

Reliability of concentric and eccentric strength of hip abductor and adductor muscles in young soccer players

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ABSTRACT: The concentric and eccentric strength profile and muscular balance of the hip joint are important parameters for success in soccer. This study evaluated the reliability for the assessment of hip abduction and adduction isokinetic strength over a range of angular velocities (30 and 90°/s) and types of muscular actions (concentric and eccentric) in young soccer players. The reliability for the assessment of reciprocal (conventional and functional) and bilateral torque ratios was also examined. Fifteen male soccer players (15±1 years) performed two sessions, separated by three days. The testing protocol consisted of five maximal concentric and eccentric hip abductions and adductions of both legs at angular velocities of 30°/s and 90°/s. The peak torque was evaluated in young soccer players using an isokinetic dynamometer (Cybex Norm), and the reciprocal strength ratios (conventional and functional) and bilateral ratios (non-preferred to preferred leg ratios) were calculated. The test-retest reliability for the assessment of peak torque (ICC=0.71-0.92) and of reciprocal muscle group ratios (ICC=0.44-0.87) was found to be moderate to high. Bilateral torque ratios exhibited low to moderate reliability (ICC=0.11-0.64). In conclusion, isokinetic strength of hip abductor and adductor muscles and the conventional and functional strength ratios can be reliably assessed in young soccer players, especially at low angular velocities. The assessment, however, of bilateral strength ratios for hip abductor/adductor muscles should be interpreted with more caution.

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INTRODUCTION

Hip muscle strength is an important physical attribute in soccer for several fundamental skills such as kicking, accelerating and sudden change of direction [1]. The intensive nature and increased physical demand of soccer may lead to a number of lower limb injuries [2,3], with groin and hip [4,5] accounting for a great percentage (10-18%) of these injuries. Adductor-to-abductor strength imbalance was suggested to be among the main risk factors for adductor injuries and strain of the hip joint [6]. The evaluation, therefore, of strength of the hip abductors and adductors and the calculation of reciprocal and bilateral torque ratios are often used in sports medicine to assess the strength profile of the hip joint and to monitor potential groin- and hip-related injuries [1,7,8].

Isokinetic dynamometers have been considered as simple, easily applicable and reliable devices for assessing lower limb muscle strength (i.e. knee, ankle and hip) in sports and clinical settings [9, 10,11]. Previous studies have found moderate to high reliability (ICC=0.56-0.90) of isokinetic devices in assessing concentric and eccentric strength of hip abductor and adductor muscles in untrained and physically active adults or in elite hockey players [7,8,12]. The

reliability, however, of strength measurement could be influenced by age [13,14]. Differences in motivation, learning effect, and the ability to focus on the task may account for these age-related differences in reliability [13,14].

The only study [15] that has examined the reliability for hip abduction and adduction concentric strength assessment in youths was performed in untrained children (6-10 years), reporting moderate reliability (ICC=0.49-0.59). It is known, however, that the reliability of strength measurements may vary when examining a population with different characteristics (e.g., untrained vs. trained) [13,16,17]. Specifically, there is evidence that training status may improve the test-retest reliability and increase testing accuracy [16]. The angular velocity of movement and the type of muscle action (concentric vs. eccentric) may also affect the reliability of isokinetic strength measurement [18]. The only study that has examined the reliability of isokinetic strength testing of the hip joint in children [15] was limited to an agonist muscle group using a concentric muscle action at a single angular velocity. This is despite the fact that (i) the asymmetry in strength properties of reciprocal and bilateral muscle group

ratios is a contributory factor for muscle injury at the hip joint and (ii) eccentric muscle action is as important as concentric activation for performing different fundamental skills in soccer (i.e., kicking, sudden change of direction, etc.) [19].

