

Original Research

A Novel Way of Testing Hip Extension and Flexion Strength, and Strength Ratio in the Clinical Setting: Is it Reliable?

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Background

Hip muscle strength is considered an important parameter to assess in patients with hip and groin pain. However, hip extension and flexion strength measures are often performed in hip angles suboptimal for force production and do not allow for calculating meaningful strength ratios.

Purpose

The objective was to evaluate the test-retest reliability of testing maximal isometric strength in extension and flexion in a semi-standing position with 60° hip flexion.

Study Design

Observational reliability study

Methods

Thirty healthy subjects (mean age 27 (SD 7), 43% women) were recruited. An anchored dynamometer was used to measure maximal isometric force production in hip extension and flexion in a semi-standing position with the hip at 60° flexion. One tester performed the tests on two separate occasions. For relative reliability, intraclass correlation (ICC2,1, (Two-way mixed effects, single measurement, absolute agreement) was used. For absolute reliability, standard error of measurement (SEM%), and minimal detectable change at both group (MDC%group), and individual level (MDC%ind) was used.

Results

No statistically significant differences between test sessions were observed ($p \geq 0.193$). The results showed good to excellent relative reliability for extension (ICC 0.933) and flexion (ICC 0.884) and moderate relative reliability for strength ratio (ICC 0.694). For absolute reliability SEM% for extension was 8.2%, flexion 9.1%, and strength ratio 10.6%, MDC%group ranged from 4.2% to 5.6%, and MDC%ind ranged from 22.6% to 29.5%.

Conclusion

Assessing isometric hip extension and flexion strength with the hip at 60° flexion in a semi-standing position demonstrated good intra-tester reliability in healthy young adults. The method appears suitable for detecting changes at the group level, while the relatively large individual-level variability should be considered when interpreting changes over time in individual subjects.

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Level of Evidence

3

INTRODUCTION

Muscle strength is considered an important functional parameter to assess in patients with musculoskeletal injuries and pain, and hip muscle strength is frequently impaired in individuals with hip and groin pain.^{1,2} Reduced strength has also been associated with greater symptom severity, functional limitations, and poorer quality of life in this population.³⁻⁷ Furthermore, less hip muscle strength may alter movement patterns and contribute to suboptimal loading of hip joint tissues, potentially exacerbating joint pathology, such as osteoarthritis, over time.⁸ For these reasons, accurate and reliable assessment of hip strength is of clinical importance.

According to a recent systematic review with meta-analysis of 107 studies, isometric strength testing using an anchored portable dynamometer is considered a reliable method for assessing hip muscle function.⁹ This method is also accessible in a clinical setting and more cost-effective compared to strength assessment using an isokinetic dynamometer. However, strength assessments should ideally allow for evaluation of both agonist and antagonist muscles within the same joint position, in order to generate consistent agonist-to-antagonist strength ratios. While this is routinely achieved for isometric strength testing in hip adduction and abduction, where both directions are assessed in a neutral hip position, flexion and extension are often tested in different joint positions.¹⁰⁻¹⁴ Hip extension is typically assessed in a neutral position (zero degrees of flexion),¹⁰⁻¹⁴ whereas hip flexion is measured at 45°¹¹ or 90°¹⁰⁻¹⁴ of hip flexion. The different joint positions hinder the calculation of useful flexion-to-extension strength ratios and, therefore, limits their clinical interpretability. In addition, the positions commonly used for flexion and extension strength testing may not represent the most favorable position for force production, according to principles of muscle length-tension relationships and internal moment arms.¹⁵ Also, testing hip flexion strength at 90° flexion may be poorly tolerated by patients with hip pathology, such as femoroacetabular impingement, who often experience pain or restricted motion in flexion end-range.^{1,2} Thus, there is a need for alternative testing positions that are both reliable and feasible while also enabling comparable measurements across muscle groups.

