

Original Research

Position- and Sex-Related Differences in Sagittal and Frontal Plane Concentric Isokinetic Hip Muscle Peak Torques and Agonist-Antagonist Ratios

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Keywords: adult, hip, isokinetics, strength

<https://doi.org/10.26603/001c.124117>

International Journal of Sports Physical Therapy

Vol. 19, Issue 11, 2024

Background

Hip muscle weakness is associated with many musculoskeletal conditions and athletic injuries. Isokinetic testing is often performed to measure a patient's strength or to assess treatment response. Patient sex and positioning during isokinetic strength testing may influence peak torque production and the agonist-antagonist peak torque ratios. However, different test positions are used clinically and in research to measure hip muscle strength. It is unknown how patient test position or sex impacts test results.

Hypothesis/Purpose

The purpose of this study was to determine whether concentric isokinetic peak torques of sagittal and frontal plane hip muscles differ when tested in recumbent versus standing positions and if results were impacted by patient sex.

Study Design

Cross-sectional observational

Methods

Forty healthy adults (20 male, 20 female) participated. Concentric isokinetic hip torques of the hip flexors, extensors, abductors, and adductors were measured with participants in two positions (recumbent versus standing; 60°/second angular velocity). Peak torque values were normalized by body mass and height. Data were analyzed with mixed-model ANOVAs (sex x position). Effect sizes were examined using partial eta squared.

Results

No significant interactions or main effects for sex were found. Significant main effects for position were found for hip extensor and abductor peak torques and for hip flexor-extensor ratio. Hip extensor peak torque was greater when tested supine versus standing with a large effect size ($p=.02$, effect size $=.14$). Hip abductor peak torque was greater when tested sidelying versus standing with a medium effect size ($p=.03$, effect size $=.12$). Hip flexor-extensor agonist-antagonist ratio was greater when tested standing versus supine with a large effect size ($p<.001$, effect size $=.27$).

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Conclusion

Hip extensor and abductor concentric isokinetic peak torques were greater when tested in recumbent versus standing positions. In contrast, hip flexor-extensor ratio was greater when tested in standing versus supine.

Level of Evidence

3

INTRODUCTION

Adequate hip muscle strength is critical for proper function of the hip joint and performance of many activities of daily living and sport.¹ The hip muscles stabilize the pelvis on the lower extremity (LE) and provide forces for propulsion during activities including walking, running, vertical jumping, and landing from jumps.^{1,2} Hip muscle weakness is associated with many conditions affecting athletes including patellofemoral pain,^{3,4} iliotibial band syndrome,⁵ anterior cruciate ligament injury,^{6,7} femoroacetabular impingement,^{8,9} groin injury in sport,¹⁰ and low back pain.¹¹ Hip muscle weakness is also reported in patients with knee osteoarthritis,¹² and hip osteoarthritis.^{13,14}

The hip muscles that control the sagittal and frontal planes of motion are reported to be particularly important to function. The hip extensors (EXT) and hip abductors (ABD) generate large torques to propel the body forward and stabilize the pelvis on the LE.^{1,13} Female athletes with weakness of hip EXT and hip ABD were found to have excessive lumbopelvic motion and velocity during single-leg jump landing indicating possible risk for injury.² Reduced preseason hip ABD strength was a risk factor for noncontact anterior cruciate ligament injury in male and female collegiate athletes.⁷ Male athletes with hip EXT weakness had lower peak heights during vertical jump testing.¹⁵ Reduced hip adductor (ADD) strength is a risk factor for groin injury in sport.¹⁰ Since hip muscle weakness is a common impairment for many patients, it is important for clinicians to quantify hip muscle strength to determine if weakness is present and to assess response to treatment.