To the best of our knowledge, there are no reports on test-retest reliability for the assessment of isokinetic strength profile of the hip joint over a range of muscle actions (concentric and eccentric) and angular velocities in young soccer players. The reliable evaluation of hip abduction and adduction muscle strength as well as of reciprocal and bilateral muscle group ratios in young soccer players is fundamental for accurate monitoring of strength, training planning, and injury prevention/rehabilitation. Therefore, the aims of the present investigation were to evaluate the test-retest reliability for assessment (i) of isokinetic (concentric and eccentric) peak torque of hip abductor and adductor muscles over a range of different angular velocities (30 and 90°/s) and types of muscular contraction (concentric and eccentric), (ii) of conventional and functional reciprocal muscle group torque ratios at the hip joint and (iii) of bilateral ratios (non-preferred to preferred leg ratios) in young soccer players.

MATERIALS AND METHODS

Fifteen young elite male soccer players (age: 15.0 ± 0.6 years; body height: 172.53 ± 6.83 cm; body mass: 63.62 ± 6.39 kg; Tanner stage: 3-4), members of the Greek Amateur Soccer Association, volunteered to participate in the present study. The participants trained four to six times per week (4.87 ± 0.64 days/week), for more than three years (6.13 ± 1.81 years). The research was conducted according to the ethical standards of the Helsinki Declaration. Before the initiation of the study, the institutional review board committee approved the experimental protocol and the parents of children signed an informed consent form. All children's parents completed a physical activity questionnaire, as modified by Bar-Or [20], and a medical history form. All participants were healthy and had no previous injury of lower limbs and no previous experience with isokinetic evaluation.

Three days before the initiation of the study the participants performed a familiarization session to get acquainted with the isokinetic dynamometer. On the same day, the participants' parents completed a medical history form, the pubertal stage was determined according to pubic hair development [21], and the assessment of "leg preference" was performed by asking the participant "Which leg do you use to kick a ball?" Following the familiarization session, the participants reported to the laboratory on two separate occasions. Upon each visit, the participants performed a 10-min standardized warm-up that included 5 min of stationary cycling at 70 rpm (Monark, Vansbro, Sweden) and 5 min of dynamic stretching exercises of the evaluated muscle groups.

The testing protocols were performed using an isokinetic dynamometer (Cybex Norm, Lumex Corporation, Ronkahoma, NY). The participants lay down on their side with the hip and knee of the tested leg extended and neutrally rotated. Velcro straps were used to stabilize the trunk, waist, and thighs of the tested and non-tested

legs. The resistance pad was placed proximally to the knee over one-half of the thigh. The axis of rotation of the dynamometer was carefully aligned with the approximate hip joint axis of rotation (greater trochanter of the hip) [8]. The non-tested leg was positioned at approximately 30° of hip flexion in order to avoid contact with the tested leg during adduction movements [8]. The set-up of the subject during testing is shown in the Figure 1.

After adopting the testing position, the participants performed 8 to 10 preliminary familiarization trials at very low intensity not capable of inducing muscle fatigue. Next, the isokinetic peak torque of hip abductor and adductor muscles was evaluated for two different types of muscle action (concentric and eccentric). Both concentric and eccentric tests consisted of five continuous maximal hip abductions and adductions (concentric or eccentric, according to the test) at two different angular velocities (30°/s and 90°/s). The eccentric and concentric tests were performed separately in a randomized order with five-minute rest interval between the muscle action tests (concentric and eccentric). A five-minute rest was given between the angular velocity (30°/s and 90°/s) tests. The testing protocol was performed on both legs (preferred and non-preferred). Following the testing of one leg, there was a 10-minute rest prior to the initiation of testing of the other leg. The order of testing the "preferred" and the "non-preferred" legs in test and retest sessions was randomized to avoid cross-over effects. For all participants, the range of motion was set from -10° (full adduction) to 35° (full abduction). The moments were corrected for the effects of gravity, and the highest torque value of 5 attempts was used for the statistical analysis.

