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The influence of three different test positions and thigh asymmetry on measurements of isometric hip flexion strength in men and women

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Purpose: The aim of this study was to compare muscle strength at 90° hip and knee flexion as measured in three different positions and to investigate whether an internal or external deficit in the range of rotation in the hip joint affects flexor muscle strength. *Methods*: We measured the peak muscle torque of rotation in the hip joint, using isometric torquemeter, and hip ROM in healthy participants $N = 40$, aged 21.6 ± 1.9, in three different measurement positions. We tested for differences between the positions, and for the potential influence of participant's sex and ROM asymmetry. *Results*: The measured peak muscle torque was affected not only by sex and the value of hip flexion affect, but also by the position in which it is measured. Subjects with restricted external rotation of the hip joint (CERD) had significantly higher flexor peak muscle torque compared to subjects with restricted internal rotation (CIRD), in all but the supine position. For CERD, the results were: Supine (SuP) 1.02 ± 0.26; Sitting (StP) 1.32 ± 0.58; Standing (SP) 1.53 ± 0.47; and for CIRD, the results were: Supine (SuP) 1.05 ± 0.17; Sitting (StP) 1.05 ± 0.40; Standing (SP) 1.47 ± 0.53. *Conclusions*: Overall, measurement position and passive ROM significantly influence the peak muscle torque in isometric conditions. Moreover, an imbalance in thigh rotation movement significantly determines the magnitude of muscle torque of the hip flexion movement. Individuals with increased internal-to-external rotation achieved significantly higher values for flexor muscle torque force moments. Overall, these findings are of importance for interpreting or comparing any reported values for muscle torque force moments.

Key words: *hip joint, rotation, muscle torque, force measurements*

1. Introduction

Muscle strength assessment is widely used in clinical and athletic populations. A deficit in hip strength increases the risk of falls [15] and has been identified as an important variable in multiple pathologies, including chronic ankle instability [22], patellofemoral pain [27], patellofemoral [25] and hip or knee osteoarthritis [28], knee ligament injuries [19] and lower back pain [4]. It is also considered a determinant of athletic performance [26]. Additionally, the ratio of the moments of muscle strength of individual muscle groups has been used in estimating the risk of sports injury [18].

A number of methods for measuring muscle strength have been described in the literature, such as manual muscle testing, hand-held dynamometry, motor-driven dynamometry, and externally fixed dynamometers [6], [21], [30]. However, the measuring position of the hip joint and type of movements tested affect the muscle strength measured. The two main types of movements assessed are isokinetic and isometric. Both have been shown to be reliable. Isokinetic testing is more representative of dynamic muscle action during daily life [24], however, isometric testing minimizes the risk of muscle injury and delayed onset muscle soreness, so it is more beneficial in physiotherapy patients [31]. Hip flexor and rotator strength measurements have been performed in a number of different positions [2], [14],

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[16], [33], the most common of these being a sitting position with a hip/knee flexed at 90°, however, no optimal hip strength testing position has been identified in the published research. From the kinesiological point of view, it would be important to know – yet it remains unclear – whether isometric hip muscle strength is different at 90° flexion, measured in the various testing positions (sitting, lying, or standing), and if so whether this is the similar for men and women.

Moreover, joint motion studies have shown that adults usually have an asymmetrical hip rotation range of motion [29] – either CERD (*coxal external rotation deficit*), where external rotation exceeds internal rotation, or CIRD (*coxal internal rotation deficit*), where internal rotation exceeds external rotation (terms adopted from [3]). This asymmetry is something quite evident in daily physiotherapy practice. A growing number of studies have suggested that hip asymmetry is related to lower extremity musculoskeletal condition or to the societal shift towards more sedentary lifestyles. It, therefore, seems important to know, yet, it also remains unclear whether the asymmetric distribution of thigh rotation affects the strength measurements of individual muscle groups, and if so whether this is the same for men and women, as in previous findings it has been reported that women are more prone to ER deficit [3].

Therefore, the purpose of this study was twofold: 1) to compare isometric hip muscle strength at 90° of hip and knee flexion in males and females, as measured in three different positions: sitting position (StP), standing position (SP), and supine position (SuP), 2) to investigate whether the presence of an identified internal or external deficit in the range of rotation in the hip joint (CERD/CIRD) affects measured values of isometric hip flexion muscle strength in males and females.