Assessing both hip extension and flexion at 60° of hip flexion in a semi-standing position may address these limitations. This position provides a more mid-range joint angle, potentially facilitating greater force production while also reducing discomfort associated with end-range positions. Biomechanical studies have demonstrated that the function of the psoas major is angle-dependent, transitioning from a predominantly stabilizing role at lower flexion angles to a more effective hip flexor at approximately 45–60° of hip flexion.¹⁶ Furthermore, a recent systematic review reported greater iliopsoas activation during rehabilitation exercises performed within the 30–60° hip flexion

range.¹⁷ Together, these findings suggest that testing at 60° of hip flexion may provide a more favorable position for assessing hip flexor force-generating capacity compared with more extended or end-range flexed positions. By standardizing the angle for both movements, this approach also enables flexion-to-extension strength ratios to be derived within the same joint position.

Therefore, the objective was to evaluate the test-retest reliability of testing maximal isometric strength in extension and flexion in a semi-standing position with 60° hip flexion. It was hypothesized that the method would demonstrate good reliability.

METHODS

STUDY DESIGN AND ETHICS

The reporting of this reliability study corresponds to the Guidelines for reporting reliability and agreement studies (GRAAS).¹⁸ The Swedish Ethical Review Authority (Dnr: 2022-05023-01) approved the study and the participants signed an informed consent form prior to data collection.

PARTICIPANTS

By convenience sampling, participants were recruited from students and personnel at the Faculty of Medicine at Lund University, Lund, Sweden. The participants had to be injury- and pain-free at the time of testing. The target in the present study was to recruit 30 participants. The target sample size of 30 participants was based on feasibility and previous reliability studies using similar methodologies.¹⁰⁻¹⁴ No formal precision-based sample size calculation was performed, which should be considered when interpreting the width of the confidence intervals.

TESTER

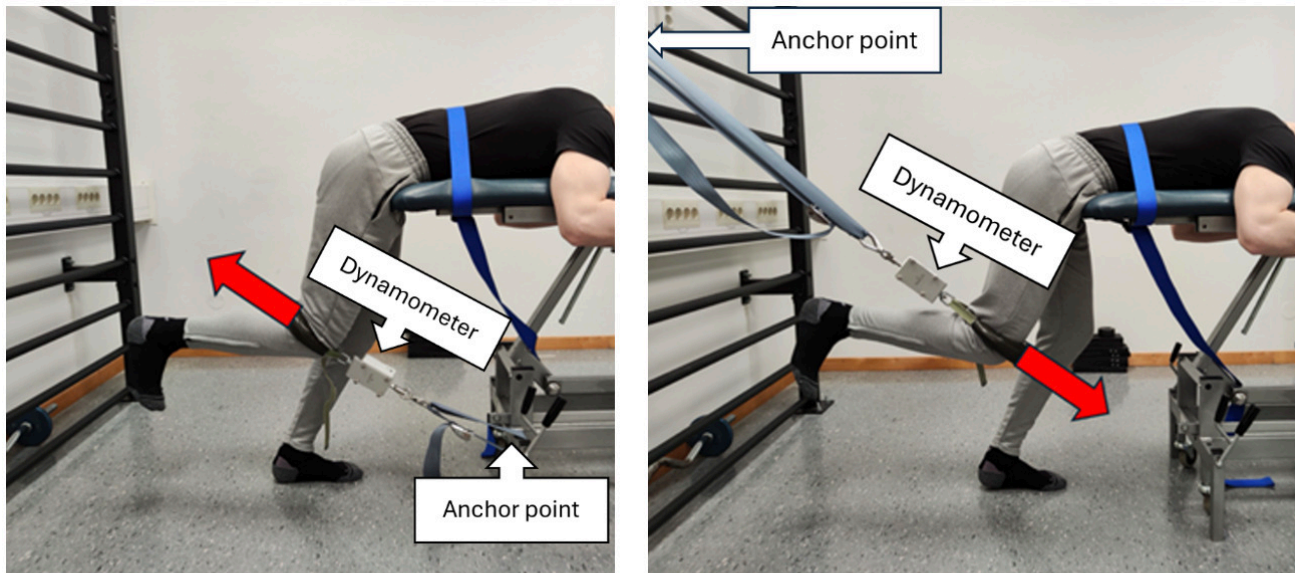
The test leader (AP) is a physiotherapist with 5+ years of experience in strength testing in clinical and research settings. Prior to the data collection, pilot testing on three subjects was conducted.