Altered ratios of hip agonist and antagonist muscle strength have also been reported to be factors associated with painful musculoskeletal conditions. Agonist-antagonist strength imbalances of hip muscles were found in injured athletes and reported to be a risk factor for injury.^{16,17} Reduced hip ADD strength relative to hip ABD strength is a risk factor for groin injury in sport.¹⁰ Eccentric hip ADD-ABD peak torque ratios were altered in females with patellofemoral pain such that hip ABD strength was reduced relative to hip ADD strength.¹⁶ Weakness of an agonist relative to its antagonist may result in reduced joint stability and aberrant movement, for example collapse into femoral adduction and knee valgus due to weakness of the hip ABD.¹⁸

Isokinetic dynamometry is used to measure muscle torque and is considered the “gold standard” for strength measurement.^{19,20} Peak isokinetic torque is often used as a measure of muscle strength to determine if weakness is present or to measure response to rehabilitation.^{6,21,22} Use of an instrumented dynamometer is particularly important

for hip muscle strength testing due to reported inaccuracy for hand-held dynamometry strength test results for large muscles.²³ Many factors may impact isokinetic strength test results including testing mode (concentric, eccentric, isometric), angular velocity, dynamometer lever arm alignment, participant positioning, and participant sex.^{22,24} An angular velocity of 60°/second for hip flexor (FLEX) and EXT peak torque assessment was reported to be commonly used and recommended as the most reliable testing velocity.^{22,24} Studies testing hip ABD and ADD strength were reported to use 60°/second or 30°/second.²⁴

Patient position during hip muscle isokinetic testing lacks consensus on the optimal position.^{22,25} Hip FLEX and EXT isokinetic testing were reported to be performed with the patient lying supine, standing, and in a forward bent semi-standing position.^{22,24} Hip ABD and ADD isokinetic testing has been performed in sidelying and standing positions.²⁴ Both recumbent and standing position tests are used clinically as well as in research.^{22,24-26} Alteration of body position during testing may alter results of peak hip torques due to altered muscle length and consequent altered muscle length-tension relationships.¹ In addition, stabilization of adjacent body regions may be altered in different testing positions. Proponents of standing test positions report this to be preferable since the upright posture more closely approximates trunk and LE position during walking, running, and other functional activities.²⁷ But other researchers and clinicians support a recumbent testing position since it may better stabilize non-tested body segments, enable the patient to exert greater peak torques, and reduce compensatory movement.²² To the authors' knowledge no study to date has directly compared the recumbent and standing positions for isokinetic peak torque of the hip FLEX, EXT, and ADD muscles. Only one recent study with healthy male adults has examined concentric and eccentric peak torques of the hip ABD tested in sidelying and standing positions and found no difference between positions.²⁸ No study to date has compared the agonist-antagonist peak torque ratios of the hip FLEX-EXT and hip ABD-ADD obtained in recumbent and standing positions. It is unknown how use of the recumbent compared to the standing position during testing will impact concentric isokinetic hip muscle peak torque as well as the agonist-antagonist ratios.²⁴ In addition, it is unknown if changes in body position will have the same impact on peak torques and agonist-antagonist ratios for males and females. Males have been reported to have greater isokinetic peak torque for some hip muscles than females, which may yield different agonist-antagonist torque ratios.²⁴ Thus, the purpose of this study was to determine whether concentric isokinetic peak torques of sagittal and frontal plane hip muscles

differ when tested in recumbent versus standing positions and if results were impacted by patient sex.

METHODS

STUDY DESIGN

This cross-sectional observational study was approved by the Institutional Review Board of Thomas Jefferson University and carried out according to the Declaration of Helsinki Code of Ethics. All participants were given written copies of the consent form and the opportunity to ask questions about the study procedures prior to giving their informed consent. The study was conducted in a research laboratory at Thomas Jefferson University between January 30, 2021 and November 4, 2022. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed in reporting the study findings.²⁹

PARTICIPANTS

Participants were recruited from Thomas Jefferson University and the surrounding community through flyers and word of mouth. Inclusion criteria included age 18–40 years and the ability to walk without an assistive device. Exclusion criteria included a history of hip arthroplasty, hip dislocation, or hip deformity; hip or knee joint surgery within the previous year; LE or low back pain rated 3 or greater on a numeric pain rating scale (0–10, 10 = worst pain); LE or low back pain or injury in the prior six months that limited function more than two days; fracture of the pelvis or LE bones within the previous year; any condition that might cause LE pain or muscle weakness (eg, rheumatoid arthritis); current known pregnancy due to possible difficulty stabilizing the pelvis during testing and to avoid any possible adverse effects from maximal muscle contractions; any condition that might make it unsafe for a person to exert maximal hip muscle force (eg, cardiac conditions); and body weight > 400 lbs due to weight limits of the instrumentation.