2. Materials and methods

A total of forty participants (20 male and 20 female, all university students studying physiotherapy), aged 21.6 ± 1.9, took part in the study. Inclusion criteria were as follows: age between 20–25 years, a declared average level of physical activity, no history of lower limb injury, and consent to participate in the study. Subjects were excluded from the study if they competitively played various sports, declared a low or high level of physical activity, or had a previous diagnosis of dysplasia, femoroacetabular impingement, hip acetabular rim injury or unidentified hip pain.

An anamnesis was taken and anthropometric measurements were conducted: body weight, body height, waist and hip circumference. The following measuring instruments were used: a scale and a centimeter tape. The detailed anthropometric data of the subjects are shown in Table 1.

The peak muscle torque of the flexor muscle group and ranges of motion (ROM) of the hip joint were measured in SuP, StP and SP. The muscles were measured under isometric conditions using a JBA Staniak isometric torquemeter. The above measurements of the muscle torque were applied in accordance with the maximum voluntary contraction method. In all muscle strength and ROM measurements, the tested limb was flexed to 90° at the hip and knee joints, and the subjects' arms were crossed over the chest. In measurements in the supine position (SuP), the pelvis was stabilized by a belt at the level of the superior anterior iliac spines of the pelvis. For measurements in the sitting position (StP), the subjects were stabilized by a close-fitting roller to the torso at the level of the lumbar spine, and trunk movements in the frontal plane were restricted by the physiotherapist's hands placed on the shoulders. Measurement positions are presented in Fig. 1.

When measuring ROM in the SP, subjects were stabilized by the physiotherapist's hands on the hipbones. When measuring thigh flexor muscle force moments in the StP and SuP, the lever arm was positioned parallel to the limb axis, and in the standing position at a 30-degree angle of inclination. The force measurement rollers were positioned 5 cm above the base of the patella. Verbal encouragement was allowed during the measurement. All measurements were performed by the same physiotherapist with an assisting physiotherapist (Fig. 1). Normalized values of hip flexor torque muscle moments per body weight of each subject were performed.

Additional measurements were performed of internal and external rotations in sitting position with proper stabilization. Only StP was the same in hip rotation and flexion measurements. Participants were secured to the therapy table with straps to rule out any compensations or excessive movements. The participant was positioned at the end of the therapy table with knees and hips flexed to a 90° angle, with the lower leg hanging from the table and the femurs fully supported on the table. The upper limbs were crossed on the chest and the participant was stabilized by an assistant sitting in back-to-back position. The axis of the goniometer was placed at the apex of the patella, with one of the arms of the goniometer parallel to the shin and the other perpendicular to the floor. Subjects

Table 1. Anthropometric characteristics

	n	Age [years]	Body mass [kg]	Body height [cm]	Waist circumference [cm]	Hip circumference [cm]
Males	20	21.7 ± 2.0	77.5 ± 11.8	179 ± 7	82.75 ± 9.55	97.30 ± 7.52
Females	20	21.5 ± 1.8	63.7 ± 7.8	167 ± 5	76.25 ± 7.37	97.38 ± 7.80
Total	40	21.6 ± 1.9	70.6 ± 12.1	173 ± 9	79.5 ± 9.04	97.34 ± 7.57