DATA COLLECTION

ISOMETRIC STRENGTH MEASUREMENT

The participants were asked not to do any high intensity training the day before the tests to avoid fatigue or potential muscle soreness. Isometric hip muscle strength was measured with an anchored dynamometer (Mark-10 Series 3, Mark-10 Corporation, Copiague, New York, USA).

The participants were tested in prone with their upper bodies on a testing table. The height of the table was adjusted to the level of the greater trochanter of the participant. A strap, positioned at the level of the iliac crest, stabilized the trunk and secured them to the table. The tested



A

B

Figure 1. Testing position for isometric hip extension (A) and flexion (B)

leg was positioned at a hip angle of 60° (measured with a goniometer), and the knee flexed to 90° (visual estimation). The foot on the non-tested side was in contact with the floor, ensuring stability. This setup was designed to fixate the testing position and, ensure that the force exerted was purely isometric, thus meaning no movement of the limb was possible. All measurements were performed on the right leg to ensure consistency across participants

During isometric extension, the dynamometer was anchored at the base of the table, and the participant applied force against a cushioned strap (width 3 cm) positioned at the popliteal space ([Figure 1A](#)).

During isometric flexion, the dynamometer was anchored at the wall, and the participant applied force against a cushioned strap (width 3 cm) positioned directly proximal to the patella (the edge of the strap in contact with the proximal part of the patella) ([Figure 1B](#)). The line of force was perpendicular to the thigh in both extension and flexion.

Prior to data collection, the participants performed one to three submaximal contractions for familiarization. The participants performed a maximal contraction for 5 seconds under standardized strong verbal encouragement, and the peak force was recorded. The maximal peak force from the three attempts was used as the primary outcome, as maximal force output is commonly used in clinical strength assessment and was considered most representative of clinical practice. Three maximal attempts were performed with a 20-second rest period between each attempt and a two-minute rest period between testing directions. The test was repeated with the same tester after 48-72 hours for each participant. The result from the initial test was not available for the tester during the re-test.

STATISTICS

Strength measurements were expressed in Newtons (N), except in patient characteristics where the strength was normalized by thigh length (m) and bodyweight (kg) (Nm/kg). Strength ratios are presented in percent (%) calculated using the formula: (extension strength (N) / flexion strength (N))*100. For relative reliability, intraclass correlation coefficients (ICC_{2,1}) based on a two-way mixed-effects absolute agreement model were used with corresponding 95% confidence intervals. The same tester performed all measurements and was therefore considered a fixed effect. An absolute agreement model was selected because it accounts for both random measurement error and potential systematic differences between test sessions.¹⁹ The ICC values were interpreted as excellent (>0.90), good (0.76–0.90), moderate (0.50–0.75), and poor (lower than 0.50).¹⁹ For absolute reliability, standard error of measurement (SEM), SEM%, and minimal detectable change at both group (MDC%_{group}), and individual level (MDC%_{ind}) was used. Homogeneity of variance between test sessions was assessed using Levene's test, indicating no significant difference in variance ($p \geq 0.412$), supporting the assumption of equal variance. Therefore, the SEM and SEM% were determined using the following calculations: $SEM = SD_{pooled} * \sqrt{(1-ICC)}$ and $SEM\% = (SEM/mean_{pooled}) * 100$.^{20,21} MDC%_{group} and MDC%_{ind} were determined using the following calculations: $MDC\%_{ind} = SEM\% * 1.96 * \sqrt{2}$, and $MDC\%_{group} = (SEM\% * 1.96 * \sqrt{2}) / \sqrt{n}$.^{21,22} Systematic bias was analyzed with paired t-test. Bland–Altman plots with 95% limits of agreement are presented with the mean score and the difference between measurements. Proportional bias was assessed by linear regression analysis between the mean and difference scores in the Bland–Altman analysis.

Table 1. Participant characteristics and hip muscle strength in flexion and extension expressed in Newton-metre per kilogram bodyweight (Nm/kgBw) for men and women, n=30.

