize themselves with the procedures and warmup. Protocol during the test demanded 5, 10, 15, and 20 maximal repetitions of knee extension and flexion in concentric–concentric mode on an angular velocity of 60, 120, 180, and 240°/s. A 1-min rest period was set between evaluations of different velocities, and a 3-min rest period between DL and NDL evaluations. Athletes were tested by the same examiner with the use of verbal incentives for stimulation and encouragement to their maximum strength.

Statistical analysis

Isokinetic variables—peak torque (PT, N/m) and the flexor/extensor ratio (%)—were considered for the analysis. The means values for PT and the flexor/extensor ratio for the knee joint musculature were evaluated statistically on the SPSS 17.0 software (Statistical Package to Social Science for Windows). To verify the normality of the data distribution, the Shapiro–Wilk test was used. The mean values for the DL and NDL tests were evaluated with student's T test and one-way analysis of variance (ANOVA). Post hoc Tukey was used to compare different positions (defenders, midfielders, and forwards) at the significance level of 0.05.

Results

We accessed isokinetic evaluations from 32 adolescent male soccer athletes. The PT concentric isokinetic data results of the DL and NDL are presented in Table 1. At the velocity of 60°/s, the average values for flexors on the NDL were significantly smaller than those of the DL. In the bilateral comparison of the flexor/extensor ratio values, a significant difference was observed at the angular velocity of 60°/s (Table 2). Bilateral asymmetry between DL and NDL was also evaluated. To calculate the bilateral asymmetry of the PT, the difference between the PT of the DL and NDL was divided by the PT of DL and multiplied by 100 ($\frac{PTDL-PTNDL}{PTDL} * 100$). The flexor/extensor ratio's bilateral asymmetry was calculated by dividing the difference between the flexor/extensor ratio of the DL and NDL with the flexor/extensor ratio of the DL and the result was multiplied by 100 $\left(\frac{flexor/extensorratioDL-flexor/extensorratioNDL}{flexor/extensorratioDL} * 100\right)$ [38, 40].

When averaged separately, the DL and NDL values of the defenders, midfielders, and forwarders (Table 3) demonstrated no statistical differences. The playing positions did not appear to be significantly influenced by the PT of the extensors and flexors and flexor/extensor ratio in adolescent soccer athletes.

Discussion

The purpose of this study was to determine whether adolescent male soccer athletes had knee extensor and flexor muscular contralateral strength asymmetries, flexors/extensors asymmetries, and muscular strength differences associated with the different soccer positions. Bilateral and agonist/antagonist muscle strength comparisons are important, because asymmetries may be responsible for serious risk of injuries in professional and semi-professional players [30, 41]. Position specific training can be optimized with a greater understanding of the players' muscular strength. The isokinetic evaluations were held during the pre-season, an ideal time for detecting strength imbalances, and training accordingly to reduce the risk of injury [14, 19]. Soccer players can present various muscle strength asymmetries that could be attributed to unilateral soccer skills [13, 42, 43] and prioritization of the DL for kicking. This can provide more strength to the DL compared to the NDL [36, 44]. Nonetheless, differences between DL and NDL for soccer players are a controversial subject as some studies demonstrate significant asymmetries while other asymmetries in the knee's extensors and flexors strength.

The results of the present study showed no significant differences in the mean values for the PT of the extensor musculature between the DL and the NDL at any of the angular velocities analyzed. Previous studies involving soccer players showed similar results in the PT concentric analysis of extensor musculature using the same as well as different angular velocities. In the analysis of young soccer players aged 20 years and younger, Lehnert et al. [19] at 60, 180, and 360°/s and Silva et al. [38] at 180°/s demonstrated no differences in the extensors' strength between the limbs. At 60°/s, 156 athletes between the ages of 11 and 18 years were evaluated; however, no statistical differences were found [27]. The results of professional soccer players at 60 and 180°/s [45], 60 and 240°/s [29], 60, 120, and 300°/s [23], and at 60, 180, and 300°/s [12, 24, 25] showed no differences between the extensors' strength. Nevertheless, Fousekis, Tsepis, and Vagenas [15] reported significant differences between the limbs at 60°/s; while Eniseler et al. [46] did not find any significant differences

Table 1 Mean and standard deviation values for PT and the bilateral asymmetry of the extensors and flexors of the dominant limb's and the non-dominant limb's knees in adolescent soccer players

Angular velocities (°/s)	PT knee extensors (N/m)			Bilateral asymmetry (%)
	DL	NDL	"p"	
60	214.03 (±36.05)	218.38 (±35.30)	0.44	1.99
120	175.83 (±23.29)	178.49 (±25.32)	0.30	1.49
180	145.66 (±21.49)	148.79 (±21.66)	0.25	2.10
240	114.28 (±27.07)	118.59 (±19.33)	0.29	3.63
Angular velocities (°/s)	**PT knee flexors (N/m)**			**Bilateral asymmetry (%)**
	DL	NDL	"p"	
60	128.52 (±42.93)	115.21* (±29.64)	0.04	10.35
120	102.14 (±28.13)	103.63 (±24.55)	0.69	1.44
180	83.10 (±16.79)	86.44 (±15.90)	0.15	3.86
240	68.92 (±15.17)	72.39 (±16.14)	0.15	4.79