For the maximization of the participant's performance, standardized oral encouragement was given, while feedback for the exercise intensity, total work production and duration was provided automatically on the computer screen of the isokinetic dynamometer. The two testing sessions (test and retest) were performed at the same time of day, 3 days apart. Participants were asked to follow their normal diet for 2 days before the study, to abstain from intense exercise activity for 48 h before the study, and to have sufficient rest the night before the study. All measurements were performed at the same time of day to prevent potential confounding effects of daily biorhythms.



FIG. 1. Position of the subject during the isokinetic evaluation.

Hip muscle strength test-retest reliability

The parameters used for analysis were the peak torque (Nm), the reciprocal (conventional and functional), and the bilateral torque ratios (non-preferred to preferred leg ratios) [9,22,23]. Reciprocal muscle group ratios (conventional and functional) of hip abductor to adductor muscles constitute a measure of hip joint stability and may provide information on hip function and injury risk. The hip abduction (HAB) to hip adduction (HAD) torque ratios during concentric (CON_{HAB}/CON_{HAD}) or eccentric action (ECC_{HAB}/ECC_{HAD}), often referred to as conventional ratios, are the two most common means to estimate the reciprocal muscle group torque ratios at the hip joint. However, several researchers have proposed the implementation of torque ratios more relevant to athletic performance to evaluate muscular balance, that is the eccentric to concentric actions of the antagonist muscles or vice versa (ECC_{HAB}/CON_{HAD} and CON_{HAB}/ECC_{HAD}), often referred to as functional ratios. It has been suggested that the estimation of both conventional and functional strength ratios may provide a better and more complete profile of muscle balances or imbalances around a joint [10, 22, 23]. The reliability of measurements of bilateral torque ratios was also examined. The bilateral torque ratios were calculated by dividing the maximal concentric or eccen-

tric torque of hip abductor and adductor muscles of the non-preferred leg by the respective measures of the preferred leg.

All data are presented as means \pm SD, and were analysed using SPSS 15.0 (Illinois, USA). Test-retest data were analysed using the intraclass correlation coefficient (ICC) for single measures using a two-way random effect model of absolute agreement. We also assessed the absolute reliability using the standard error of measurement (SEM) and the 95% limits of agreement (LOA). The SEM was calculated by means of the following equation: $SEM=SD \cdot (1-ICC)$, where SD=the sample standard deviation and ICC=the calculated intraclass correlation coefficient [24]. The LOA was calculated using the equation: $LOA=inter\text{-}trial\text{ mean difference} \pm 1.96\text{ SD of the inter-trial difference}$ [24]. The presence of heteroscedasticity was tested using the Pearson correlation test to examine whether the absolute inter-trial difference was associated with the magnitude of the measurement. All variables were found to be homoscedastic. Paired t-tests were used to identify differences between test and retest values of the following parameters: (i) the isokinetic peak torque of hip abductor and adductor muscles, (ii) the ratio for peak torques of non-preferred to preferred leg and (iii) the ratio for peak torque of con-

TABLE I. Test and retest values, and indices of relative and absolute reliability of peak torque of hip abductor and adductor muscles at different angular velocities and muscle actions.