Sex, n (%) women	13 (43)
Age, mean (SD)	27 (7)
BMI, mean (SD)	23.61 (2.37)
Extension strength for men, mean Nm/kgBw (SD)	4.18 (0.86)
Extension strength for women, mean Nm/kgBw (SD)	3.15 (0.60)
Flexion strength for men, mean Nm/kgBw (SD)	3.52 (0.48)
Flexion strength for women, mean Nm/kgBw (SD)	2.72 (0.53)

RESULTS

Thirty participants with mean age 27 (SD 7) and 43% women were recruited. Due to technical issues one participant had missing data on isometric extension at test session 2 and one participant had missing data on isometric flexion at test session 1. Participant characteristics and hip muscle strength in flexion and extension for men and women respectively are presented in [Table 1](#).

No statistically significant differences between test sessions were observed ($p \geq 0.193$). However, mean values were consistently slightly higher during the second test session, which may indicate a small familiarization or learning effect. However, no significant proportional bias was observed for extension or flexion ($p=0.177$ and $p=0.613$ respectively). Relative reliability for extension was excellent (ICC 0.932), good for flexion (ICC 0.884) and moderate for strength ratio (ICC 0.694). For absolute reliability, SEM% was 8.2% for extension, 9.1% for flexion, and 10.6% for strength ratio. MDC%_{group} was 4.2% for extension, 4.7% for flexion, and 5.6% for strength ratio. MDC%_{ind} was 22.6% for extension, 25.2% for flexion, and 29.5% for strength ratio ([Table 2](#), [Figure 2](#)).

DISCUSSION

The findings of the present study demonstrate that assessing maximal isometric hip strength of both extension and flexion at 60° of hip flexion in a semi-standing position resulted in good to excellent relative test-retest reliability for extension and flexion strength, while the strength ratio demonstrated only moderate reliability. By assessing both movements within the same joint position, the protocol provides a standardized approach for evaluating hip flexion and extension strength under comparable biomechanical conditions.

The relative reliability observed for extension and flexion (ICC 0.88–0.93 and SEM% 8.2–9.1%) is largely in line with previous studies investigating isometric hip strength testing using anchored handheld dynamometry in other testing positions.^{10–14} However, the strength ratio demonstrated lower reliability (ICC 0.694), and the corresponding confidence interval was relatively wide (95% CI 0.439–0.846), including values consistent with both poor and good reliability. These findings indicate considerable

uncertainty in the precision of the estimate and suggest that the strength ratio should be interpreted cautiously, particularly until replicated in larger samples.

Although no statistically significant differences between test sessions were observed, all outcomes demonstrated slightly higher mean values during the second test session. This consistent directional change may indicate a familiarization or learning effect. Given the relatively limited sample size, the study may not have been sufficiently powered to detect small systematic between-session differences, and the absence of statistically significant differences should therefore be interpreted cautiously rather than as definitive evidence of absence of systematic bias.

The Bland–Altman analysis further contributes to the interpretation of the findings by illustrating the variability between sessions at the individual level. Although no significant proportional bias was observed in the regression analysis, the limits of agreement demonstrated relatively large between-session variability, which is consistent with the observed MDC values. This variability was particularly evident for the strength ratio and indicates that substantial changes may be required before a true change can be distinguished from measurement error in individual subjects.

The relatively large MDC values at the individual level (22.6–29.5%) suggest that the protocol is more suitable for detecting changes at the group level than for monitoring smaller longitudinal changes in individual subjects. While similar MDC values have previously been reported for isometric hip strength testing,^{11,12,14} these findings remain clinically important, as changes below approximately 25% may not confidently represent true change beyond measurement error.

Several factors may have contributed to the between-session variability observed in the present study. In addition to normal day-to-day variation in maximal force production, small differences in positioning and standardization of the 60° hip flexion angle between sessions may have influenced the results. Furthermore, although familiarization trials were performed, the relatively short 20-second rest interval between maximal contractions and the 48–72-hour interval between sessions may potentially have contributed to fatigue or learning effects. However, only five-second maximal contractions were performed, and no clear evidence of proportional bias was observed.

Table 2. Test-retest reliability intraclass coefficient mean (ICC_{2,1}), SEM, SEM%, MDC%ind, and MDC%group.