DL dominant limb, *NDL* non-dominant limb, *PT* peak torque

* $p < 0.05$ when compared with dominant limb

Table 2 Mean and standard deviation values for the flexor/extensor ratio and the bilateral asymmetry of the dominant limb's and the non-dominant limb's knees in adolescent soccer players

Angular velocities (°/s)	Flexor/extensor ratio (%)			Bilateral asymmetry (%)
	DL	NDL	"p"	
60	60.33 (±18.06)	53.15* (±10.84)	0.01	11.90
120	58.32 (±15.17)	58.18 (±12.06)	0.95	0.24
180	57.36 (±9.29)	58.86 (±10.04)	0.44	2.55
240	59.28 (±10.92)	61.59 (±12.75)	0.30	3.75

DL dominant limb, *NDL* non-dominant limb

* $p < 0.05$ when compared with dominant limb

Table 3 Mean and standard deviation values for the peak torque of the extensors and flexors, and flexor/extensor ratio of the dominant and the non-dominant limb's knees average of defenders, midfielders, and forwarders at different velocities

	Defenders	Midfielders	Forwarders	"p"
PT knee extensors 60°/s (N/m)	227.36 (±35.36)	212.59 (±32.70)	210.69 (±28.39)	0.48
PT knee flexors 60°/s (N/m)	119.39 (±33.00)	121.39 (±34.85)	125.08 (±30.76)	0.93
Flexor/extensor ratio 60°/s (%)	53.28 (±13.18)	57.25 (±13.37)	59.40 (±11.55)	0.59
PT knee extensors 120°/s (N/m)	185.94 (±22.52)	174.43 (±23.57)	172.64 (±23.75)	0.42
PT knee flexors 120°/s (N/m)	111.75 (±33.63)	98.94 (±20.44)	100.14 (±18.04)	0.44
Flexor/extensor ratio 120°/s (%)	60.42 (±18.51)	57.08 (±11.33)	57.89 (±5.92)	0.82
PT knee extensors 180°/s (N/m)	153.14 (±18.12)	114.86 (±20.74)	144.98 (±22.30)	0.60
PT knee flexors 180°/s (N/m)	91.06 (±16.87)	80.63 (±11.92)	84.93 (±16.99)	0.28
Flexor/extensor ratio 180°/s (%)	59.33 (±6.28)	56.96 (±9.76)	58.68 (±7.15)	0.77
PT knee extensors 240°/s (N/m)	119.69 (±13.24)	112.95 (±24.62)	118.58 (±21.02)	0.71
PT knee flexors 240°/s (N/m)	72.57 (±15.43)	70.36 (±10.40)	69.21 (±19.01)	0.88
Flexor/extensor ratio 240°/s (%)	60.49 (±10.06)	61.62 (±8.99)	58.54 (±12.60)	0.79

DL dominant limb, *NDL* non-dominant limb, *PT* peak torque

in the evaluation of professional soccer at 60, 300, and 500°/s when evaluated at the beginning of the competitive season. The mean PT of the flexor muscle of the NDL was significantly lower ($p < 0.04$) than the DL at 60°/s. At 60, 180, and 300°/s, Fousekis et al. [15] described significant differences at 60 and 180°/s, while Fonseca et al. [24] reported significant differences at 180 and 300°/s. After evaluations at 60, 120, and 300°/s, Rahnama et al. [23] reported bilateral flexor differences at 120°/s, while Teixeira et al. [45] presented differences in both velocities at 60 and 180°/s. However, some studies showed no differences in the flexor strength between the limbs at 60°/s [12, 20, 24, 29, 46], 180°/s [12, 20, 24, 38], 240°/s [29], 300°/s [12, 24, 46], 360°/s [20], and 500°/s [47].

In addition, the differences between the limbs were examined by the bilateral asymmetry analysis. At 60°/s, the PT of the flexor showed the unique result higher than 10% (10.35%) in the PT results of the extensor and flexor muscles. Although this is a small difference, bilateral differences of higher than 10 or 15% in the knee muscles increase the injury risk [45, 48, 49]. Croisier et al. [14] asserted that soccer players with strength asymmetries higher than 15% are four-to-five times more likely to sustain a hamstring strain. Nevertheless, we believe that the asymmetries for the flexors muscle can be explained by the specific motor demands during the soccer activity. According to Rahnama et al. [23], the difference between the limbs' flexors' strength occurs due to the biomechanical condition of the NDL during the kick, where the flexors stabilize the joint, support the weight, and resist the torque reaction from the DL, but it is not involved in stabilizing the knee during the kick action [50]. Furthermore, the flexors' asymmetry between the DL and the NDL was observed just for the lower angular velocity (60°/s), that despite being the most common velocity and more useful to determine a player's muscle characteristics [51], the athletes were not in the highest training and competitiveness to determine all their muscle strength capacity. In addition, higher velocities may not transmit the real sprint efforts [52]. The higher angular velocities are considered more functional and relevant for the soccer players' study [53], because the muscle contractile force occurs quickly [54]. Furthermore, we really have confidence that this difference at 60°/s represents a lower risk of injury when compared to higher velocities, because the majority of flexors injuries occur during higher velocity movements [9, 53, 55].