Variables		Test (Nm)	Retest (Nm)	95% CI		ICC	SEM (Nm)	Bias (Nm)	95% LOA (Nm)	
				Lower	Upper				Lower	Upper
Abd										
Con	Peak torque 30°/s									
	Preferred leg	120.0 \pm 27.3	118.5 \pm 24.2	-6.9	9.9	0.85	9.6	-1.5 \pm 14.5	-30.0	27.0
	Non-preferred leg	120.0 \pm 25.9	122.5 \pm 26.1	-13.7	8.7	0.73	12.5	2.5 \pm 19.4	-35.5	40.5
	Peak torque 90°/s									
	Preferred leg	106.0 \pm 23.0	106.4 \pm 22.8	-6.0	5.3	0.91	6.7	0.4 \pm 9.9	-18.95	19.7
	Non-preferred leg	106.6 \pm 21.5	103.7 \pm 22.5	-5.9	11.7	0.77	9.9	-2.9 \pm 15.2	-32.7	27.0
Ecc	Peak torque 30°/s									
	Preferred leg	121.7 \pm 33.1	127.3 \pm 29.5	-12.7	1.5	0.91	9.2	5.6 \pm 12.3	-18.5	29.7
	Non-preferred leg	121.7 \pm 26.2	124.9 \pm 27.1	-15.1	0.3	0.71	13.2	3.2 \pm 20.6	-37.1	43.5
	Peak torque 90°/s									
	Preferred leg	117.6 \pm 28.9	123.4 \pm 29.6	-11.9	0.3	0.92	8.1	5.8 \pm 10.6	-14.9	26.5
	Non-preferred leg	118.8 \pm 24.1	120.0 \pm 28.0	-11.7	9.3	0.77	11.7	1.2 \pm 18.2	-34.4	36.8
Add										
Con	Peak torque 30°/s									
	Preferred leg	100.5 \pm 29.0	107.2 \pm 28.9	-14.2	0.8	0.88	9.8	6.7 \pm 13.0	-18.7	32.1
	Non-preferred leg	102.3 \pm 24.3	107.8 \pm 27.4	-13.6	2.6	0.84	10.0	5.5 \pm 14.1	-22.1	33.1
	Peak torque 90°/s									
	Preferred leg	85.1 \pm 28.4	94.5 \pm 27.3	-19.5	0.6	0.77	12.7	9.4 \pm 17.4	-24.6	43.5
	Non-preferred leg	91.9 \pm 25.1	95.1 \pm 24.9	-13.5	6.9	0.76	11.5	3.3 \pm 17.7	-31.4	38.0
Ecc	Peak torque 30°/s									
	Preferred leg	111.96 \pm 32.4	119.7 \pm 29.3	-15.7	0.03	0.88	10.4	7.9 \pm 13.7	-18.9	34.6
	Non-preferred leg	116.8 \pm 29.1	115.1 \pm 26.9	-10.4	13.7	0.74	13.3	-1.6 \pm 20.9	-42.5	39.3
	Peak torque 90°/s									
	Preferred leg	105.2 \pm 25.5	112.4 \pm 25.4*	-13.8	0.6	0.87	9.0	7.2 \pm 11.4	-15.1	29.5
	Non-preferred leg	110.7 \pm 27.2	110.3 \pm 25.7	-9.7	10.5	0.79	11.4	-0.4 \pm 17.5	-34.7	33.9

Notes: Abd: abductors, Add: adductors, Con: concentric, Ecc: eccentric, 95% CI: 95% confidence interval of the difference, ICC: intraclass correlation coefficient, SEM: standard error of measurement, Bias: difference between test and retest (retest-test), 95% LOA: 95% limits of agreement.

*p < 0.05 vs. test values, d (effect size between test and retest): 0.28 (small effect size).

ventional and functional muscle group ratios. The effect sizes were calculated using the following equation: $d = \text{difference between means} / \text{pooled SD}$ [25]. The level of significance was set at $p < 0.05$.

RESULTS

Peak torque. Paired t-tests indicated non-significant differences between test and retest for all, except one, testing variables. A significant difference, with a small effect size, between testing and retesting was found only for the eccentric peak torque at 90°/s for hip adductors of the preferred leg ($p < 0.05$; $d = 0.28$, small effect size). The ICC analysis revealed moderate to high reliability ($\text{ICC} = 0.71\text{--}0.92$) for assessment of isokinetic peak torque of the preferred and the non-preferred legs irrespective of angular velocities and muscle actions. Test and retest peak torque values (mean \pm SD) as well as relative and absolute reliability indices (ICC, SEM, bias, 95%LOA) for each leg are presented in Table 1.