Maximal isometric force output	Test 1 Mean (SD) (n=29)	Test 2 Mean (SD)	Diff. test 1-test 2 Mean (SD)	Paired-t-test p-value	ICC (95%CI)	SEM	SEM%	MDC% _{ind}	MDC% _{group}
Extension (N) (n=29)*	587.9 (177.7)	605.1 (198.4)	-17.2 (69.3)	0.193	0.932 (0.861; 0.967)	48.3	8.2	22.6	4.2
Flexion (N) (n=29)**	494.8 (132.8)	508.2 (136.7)	-12.5 (65.5)	0.314	0.884 (0.769; 0.943)	45.6	9.1	25.2	4.7
Strength ratio (%) ((extension/flexion))*100 (n=28)***	121 (26)	119 (21)	0.02 (19)	0.594	0.694 (0.439; 0.846)	13	10.6	29.5	5.6

*=Due to technical issues one participant had missing data on isometric extension at test session 2

**=Due to technical issues one participant had missing data on isometric flexion at test session 1.

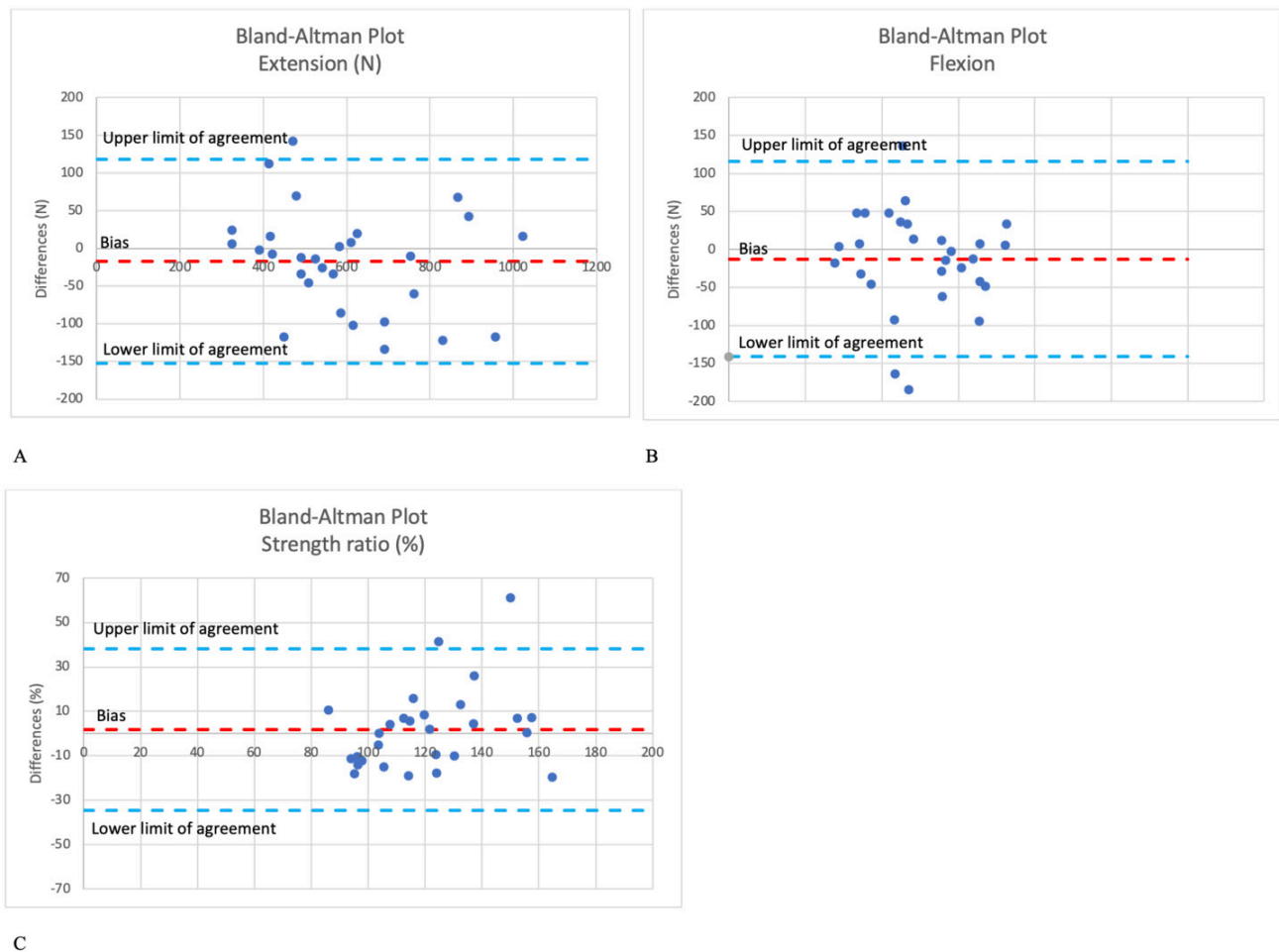


Figure 2. Bland-altman plot for test-retest with 95% limit of agreement and bias in extension (A), flexion (B), and strength ratio (C).