Demographic and anthropometric data were collected at the beginning of testing. Participants completed a questionnaire reporting demographics, relevant health history, hours of weekly physical activity, and LE dominance. Participant sex was determined from self-report. The LE used to kick a ball was defined as dominant.³⁰ The Tegner Activity Scale (TAS) was used to measure physical activity level.³¹ The TAS is reliable and valid for use with patients with LE musculoskeletal conditions.^{32,33} Participant height and weight were measured using a medical scale.

HIP MUSCLE STRENGTH

Isokinetic muscle strength of participants' dominant LE was measured using the Biodex System 4 Pro™ instrumented dynamometer (Biodex Medical Systems, Shirley, New York). Concentric-concentric peak torque of hip EXT, FLEX, ABD, ADD were assessed at 60°/second.²⁴ The cushion setting was "hard" as recommended during peak torque testing. The dynamometer was calibrated according to

manufacturer instructions prior to each participant's testing. Peak torques for agonists and antagonists were collected during the same test but when the hip was moving in opposite directions. Hip FLEX and EXT were tested in supine, as per the manufacturer's instructions, and also while standing on the non-tested LE. Hip ABD and ADD were tested in sidelying with the tested LE uppermost, per manufacturer's instructions, and also while standing on the non-tested LE. During hip FLEX-EXT testing, the dynamometer axis of rotation was aligned opposite the superior border of the patient's greater trochanter. During hip ABD-ADD testing, the dynamometer axis of rotation was positioned opposite the center of the tested LE buttock in the same transverse plane as the superior border of the greater trochanter. The dynamometer lever arm resistance pad was firmly attached to the participant's tested LE using rigid fabric straps with hook and loop connectors. The resistance attachment was positioned with its distal edge 1" proximal to the superior patella for FLEX-EXT tests and 1" proximal to the lateral femoral epicondyle for ABD-ADD testing. Participants were stabilized with rigid fabric straps placed over the pelvis, trunk, and non-tested LE during supine testing and over the pelvis during sidelying tests. Participants were stabilized during standing tests by grasping a stable support. Testing bench position, dynamometer platform position, height, tilt, rotation, and resistance attachment length were recorded. The distance from the center of the dynamometer axis of rotation to the center of the resistance attachment pad was measured and recorded as the lever arm length. The tested limb weight was measured according to the manufacturer's instructions. Gravity correction for mitigating the impact of limb weight on torque results was automatically applied in the data acquisition software. Testing order was randomized using a random sequence generator.

Participants performed a warm-up activity of ten repetitions of tested LE swings in hip FLEX-EXT and hip ABD-ADD. The participant was positioned either standing adjacent to the dynamometer head or lying on the dynamometer padded bench, dependent upon the randomly determined starting test. The dynamometer head, platform, and resistance lever arm were adjusted to properly align the dynamometer axis of rotation with the participant's tested hip axis of rotation at the superior border of the greater trochanter. The participant's tested LE was firmly attached to the resistance lever arm with rigid straps. Participants moved their LE through the tested motions of hip FLEX-EXT or hip ABD-ADD for several submaximal reciprocal practice trial repetitions to become familiarized with the motions and isokinetic resistance. Standardized scripts were used to instruct participants "to move (their) leg back and forth as hard as (they could), pushing against the machine." Following practice trials, participants performed five maximal reciprocal repetitions. Verbal encouragement was given during testing to encourage maximal muscle force in both directions. Participants were given 60 seconds to rest following each set of maximal repetitions. Three sets of five repetitions in each motion direction were recorded. Following completion of testing in one position,

the participant and dynamometer were moved to perform testing of the other motions and positions.