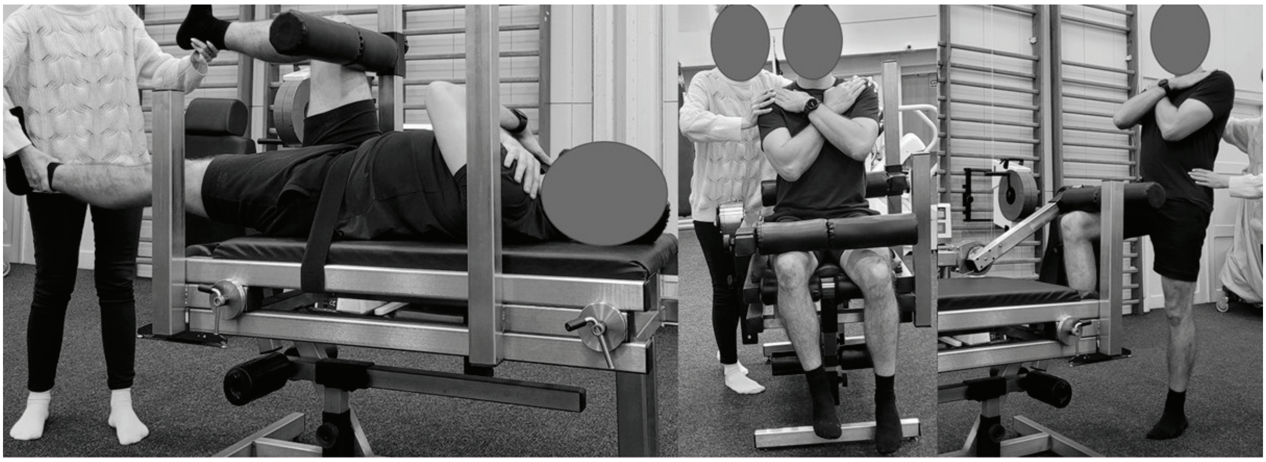

Fig. 1. Measurement for hip flexors isometric muscle torques, in three different positions (from left to right): SuP, StP and SP

were classified into CIRD and CERD groups, according to the ratio of the range of external to internal rotation of the thigh (ER/IR) determined in the StP. The first group (CERD – *coxal external rotation deficit*) consisted of subjects with an ER/IR ratio below <1, and the second group with an ER/IR ratio above >1 (CIRD – *coxal internal rotation deficit*).

Ethical clearance for the study was granted by the local Ethics Committee (SKE 01-45/2021). This work was supported by the Ministry of Science and Higher Education in 2020–2022 under Research Group no. 3 at Józef Piłsudski University of Physical Education in Warsaw, "Motor system diagnostics in selected dysfunctions as a basis for planning the rehabilitation process".

Statistical analysis was performed using STATISTICA v. 13.0 (StatSoft). The normal distribution of the data was assessed using the Shapiro–Wilk test. Simple cross-sectional ANOVA were performed. To assess the interaction between measurement position and isometric hip muscle strength values, an ANOVA test for repeated measures and Bonferroni's post-hoc tests were performed. Due to the lack of sphericity, probability values were assessed using the G-G correction. A significance level of $p \leq 0.05$ was assumed.

3. Results

In all the positions tested, in both active and passive movement, ROM scores were found to be higher in the female group, with significant differences in the StP and SP positions ($p < 0.05$). A SEX x PASSIVE ROM FLEXION interaction was also demonstrated ($F(2,76) = 4.00$, $p = 0.02$). Passive flexion ROM values in the male group differed significantly between SuP and StP ($p < 0.001$), and SuP and SP ($p < 0.001$). In the female group, they differed significantly between SuP and StP ($p = 0.003$), and SuP and SP ($p = 0.004$). Moreover, muscle torque values were normalized to the subjects' body weight. Significantly higher muscle strength values were found in the male group ($p < 0.001$). In addition, they developed the highest torque of strength in the SP. An interaction of SEX x NORMALIZED FLEXOR STRENGTH across the three measurement positions was also observed ($F(2,76) = 5.79$, $p = 0.005$). Post-hoc tests showed significant differences between men's strength measured in the SP and their strength measured in the SuP ($p < 0.001$), and StP ($p < 0.001$), and women's isometric hip muscle strength measured in all measurement positions: SuP, StP and SP ($p < 0.001$).

Table 2. Differences in values of active and passive hip flexion movement ranges and normalized values hip flexion torque in different measurement positions, by sex

		SuP	StP	SP
Males	A ROM	124 ± 8.28	112.05 ± 11.95	112.7 ± 8.54
	P ROM	137.1 ± 9.31[1, 2]	120.3 ± 12.46[1]	119.85 ± 7.71[2]
	strength	1.14 ± 0.16[3]	1.17 ± 0.64[4]	1.75 ± 0.40[4, 3]
Females	A ROM	129.1 ± 8.03	121.55 ± 10.22	121.9 ± 8.54
	P ROM	141.1 ± 6.4[5, 6]	131.95 ± 10.99[5]	132.25 ± 10.02[6]
	strength	0.93 ± 0.21[7, 8]	1.17 ± 0.31[7, 9]	1.24 ± 0.47[8, 9]

A ROM – active ROM, P ROM – passive ROM, SuP – supine position, StP – sitting position, SP – standing position, [1, 2, 5, 6] – Bonferroni post-hoc analyses results $p < 0.005$, [3, 4, 7, 8, 9] – Bonferroni post-hoc analyses results $p < 0.001$.