Reciprocal muscle group ratios (conventional and functional)

Paired t-tests revealed non-significant differences between test and retest for most testing variables (Table 2). Significant differences between test and retest were found only for the concentric conventional ratio ($\text{CON}_{\text{HAB}}/\text{CON}_{\text{HAD}}$) at 30°/s for the preferred leg ($p < 0.05$;

$d = 0.50$, moderate effect size), and for functional ratios ($\text{CON}_{\text{HAB}}/\text{ECC}_{\text{HAD}}$) at 30°/s ($p < 0.05$; $d = 0.64$, moderate effect size) and at 90°/s also for the preferred leg ($p < 0.05$; $d = 0.57$, moderate effect size). The analyses of relative and absolute reliability (ICC, SEM, bias, 95%LOA) revealed moderate to high reliability for the assessment of conventional and functional reciprocal muscle group ratios of the preferred and the non-preferred legs at both angular velocities (Table 2).

Bilateral torque ratios

Paired t-tests indicated non-significant differences between test and retest for all, except one, testing variables. A significant difference between test and retest was found only for the eccentric non-preferred/preferred leg muscle ratio at 90°/s for hip adductors ($p < 0.05$; $d = 0.64$, moderate effect size). The reliability analyses (ICC, SEM, bias, 95%LOA) revealed low to moderate reliability for the assessment of bilateral strength ratios irrespective of angular velocity and muscle action (Table 3).

DISCUSSION

The novel aspect of this study is that it examined the reliability of commonly used isokinetic tests to assess the muscle strength of hip

TABLE 2. Test and retest values, and indices of relative and absolute reliability of conventional and functional abductor to adductor ratios (%) at different angular velocities and muscle actions.

Variables	Test (%)	Retest (%)	95% CI		ICC	SEM (%)	Bias (%)	95% LOA	
			Lower	Upper				Lower	Upper
CONabd/CONadd 30°/s									
Preferred leg	121.8 \pm 17.1	113.2 \pm 17.2*	0.8	16.4	0.63	9.6	-8.6 \pm 13.5	-35.1	17.8
Non-preferred leg	118.1 \pm 9.9	115.7 \pm 16.4	-6.0	10.7	0.44	8.6	-2.4 \pm 14.5	-30.7	26.0
CONabd/CONadd 90°/s									
Preferred leg	133.8 \pm 45.1	115.9 \pm 20.9	-2.7	38.3	0.45	22.5	-17.8 \pm 35.5	-87.4	51.7
Non-preferred leg	119.1 \pm 16.7	110.9 \pm 13.9	-0.3	16.7	0.49	9.7	-8.2 \pm 14.8	-37.2	20.8
ECCabd/ECCadd 30°/s									
Preferred leg	110.4 \pm 16.4	108.2 \pm 19.9	-3.6	7.9	0.85	6.8	-2.2 \pm 10.0	-21.8	17.5
Non-preferred leg	106.4 \pm 18.5	110.5 \pm 18.9	-11.8	3.5	0.75	8.7	4.2 \pm 13.2	-21.6	29.9
ECCabd/ECCadd 90°/s									
Preferred leg	112.8 \pm 18.2	110.8 \pm 19.9	-5.4	9.4	0.78	8.4	-2.0 \pm 12.8	-27.1	23.1
Non-preferred leg	109.8 \pm 20.5	110.9 \pm 23.3	-7.9	5.6	0.87	7.6	1.2 \pm 11.7	-21.7	24.1
ECCabd/CONadd 30°/s									
Preferred leg	122.9 \pm 20.1	121.8 \pm 25.3	-7.1	9.3	0.82	9.2	-1.1 \pm 14.3	-29.1	26.9
Non-preferred leg	120.8 \pm 20.2	118.1 \pm 18.6	-6.8	12.3	0.65	10.4	-2.8 \pm 16.6	-35.2	29.7
ECCabd/CONadd 90°/s									
Preferred leg	147.1 \pm 46.5	135.3 \pm 34.3	-10.0	33.7	0.57	23.8	-11.8 \pm 37.8	-86.0	62.3
Non-preferred leg	133.9 \pm 26.7	129.4 \pm 26.4	-10.8	19.9	0.51	16.1	-4.6 \pm 26.7	-56.8	47.7
CONabd/ECCadd 30°/s									
Preferred leg	109.8 \pm 16.1	100.5 \pm 12.6*	2.4	16.1	0.56	8.7	-9.3 \pm 11.9	-32.5	14.0
Non-preferred leg	104.2 \pm 12.8	108.3 \pm 17.0	-9.1	0.9	0.81	6.3	4.1 \pm 8.7	-12.9	21.1
CONabd/ECCadd 90°/s									
Preferred leg	101.8 \pm 11.5	95.3 \pm 11.4*	0.3	12.7	0.50	7.1	-6.5 \pm 10.7	-27.5	14.5
Non-preferred leg	98.2 \pm 16.0	95.5 \pm 14.8	-4.5	10.1	0.67	8.1	-2.8 \pm 12.7	-27.6	22.0