Eight participants (four male, four female) returned for a second test session within one month of the first testing session to assess intrarater test-retest reliability. The recorded settings for the dynamometer, bench, and resistance lever arm from the first session were used to position the instrumentation at the second session. Muscle group testing was performed in the same order as randomly determined for the first session. Intrarater test-retest reliability for normalized peak torque values was examined using intraclass correlation coefficients (3,k) ($ICC_{3,k}$). The $ICC_{3,k}$ results were as follows: FLEX (recumbent = .925, standing = .761), EXT (recumbent = .861, standing = .903), ABD (recumbent = .606, standing = .893), ADD (recumbent = .727, standing = .829). These were interpreted as moderate – excellent reliability with ratings of $ICC \leq .5$ = poor, $.5 < ICC \leq .75$ = moderate, $.75 < ICC \leq .9$ = good, and $ICC > .9$ = excellent reliability.³⁴

STUDY SIZE

An a priori power analysis was conducted using the software program G* Power version 3.1.9.2.³⁵ For a medium effect size of .50, $\alpha = .05$, and 80% power, 34 participants were necessary to find a significant difference. Forty participants were enrolled to ensure adequate sample size in case of participant drop-out or data loss.

STATISTICAL ANALYSIS

Descriptive statistics were calculated for demographic, physical activity, and anthropometric data including means and standard deviations (SD). Participant mean peak torques were calculated for each muscle group in both test positions. Mean peak torques were normalized according to body mass and height (Nm / kg * m) as recommended for hip muscle strength assessment.³⁶ Group mean (SD) normalized peak torques were calculated for the two tested positions in males and females. Mixed-model analyses of variance (ANOVA), 2-tailed (factors of sex and position) were used to examine normalized peak torque variables. Significant interactions were examined followed by simple main effects using a Bonferroni correction for multiple comparisons. Agonist-antagonist ratios were calculated from sagittal plane (hip FLEX-EXT) and frontal plane (hip ABD-ADD) muscle peak torques in recumbent and standing positions. Agonist-antagonist ratios were compared with mixed-model ANOVAs (sex x position), 2-tailed. Examination included significant interactions followed by planned post hoc comparisons for simple main effects with Bonferroni correction, when no interactions were significant. The significance level was set a priori at $p = .05$ for all comparisons. Effect sizes were examined using partial eta squared (η_p^2) with $\eta_p^2 < .01$ considered a negligible effect, $.01 \leq \eta_p^2 < .06$ a small effect, $.06 \leq \eta_p^2 < .14$ a medium effect, and $\eta_p^2 \geq .14$ a large effect size.³⁷ Statistical analyses were conducted using SPSS statistical software version 28 (SPSS Inc, Chicago, IL).

RESULTS

PARTICIPANT CHARACTERISTICS

Study participants included 20 males and 20 females. There were no significant differences between sexes for age, TAS, and reported hours of physical activity per week (Table 1). The males were significantly heavier, taller, and had a greater body mass index than females. All male participants were right LE dominant while 18 of the females were right LE dominant and two females were left LE dominant.

NORMALIZED MUSCLE TORQUE

No significant sex x position interactions were found for any normalized muscle group torques ($p > .05$) (Table 2). Planned post hoc comparisons for sex and position revealed no significant main effects for sex. Significant main effects for position were found for hip EXT and hip ABD normalized peak torques (Table 2). Hip EXT normalized peak torque was greater when tested in the recumbent position than in the standing position with a large effect size ($\eta_p^2 = .14$). Hip ABD normalized peak torque was also greater when participants were tested in the recumbent position compared to standing, with a medium effect size ($\eta_p^2 = .12$) (Table 2).