Related to the flexor/extensor ratio, the present study demonstrated that the NDL mean values were significantly smaller ($p < 0.01$) than the DL and the bilateral asymmetry was 11.90% at 60°/s. The flexor/extensor ratio analysis used in this study is conventional; it is calculated by the ratio between the concentric flexors' PT and concentric extensors' PT [49, 56], and it can be used to determine if there is a balance between the limbs and between the posterior (flexors) and anterior (extensors) muscles of the thigh [17]. Thus, this result is related to the difference between the limbs in the flexors' PT, which also showed significant differences at 60°/s. Other soccer studies compared the flexor/extensor ratio between the limbs, but did not find any significant differences at 60°/s [12, 23, 25, 26, 29, 35], at 120°/s [23], at 180°/s [12, 26, 35, 38], at 240°/s [29, 35], and at 300°/s [23]. These results support that soccer practice has maintained strength balance between the DL and the NDL. However, Fonseca et al. [25] demonstrated significant differences between the limbs at 180 and 300°/s. The mean values of the DL and the NDL were between 53.15 and 61.59% at the four angular velocities analyzed. These values are in the range reported in the literature (50–80%) required to prevent thigh and knee injuries [56–58]; however, some studies propose that values lower than 60% increase the risk of non-contact leg and knee injuries [16, 59]. The ratio values are directly proportional to the angular velocity; therefore, they increase with the increase in velocity [49, 57–60]. Surprisingly, the present study does not show higher values at the higher angular velocities, which could be attributed to the musculoskeletal immaturity. The understanding of the flexor/extensor ratio is important, because it is considered to be one of the determining factors of thigh and knee injuries [13, 18, 61]. Contrary to our results, Iga et al. [36] demonstrated a greater increase in the strength of the extensors compared with flexors in adolescent soccer and it may be attributed to soccer training. This result could be due to disproportionate extensors development during soccer practice, since the extensors are more involved in running, jumping, and kicking the ball, whereas the knee flexors are involved in running and stabilizing the knee joint during changes in direction, acceleration, and deceleration [17, 34, 62].

Relative to the comparison of the extensors' and flexors' PT values and flexor/extensor ratio values between the defenders, midfielders, and forwarders, no statistical differences were found in any of the four angular velocities. Previous studies with similar comparison have presented divergent results. Weber et al. [34] analyzed 27 professional soccer players at 60°/s reported no differences between the different playing positions. Arabi et al. [35] evaluated 38 soccer players with a mean age (14.57 years) similar to the present study and showed no difference between the strikers, defenders, and goalkeepers at 60, 180, and 240°/s. Silva et al. [37] and Goulart et al. [33] evaluated soccer players of U20 category. Silva et al. [38] evaluated 21 athletes and did not find differences at 180°/s in the concentric evaluations, but in the eccentric evaluations, the defenders had statistically higher values than the midfielders and forwarders in the extensors' PT. However, Goulart et al. [33] evaluated 78 soccer players and showed that defenders presented lower values compared to the other athletes at 60, 180, and 240°/s.

Conclusion

The principal finding of this study indicated that muscular demands of adolescent soccer players do not cause large asymmetries and imbalances for the extensors and flexors muscles of the knee. The results of this study indicated two bilateral differences between the limbs for the flexor's PT and the flexor/extensor ratios at 60°/s, where the NDL had significantly lower values than the DL. We believe that the lower flexors' PT at this angular velocity and the lower flexor/extensor ratio may be due to the fact that the evaluations were completed in the pre-season when the athletes were not at their training peak. However, we are certain that the differences in this angular velocity do not greatly increase the injury risk, because the soccer's actions occur at higher velocities. Other results showed that the flexor/extensor ratios were between the normal values and that different playing positions do not significantly affect the peak torque and flexor/extensor ratio results. Although there are numerous studies evaluating soccer athletes, there is no consensus as to whether soccer's demanding training negatively affects the strength of knee muscles. Further research may use different angular velocities, and isokinetic eccentric and isometric contractions for a more thorough knowledge of muscular balance. This will expand our knowledge related to isokinetic muscular function evaluations on male adolescent soccer players.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Ethical approval All procedures of the present study were approved by the Ethical Research Committee of the Faculdade Cenecista Bento Gonçalves, and they were performed in accordance with the ethical standards of the 1964 Helsinki declaration and conducted according to the 2012 Law No. 466 of the National Health Council, which approves the guidelines and rules for research involving human beings.

Informed consent Informed consent was obtained from all subjects included in the study.

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