From a biomechanical perspective, testing hip extension and flexion at 60° of hip flexion may represent a favorable mid-range testing position. Previous biomechanical studies have demonstrated angle-dependent function of the psoas major and increased iliopsoas activation within the 30–60° range of hip flexion.^{16,17} In addition, Bazett-Jones et al. reported greater hip extension force production in flexed hip positions compared with neutral position.²³ Nevertheless, the present study did not directly compare force production between different hip positions, and conclusions regarding superiority of this position should therefore be interpreted cautiously.

The present study introduces a standardized protocol for assessing hip flexion and extension strength within the same joint position, which may help overcome some limitations associated with traditional testing protocols where flexion and extension are assessed at different joint angles. However, further studies are needed to evaluate responsiveness, inter-tester reliability, validity against reference methods, and applicability in clinical populations with hip-related pain.

LIMITATIONS

Several limitations should be considered when interpreting these findings. First, the study included a relatively small and homogenous sample of healthy young adults, which limits the generalizability of the results to clinical populations such as patients with hip pathology or older adults. Second, only one tester conducted all measurements, preventing conclusions about inter-tester reliability. This may restrict the applicability of the findings in settings where multiple clinicians are involved in testing. Third, the study did not assess the responsiveness of the method to changes over time, for instance following rehabilitation or training interventions, which is a key property for outcome measures in clinical practice. Finally, as with all isometric testing protocols, the external validity in relation to dynamic functional activities remains uncertain.

CONCLUSION

The results of this study demonstrate that assessing isometric hip extension and flexion strength with the hip at 60° flexion in a semi-standing position has good test-retest reliability in healthy young adults. In addition, the protocol enables assessment of extension-to-flexion strength ratio

within the same joint position, although the reliability of the strength ratio should be interpreted cautiously due to wider confidence intervals and greater individual-level variability. The method appears suitable for detecting changes at the group level, while variability at the individual level should be considered when interpreting longitudinal changes over time.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no competing interests.