AGONIST-ANTAGONIST RATIOS

No significant sex x position interactions were found for any agonist-antagonist peak torque ratio. Planned post hoc comparisons revealed no significant main effects for sex. A significant main effect for position was found for hip FLEX-EXT ratio in which the ratio is greater when participants were tested in the standing position than in the recumbent position with a large effect size ($\eta_p^2 = .27$) (Table 3). That is, the hip FLEX peak torque was greater in relation to the hip EXT peak torque when tested with the participant standing compared to when participants were recumbent.

DISCUSSION

The primary aim of this study was to compare concentric isokinetic normalized peak torques of the hip FLEX, EXT, ABD, and ADD muscle groups when patients were tested in recumbent compared to standing positions, and to determine if any relationships were modified by sex. A secondary aim was to determine if the agonist-antagonist ratios were different according to testing position and sex. The study results showed that the normalized peak torques of the hip EXT and hip ABD were greater when patients were tested in recumbent positions compared to the standing position. In addition, the hip FLEX-EXT ratio was significantly greater when patients were tested in the standing position rather than while recumbent.

Previous studies examining isokinetic peak torques of hip muscles have used recumbent, standing, and semi-standing positions. It is acknowledged in the scientific literature that comparison of hip muscle peak torques ob-

Table 1. Demographic Characteristics

	Total Group (n = 40): Mean ± SD	Male (n = 20): Mean ± SD	Female (n = 20): Mean ± SD	Male: Female Comparison p value
Age, years	25.20 ± 2.30	25.75 ± 3.48	24.65 ± 2.39	0.252
Mass, kilograms	72.47 ± 11.96	80.84 ± 7.88	64.10 ± 9.17	<0.001*
Height, meters	1.71 ± 0.08	1.76 ± 0.07	1.67 ± 0.06	<0.001*
Body mass index	24.54 ± 2.67	26.05 ± 2.11	23.02 ± 2.31	<0.001*
Tegner Activity Scale, 0-10 (10 = most active)	5.43 ± 1.15	5.45 ± 1.15	5.40 ± 1.19	0.893
Physical activity, hours/week	8.65 ± 4.64	8.50 ± 4.76	8.80 ± 4.63	0.841

Values are presented as group mean ± standard deviation.

* Results in bold are significant, $p < 0.05$.

Abbreviations: SD, standard deviation; n, number.

Table 2. Normalized Concentric Isokinetic Peak Torque, Effect of Test Position and Participant Sex

	Normalized Muscle Torque (Nm / kg * m)		Mixed-Model ANOVA p values & Effect Sizes				
	Male: Mean ± SD (95% CI)	Female: Mean ± SD (95% CI)	Interaction (sex * position) p value	Main Effect of Position p value	Partial Eta Squared (position)	Main Effect of Sex p Value	Partial Eta Squared (sex)
Hip ABD Recumbent	1.03 ± 0.23 (0.93-1.13)	1.01 ± 0.22 (0.91-1.12)	0.26	0.03*	0.12	0.76	0.002
Hip ABD Standing	0.92 ± 0.18 (0.83-1.01)	0.98 ± 0.22 (0.88-1.07)					
Hip ADD Recumbent	0.73 ± 0.21 (0.61-0.84)	0.67 ± 0.30 (0.55-0.78)	0.78	0.05	0.1	0.33	0.03
Hip ADD Standing	0.66 ± 0.27 (0.53-0.78)	0.57 ± 0.28 (0.45-0.70)					
Hip FLEX Recumbent	1.00 ± 0.22 (0.92-1.09)	0.90 ± 0.16 (0.81-0.98)	0.2	0.17	0.05	0.23	0.04
Hip FLEX Standing	1.01 ± 0.16 (0.92-1.10)	0.99 ± 0.23 (0.90-1.08)					
Hip EXT Recumbent	1.06 ± 0.33 (0.91-1.20)	1.04 ± 0.32 (0.89-1.19)	0.37	0.02*	0.14	0.65	0.006
Hip EXT Standing	0.85 ± 0.32 (0.69-1.01)	0.94 ± 0.37 (0.79-1.10)					

Values are presented as mean ± standard deviation and (95% confidence interval).

* Bold results are significant, $p < 0.05$.