The results of the above analyses can be found in Table 2.

In order to assess the effect of asymmetry of hip rotation distribution on hip flexor isometric muscle strength moments, subjects were divided into two groups according to the ratio of the range of external to internal rotation of the thigh (ER/IR) determined in the StP. The CERD group consisted of subjects with an ER/IR ratio below <1, and the CIRD group with an ER/IR ratio above >1. In CERD group, there were 14 females and 4 males and in CIRD group, there were 6 females and 16 males. The normalized values of thigh flexor strength in the CIRD and CERD groups are shown in Table 3.

Table 3. Normalized values of hip flexor muscle torque force moments for CIRD and CERD groups

	N	SuP	StP	SP
CERD	18	1.02 ± 0.26	1.32 ± 0.58	1.53 ± 0.47
CIRD	22	1.05 ± 0.17	1.05 ± 0.40	1.47 ± 0.53

CERD – coxal external rotation deficit group, CIRD – coxal internal rotation deficit group, SuP – supine position, StP – sitting position, SP – standing position.

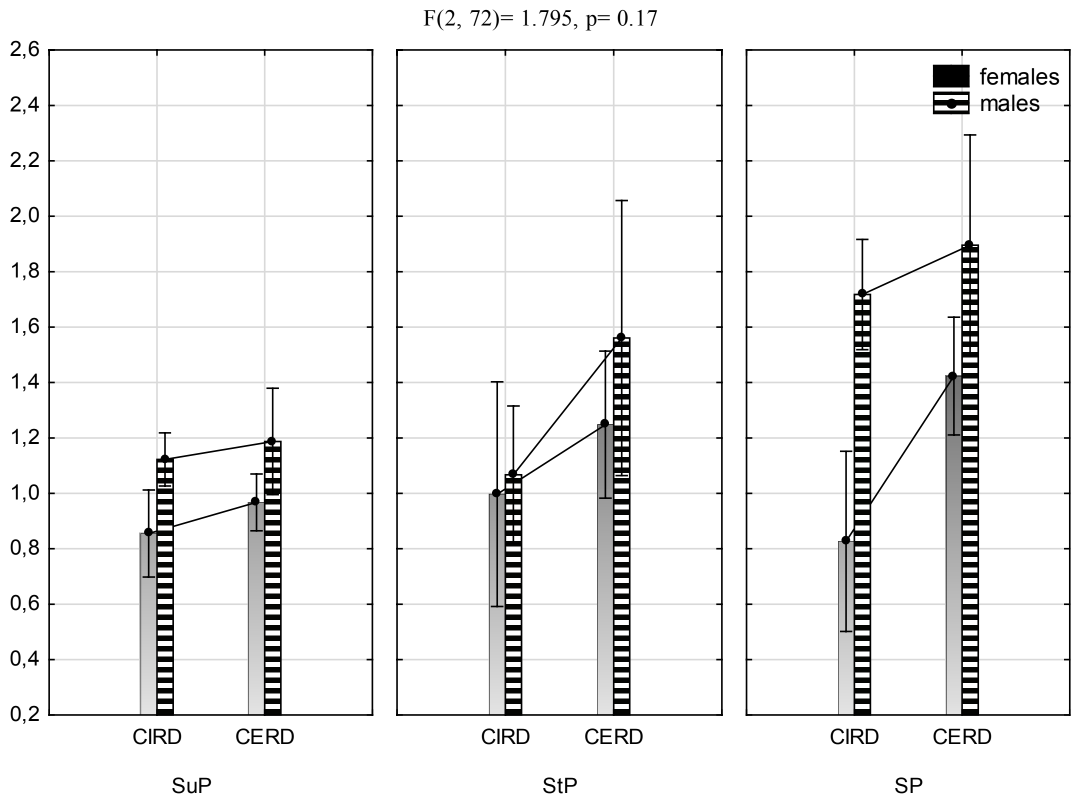

Fig. 2. Interaction results of normalized thigh flexor muscle torque force moments by CIRD, CERD and sex; SuP – supine position, StP – sitting position, SP – standing position, CIRD – coxal internal rotation deficit group, CERD – coxal external rotation deficit group