Note: 95% CI: 95% confidence interval of the difference, CONabd/CONadd: concentric abduction/concentric adduction, ICC: intraclass correlation coefficient, SEM: standard error of measurement, Bias: difference between test and retest (retest-test), 95% LOA: 95% limits of agreement, ECCabd/ECCadd: eccentric abduction/eccentric adduction, ECCabd/CONadd: eccentric abduction/concentric adduction, CONabd/ECCadd: concentric abduction/eccentric adduction.

* $p < .05$ vs. test values, d (effect size between test and retest): 0.50-0.64 (moderate effect size).

TABLE 3. Test and retest values, and indices of relative and absolute reliability of non-preferred/preferred leg muscle ratios at different angular velocities and muscle actions.

Variables	Test (Nm/Nm)	Retest (Nm/Nm)	95% CI		ICC	SEM (Nm/Nm)	Bias (Nm/Nm)	95% LOA	
			Lower	Upper				Lower	Upper
CON 30°/s									
Abductors	1.01 ± 0.14	1.04 ± 0.12	-0.12	0.08	0.11	0.09	0.03 ± 0.18	-0.32	0.38
Adductors	1.04 ± 0.15	1.02 ± 0.16	-0.06	0.10	0.64	0.08	-0.02 ± 0.13	-0.27	0.23
CON 90°/s									
Abductors	1.02 ± 0.14	0.99 ± 0.13	-0.06	0.12	0.39	0.09	-0.03 ± 0.15	-0.32	0.26
Adductors	1.12 ± 0.26	1.03 ± 0.21	-0.02	0.21	0.61	0.13	-0.09 ± 0.20	-0.48	0.30
ECC 30°/s									
Abductors	1.02 ± 0.14	1.00 ± 0.16	-0.08	0.13	0.20	0.10	-0.02 ± 0.19	-0.39	0.35
Adductors	1.07 ± 0.17	0.97 ± 0.13	-0.02	0.21	0.18	0.11	-0.10 ± 0.20	-0.49	0.29
ECC 90°/s									
Abductors	1.03 ± 0.15	0.99 ± 0.17	-0.04	0.12	0.61	0.09	-0.04 ± 0.14	-0.31	0.23
Adductors	1.06 ± 0.10	0.99 ± 0.12*	0.02	0.12	0.56	0.07	-0.07 ± 0.09	-0.25	0.11

Note: 95% CI: 95% confidence interval of the difference, CON: concentric, ICC: intraclass correlation coefficient, SEM: standard error of measurement, Bias: difference between test and retest (retest-test), 95% LOA: 95% limits of agreement, ECC: eccentric.
*p < .05 vs. test values, d (effect size between test and retest): 0.64 (moderate effect size).

abductors and adductors in young soccer players over a range of angular velocities and types of muscle actions. Additionally, to the best of our knowledge, this is the first study to investigate the test-retest reliability for measurements of reciprocal muscle group torque ratios (conventional and functional) and bilateral strength ratios at the hip joint. The test-retest reliability was moderate to high for the assessment of peak torque (ICC=0.71-0.92, SEM=6.71-13.25) and reciprocal muscle group torque ratios (ICC=0.44-0.87, SEM=6.78-23.85), while the assessment of bilateral strength ratios exhibited low to moderate reliability (ICC=0.11-0.64, SEM=0.07-0.13).