Abbreviations: SD, standard deviation; ANOVA, analysis of variance; Nm/kg*m, newton-meters normalized by weight in kilograms and height in meters; CI, Confidence interval; ABD, Abductors; ADD, Adductors; FLEX, Flexors; EXT, Extensors.

tained in one position should not be directly compared to results obtained in a different position.²⁴ Despite this, only one study to date has directly compared results of hip isokinetic peak ABD torque obtained with patients standing compared to in a recumbent position.²⁸ Isokinetic hip ABD peak torques of healthy adult males were found to be no different when tested with concentric-eccentric ABD resistance in standing and sidelying positions (median concentric peak torque = 2.1 Nm/kg standing and 2.0 Nm/kg sidelying).²⁸ This is in contrast to the current study results in which concentric isokinetic hip ABD peak torque results were significantly greater when healthy males and females were tested in sidelying compared to standing (Table 2).

Differences in study results may be due to the different isokinetic resistance modes used. In the current study, participants were tested in the concentric-concentric mode of reciprocal resistance to hip ABD and ADD rather than resistance to only the hip ABD using concentric-eccentric resistance. It may be that alternating resistance to agonist and antagonist muscle groups was more challenging to participants while they were required to be in single-leg standing on the non-tested LE, thus yielding lower ABD peak torques in that position.

No previous studies have examined how isokinetic peak torque test results obtained with participants recumbent compared to in standing test positions for hip ADD, FLEX,

Table 3. Concentric Isokinetic Peak Torque Agonist-Antagonist Ratios, Effect of Test Position and Participant Sex

	Agonist-Antagonist Ratios, Muscle Torque		Mixed-Model ANOVA <i>p</i> values & Effect Sizes				
	Male Mean $\pm$ SD (95% CI)	Female Mean $\pm$ SD (95% CI)	Interaction (sex * position) <i>p</i> value	Main Effect of Position <i>p</i> value	Partial Eta Squared (position)	Main Effect of Sex <i>p</i> value	Partial Eta Squared (sex)
Hip ABD/Hip ADD, Recumbent	1.47 $\pm$ 0.29 (1.13-1.81)	1.87 $\pm$ 1.02 (1.53-2.21)	0.84	0.22	0.04	0.08	0.08
Hip ABD/Hip ADD, Standing	1.65 $\pm$ 0.75 (1.28-2.01)	2.00 $\pm$ 0.85 (1.64-2.37)					
Hip FLEX/EXT, Recumbent	1.00 $\pm$ 0.25 (0.89-1.12)	0.93 $\pm$ 0.26 (0.81-1.04)	0.45	<0.001*	0.27	0.19	0.05
Hip FLEX/EXT, Standing	1.36 $\pm$ 0.61 (1.13-1.60)	1.17 $\pm$ 0.42 (0.93-1.40)					

Values are presented as mean $\pm$ standard deviation and (95% confidence interval).

* Bold results are significant, *p* <0.05.

Abbreviations: SD, standard deviation; ANOVA, analysis of variance; CI, Confidence interval; ABD, Abductors; ADD, Adductors; FLEX, Flexors; EXT, Extensors.

or EXT. The results of the current study indicate that concentric isokinetic hip EXT peak torques obtained with patients in supine were greater than those obtained when patients were standing. This finding supports previous recommendations to avoid comparison of hip muscle isokinetic strength tests performed with different test positions.²⁴