It was found that subjects with restricted external rotation of the hip joint (CERD) had significantly higher flexor muscle of torque moments compared to subjects with restricted internal rotation (CIRD) ($F_{1,36}$ = 8.41; p = 0,0063; η^2 = 0.189). Moreover, males had significantly higher flexor muscle of torque moments compared to females ($F_{1,36}$ = 14.58; p = 0,0005, η^2 = 0.288). Statistically significant differences were observed in isometric muscle strength between all three testing positions ($F_{2,72}$ = 12.33; $p < 0.0001$, η^2 = 0.255). Testing position differentiates between male and female groups (interaction $F_{2,72}$ = 4.74; p = 0.0117, η^2 = 0.116). However, there was not a significant interaction between POSITION x SEX x CIRD/CERD. Detailed results of the above analysis are shown in Fig. 2.

4. Discussion

The evolutionary adoption of the upright body posture by humans was associated with a number of changes in the musculoskeletal system, particularly the pelvic region and hip joints. The extension of the hip joints and lumbar spine resulted in a more vertical alignment of the femurs and the formation of the lumbar lordosis, which is crucial for bipedal gait and running and which is not observed in other anthropods [13]. However, the transition to bipedal gait led to a loss of hip joint congruency and some changes in the function of the soft tissues, and muscles surrounding it. In the upright position, part of the femoral head is not covered by the acetabulum in front, which is the case in greater flexion [17].

We studied hip flexion range of motion and isometric muscle strength at 90° of hip flexion in 3 positions: StP, SP, and SuP in a group of women and a group of men. The position in which the hip and knee joint of the examined limb are in 90° of flexion, according to the Clinical Muscle Strength Assessment method for assessing hip flexion movement strength – variant I, was taken as the reference position for muscle strength testing [34]. This is the position where the hip-lumbar muscle shows the greatest activity [32], which is sometimes weakened in many patients (based on our own clinical observations). In all positions, range-of-motion values were found to be greater in the female group, with the greatest differences observed in passive movement, in the standing position (F: 132.3 ± 10.02; M: 119.9 ± 7.7; $p < 0.001$). The reason for the differences in mobility range values between men and women may be hormonal differences that affect the tension of structures that limit the mobility range of the hip joint. The hormone responsible for the tension in the joint structures is relaxin, which women have in higher concentrations than men [5]. Another reason for the greater range of hip flexion mobility of the hip in women could be due to differences in the anatomical structure of their pelvis, which tends to be wider than in men [20]. The literature comparing thigh hip flexion mobility ROM by sex is scarce. Hallaçeli et al. [10] conducted a study evaluating the effect of sex on hip joint range of motion, finding significantly higher ROM of active and passive internal rotation and active external rotation of the thigh at the hip joint in the female group. Similar results were obtained by Bobowik et al. [3] finding significant differences in thigh rotation mobility at the hip joint according to sex and lower limb dominance presenting that in women here is a higher ER deficit (CERD).

The results obtained in our study indicate a significant influence of measurement position on the values of hip flexion range of motion. Significant differences were found in the values of passive flexion range of motion of the thigh between SuP and StP and SuP and Sp positions in both the female and male groups. The reason for the greater range of movement between the lying position and the standing and sitting positions may be due to the need to actively tone the postural muscles in the standing and sitting positions, compared to relaxing them in the lying position [7]. The increased posterior muscle chain tension required to maintain an upright posture, in elevated positions, may result in a reduced range of flexion of the thigh. In addition, the reduced active ROM in standing and sitting positions may be influenced by the fact that in these positions the movement is against the force of gravity, which is not observed in the final range of motion in the supine position. The gravitational component was already pointed out by Han et al. [11] when measuring hip rotation in three different positions. The influence of the starting position on the mobility range measurement values was also confirmed in the study by Bobowik et al. [3], who examined 40 healthy subjects and assessed the range of motion of the hip joint in three measurement positions: lying supine, lying forward, and sitting. The largest range of motion values were recorded in the supine position and the smallest in the prone position. The observed differences in hip flexor muscle force moments normalized to body weight between women and men are primarily due to higher body weight (77.49 ± 11.80 kg for men and 63.74 ± 7.82 kg for women) and the fact that women genetically have fewer muscle fibers and a smaller muscle cross-sectional area, which is also hormonally determined by testosterone [9], [12]. Normalizing muscle torque force moments to body weight allows its effect on performance to be reduced [1].