The findings of the present investigation are in line with previous studies that reported moderate to high test-retest reliability (ICC=0.56-0.90, SEM=9.91-24.11) for hip abduction and adduction muscle strength testing in untrained or physically active adults [7,8,12,26,27] using various types of isokinetic dynamometers and testing protocols. However, the only study [15] that has examined the reliability for hip abduction and adduction concentric strength assessment in youth (6-10 years) showed lower reliability (ICC=0.49-0.59) than in the present investigation. Differences in training status (untrained vs. trained in our study) and age/maturation (pre-pubertal vs. pubertal in our study) might have accounted for the differences in reliability measurements between the previous and our study. Moreover, the inadequate familiarization before testing in the previous study [15] may also explain the lower observed reliability in the present investigation. This view has been highlighted by previous studies recommending extensive familiarization before the main testing of hip isokinetic evaluation, especially in youth [15].

Several factors such as the type of dynamometer, the position of the subject during testing (standing, supine, or side-lying) and the different methods for the determination of muscle strength (average vs. best effort) may potentially affect the value and thus the reliability of isokinetic strength measurement. Indeed, a previous study in adults [28] examining the reliability of hip joint muscle strength un-

der different testing positions (standing vs. supine vs. side-lying) concluded that side-lying is the most valid and reliable position for hip strength assessments using a handheld dynamometer. Thus, the moderate to high reliability for the isokinetic assessment of hip muscle strength that we observed in young individuals may be a result of the side-lying position that we adopted. Angular velocity of the movement and the type of muscle action (concentric vs. eccentric) are additional factors that could influence the reliability of the measurement. Previous studies examining the reliability of isokinetic strength measurements over a range of muscle actions have reported that the assessment of strength with eccentric muscle action is less reliable compared to that with concentric muscle activation [18].

There is evidence that muscular imbalance of the hip joint may affect athletic performance and increase the predisposition of athletes to sports injury [1, 19]. Therefore, the calculation of reciprocal muscle group ratios (conventional and functional) and bilateral strength ratios of the hip joint is often used in sport settings to monitor potential groin- and hip-related injuries. We observed moderate to high reliability for reciprocal muscle group torque ratios (ICC=0.44-0.87, SEM=6.78-23.85) and low to moderate reliability (ICC=0.11-0.64, SEM=0.07-0.13) for bilateral strength ratios. To the best of our knowledge, the reliability of both bilateral and reciprocal strength ratios of the hip joint has not been previously assessed, so comparison with other studies is not possible. It should be noted that the reliability scores that we observed for the assessment of bilateral and reciprocal strength ratios were lower (ICC=0.11-0.87) compared to those for peak torque (ICC=0.71-0.92). Our results support earlier findings of lower reliability in the assessment of strength ratios of the knee joint compared to the peak torque values in young soccer players [18,29]. The lower reliability for the assessment of these parameters may be attributed to the fact that they are a composite of two absolute scores, each possibly varying in the same or a different direction with reassessment, resulting in error propagation [29]. Thus, the

assessment of bilateral and reciprocal strength ratios should be interpreted with more caution, independent of age.

CONCLUSIONS

The assessment of concentric and eccentric peak torque of hip abductor and adductor muscles at 30 and 90°/s, as well as their conventional and functional ratios, exhibited moderate to high reliability in young soccer players using the Cybex Norm dynamometer. However, some differences between testing and retesting trials were observed in the assessments of eccentric muscle actions. Therefore, the assessment of eccentric strength of abductor and adductor muscles of the hip joint in young soccer players, especially at higher angular velocities, should be interpreted with more caution. The

assessment of bilateral strength ratios demonstrated low to moderate reliability, emphasizing the need for a more careful interpretation of this parameter. It should be pointed out that our results are limited to young soccer players and should not be generalized to other age groups (i.e., adults or elderly) or individuals with a different training status (i.e., untrained or athletes of other sports).

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