The current study did not find a significant main effect for sex for any of the normalized muscle group torques. This differs from previous studies for the hip FLEX, EXT, and ABD muscle groups. Borges et al.³⁸ found that young males had significantly greater absolute concentric peak torque of the hip FLEX and hip EXT than young females when tested in standing at 60°/second (mean [SD]: FLEX male = 161.9 [30.0] Nm; FLEX female = 94.7 [15.8] Nm; EXT male = 155.0 [40.0] Nm; EXT female = 83.6 [30.5] Nm). Sugimoto et al.³⁹ found that young males had significantly greater body weight-normalized concentric hip ABD than young females tested in standing at 60°/second (mean [SD]: ABD male = 1.29 [0.24] Nm/kg; ABD female = 1.13 [0.20] Nm/kg). However, hip ADD body weight-normalized concentric torque was no different between sexes, which is in agreement with the results of the current study (standing position, 60°/second, mean [SD]: ADD male = 0.75 [0.32] Nm/kg ADD female = 0.72 [0.27] Nm/kg).³⁹ Differences between the findings of the current study and earlier studies may be due to different methods for analysis of muscle torque. Previous studies either did not normalize peak torque or normalized torque using body weight only.^{38,39} The current study normalized peak torque by body mass and height, as recommended for hip muscles.³⁶ Differences between study findings may also be due to differing physical activity level of participants.

A significant difference between the hip FLEX-EXT ratio for results determined from supine and standing test posi-

tions was an additional finding of this study. The FLEX-EXT ratio in standing (male FLEX = 136% of EXT, female FLEX = 117% of EXT) was greater than in supine (male FLEX = 100% of EXT, female FLEX = 93% of EXT) tests since the peak torque of hip FLEX was greater relative to the hip EXT in the standing test. The difference between these ratios was likely as a result of greater hip EXT peak torque in supine compared to the standing position in our participants. The hip FLEX-EXT ratios from the current study are different from a study that examined this ratio in a sample of male and female CrossFit participants who were tested in supine.¹⁹ The study by Rodrigues, et al.¹⁹ found that hip FLEX torques were much lower compared to hip EXT torques (male FLEX = 67.24% of EXT, female FLEX = 62.39% of EXT). The dissimilar findings may be due to differences in physical activity level, overall strength, and regular exercise regimens of participants in the two studies.

One interesting finding from this study was that isokinetic testing position seemed to have a particular impact on the hip EXT and ABD muscles. Weakness of these muscle groups has been found to be associated with or a risk factor for a variety of musculoskeletal conditions including patellofemoral pain,³ anterior cruciate ligament injury,⁷ femoroacetabular impingement,⁹ and iliotibial band syndrome.⁵ It may be that adequate strength of the hip EXT and ABD muscles is particularly critical for athletes due to their important role in stabilization of the pelvis on the LE.¹

LIMITATIONS

This study has some limitations that must be acknowledged. The participants were all young, healthy adults so generalization of study findings to persons with pathologies or of different age ranges should be cautioned. Only the dominant LE was examined so there are no results for

the non-dominant LEs. But previous authors have shown that there is no significant impact of LE dominance on concentric isokinetic hip muscle strength in healthy adults.⁴⁰ Participants may not have given maximal effort during all tests, but consistent, scripted directions and verbal encouragement were given to encourage maximal effort throughout testing. Activation of tested muscle groups is unknown since electromyography was not used. Therefore, participants may have used complementary muscles to increase torque, which may vary depending upon test positions. There may have been a learning effect with repetitions of test movements, but attempts were made to minimize this through use of practice trials prior to recorded trials. Examiners were not blinded to torque values during testing, although participants were blinded to torque values. This study did not include examination of the hip internal and external rotator muscle groups, which should be considered for future research.

CONCLUSION

Concentric isokinetic peak torque test results for the sagittal and frontal plane hip muscles were different when tested with participants in recumbent compared to standing positions. Normalized hip EXT and hip ABD peak torques were greater when tested in recumbent positions.

The agonist-antagonist ratio of hip FLEX-EXT was greater when tested in standing. There were no differences between test position results for hip FLEX and hip ADD. There were also no differences between sexes for body-mass-and-height-normalized peak torques for any sagittal or frontal plane muscle group. This information will be useful to clinicians when comparing their patients' concentric isokinetic test results to normative data, taking the test position into consideration. Since many athletic injuries and conditions are associated with weakness of the hip EXT and hip ABD, this information will be particularly relevant to clinicians treating athletes. Future studies should be conducted to determine if these relationships are present in patients with pathologies or sports injuries.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

Submitted: April 02, 2024 CST, Accepted: September 09, 2024 CST

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