The results of our study also showed an interaction between measurement position and sex when assessing hip flexor strength. The highest strength values were shown by both men and women in the SP. In particular, differences were found between men's strength measured in the SP and their strength measured in the SuP ($p < 0.001$) and StP ($p < 0.001$) and women's isometric hip muscle strength measured in all measurement positions – SuP, StP and SP ($p < 0.001$). A likely reason for the ability to generate more force in the standing position may be that the subjects were able to push off the ground with the supporting limb resulting in a compound movement in a closed kinematic chain, which, results in tensing of the hip extensors and hip flexors of the (opposite) supporting limb, that may have provided greater pelvic stabilization and increased muscle tone in the trunk, creating better working conditions for the hip flexor muscles in the tested limb. The greater stability of the proximal muscle attachment provides the muscle with better conditions for generating force at the periphery [23]. Note that Kellis et al. [18] assessed the ratio of quadriceps thigh muscle strength to sciatic-shin muscle strength in three hip angle positions: 90° of flexion, 60° of flexion and 120° of flexion. They concluded that the starting position of the study had no significant effect on the ratio of lower leg extensors to knee flexors, although the force generated by the subjects was highest in the 60° hip flexion position.

In turn, Guex et al. [8] showed that the appropriate hip joint position in the assessment of isometric muscle strength of the quadriceps of the thigh in sprinters is the thigh flexed at the hip joint to 80°. The authors reasoned that it is more or less in this hip joint angle position that the muscles of the posterior group of the thigh are most often injured. The main flexors of the hip joint above a 70–80° angle of flexion are the muscles that rotate externally (iliopsoas muscle, posterior fibers of the gluteus medius muscle, sartorius, adductor longus muscle, adductor brevis muscle, pectineus, partly the adductor magnus muscle) and internally (tensor fasciae latae, anterior fibers of the gluteus medius muscle, partly the adductor magnus muscle) and bringing the hip joint to an intermediate position (rectus femoris). In our study, it was found that the asymmetric distribution of rotation in the range of motion can affect the strength of the hip flexors. To better illustrate this problem, the terminology proposed by Bobowik et al. [3] was adopted: individuals in the CERD (*coxal external rotation deficit* – IR prevalence) group showed significantly higher hip flexor isometric muscle strength moments than those in the CIRD group (*coxal internal rotation deficit* – predominance of external rotation). This is probably due to the greater involvement of the short hip flexor muscles and internal rotator muscles mentioned above in this movement.

5. Conclusions

The value of the peak muscle torque of the hip flexors was found to be significantly affected by the position of the test subject's body during measurement. The highest results were recorded in the standing position, which is probably due to the tension of the posterior muscle chain of the supporting limb.

The value of the hip flexion ROM range was also found to be significantly affected by the position of the subject's body during measurement, with the supine position found to be the one in which it was easiest to perform this movement. Moreover, sex was found to significantly influence the extent of passive flexion ROM of the thigh in the different measurement positions. Women achieved significantly higher values of passive flexion ROM, which is probably due to the tension of the connective tissue structures. The values of the muscle torque force moments of the flexors of the hip with some values of the range of motion of the thigh flexion are inversely correlated with each other, i.e., usually as the force increases, the range of motion decreases. The higher the value of the normalized flexor muscle force moments, the lower the hip flexion range of motion.

An imbalance in thigh rotation movement significantly determines the magnitude of muscle torque force moments of the hip flexion movement. Individuals with increased internal rotation in relation to external rotation achieved significantly higher values of flexor muscle torque force moments.

Overall, we conclude that, in both physiotherapeutic practice and in future research studies, any values measured for isometric hip muscle strength should be reported together with a clear indication of which testing position was used to take such measurements, and that care should be taken only to compare values measured in the same position (or to be mindful that potential differences may stem from the use of different measurement positions, and moreover that these potential differences may not be the same for men and women). Moreover, our findings urge greater recognition of the potential for asymmetry in thigh rotation movement to influence values measured for isometric hip muscle strength.

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