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REFERENCES

1. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. *Br J Sports Med.* 2015;49(4):230-242. doi:[10.1136/bjsports-2013-093340](https://doi.org/10.1136/bjsports-2013-093340)
2. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med.* 2016;50(19):1180. doi:[10.1136/bjsports-2016-096152](https://doi.org/10.1136/bjsports-2016-096152)
3. Freke M, Kemp J, Crossley K, Sims K, Russell T, Semciw A. Strength and range of movement deficits are associated with symptom severity in people scheduled for hip arthroscopy. *Eur J Pain.* 2019;23(6):1083-1090. doi:[10.1002/ejp.1371](https://doi.org/10.1002/ejp.1371)
4. Gomes D, Ribeiro DC, Canella RP, et al. Association between severity of hip chondrolabral injuries, dynamic hip muscle strength and quality of life: A cross-sectional study in patients with femoroacetabular impingement syndrome scheduled for hip arthroscopy. *Clin Biomech.* 2021;84:105348. doi:[10.1016/j.clinbiomech.2021.105348](https://doi.org/10.1016/j.clinbiomech.2021.105348)
5. Kemp JL, Makdissi M, Schache AG, Finch CF, Pritchard MG, Crossley KM. Is quality of life following hip arthroscopy in patients with chondrolabral pathology associated with impairments in hip strength or range of motion? *Knee Surg Sports Traumatol Arthrosc.* 2016;24(12):3955-3961. doi:[10.1007/s00167-015-3679-4](https://doi.org/10.1007/s00167-015-3679-4)
6. Kierkegaard S, Mechlenburg I, Lund B, Soballe K, Dalgas U. Impaired hip muscle strength in patients with femoroacetabular impingement syndrome. *J Sci Med Sport.* 2017;20(12):1062-1067. doi:[10.1016/j.jsams.2017.05.008](https://doi.org/10.1016/j.jsams.2017.05.008)
7. Palsen A, Nae JA. The association between hip adductor and extensor strength, and hip-related patient-reported outcomes in patients with longstanding hip and groin pain: An exploratory cross-sectional study. *Phys Ther Sport.* 2024;70:61-66. doi:[10.1016/j.ptsp.2024.09.002](https://doi.org/10.1016/j.ptsp.2024.09.002)
8. Retchford TH, Crossley KM, Grimaldi A, Kemp JL, Cowan SM. Can local muscles augment stability in the hip? A narrative literature review. *J Musculoskelet Neuronal Interact.* 2013;13(1):1-12.
9. Waiteman MC, Garcia MC, Briani RV, et al. Can clinicians trust objective measures of hip muscle strength from portable dynamometers? A systematic review with meta-analysis and evidence gap map of 107 studies of reliability and criterion validity using the COSMIN methodology. *J Orthop Sports Phys Ther.* 2023;53(11):655-672. doi:[10.2519/jospt.2023.12045](https://doi.org/10.2519/jospt.2023.12045)
10. Florencio LL, Martins J, da Silva MRB, da Silva JR, Bellizzi GL, Bevilacqua-Grossi D. Knee and hip strength measurements obtained by a hand-held dynamometer stabilized by a belt and an examiner demonstrate parallel reliability but not agreement. *Phys Ther Sport.* 2019;38:115-122. doi:[10.1016/j.ptsp.2019.04.011](https://doi.org/10.1016/j.ptsp.2019.04.011)
11. Goncalves BAM, Saxby DJ, Kositsky A, Barrett RS, Diamond LE. Reliability of hip muscle strength measured in principal and intermediate planes of movement. *PeerJ.* 2021;9:e11521. doi:[10.7717/peerj.11521](https://doi.org/10.7717/peerj.11521)
12. Ishoi L, Holmich P, Thorborg K. Measures of hip muscle strength and rate of force development using a fixated handheld dynamometer: Intra-tester intra-day reliability of a clinical set-up. *Int J Sports Phys Ther.* 2019;14(5):715-723. doi:[10.26603/ijsp.20190715](https://doi.org/10.26603/ijsp.20190715)
13. Scott DA, Bond EQ, Sisto SA, Nadler SF. The intra- and interrater reliability of hip muscle strength assessments using a handheld versus a portable dynamometer anchoring station. *Arch Phys Med Rehabil.* 2004;85(4):598-603. doi:[10.1016/j.apmr.2003.07.013](https://doi.org/10.1016/j.apmr.2003.07.013)
14. Thorborg K, Bandholm T, Holmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(3):550-555. doi:[10.1007/s00167-012-2115-2](https://doi.org/10.1007/s00167-012-2115-2)
15. Neumann DA. Kinesiology of the hip: a focus on muscular actions. *J Orthop Sports Phys Ther.* 2010;40(2):82-94. doi:[10.2519/jospt.2010.3025](https://doi.org/10.2519/jospt.2010.3025)
16. Yoshio M, Murakami G, Sato T, Sato S, Noriyasu S. The function of the psoas major muscle: passive kinetics and morphological studies using donated cadavers. *J Orthop Sci.* 2002;7(2):199-207. doi:[10.1007/s007760200034](https://doi.org/10.1007/s007760200034)
17. Juan J, Leff G, Kevorkian K, Jeanfavre M. Hip Flexor Muscle Activation During Common Rehabilitation and Strength Exercises. *J Clin Med.* 2024;13(21). doi:[10.3390/jcm13216617](https://doi.org/10.3390/jcm13216617)

18. Kottner J, Audige L, Brorson S, et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. *Int J Nurs Stud*. 2011;48(6):661-671. doi:[10.1016/j.ijnurstu.2011.01.016](https://doi.org/10.1016/j.ijnurstu.2011.01.016)
19. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med*. 2016;15(2):155-163. doi:[10.1016/j.jcm.2016.02.012](https://doi.org/10.1016/j.jcm.2016.02.012)
20. Lexell JE, Downham DY. How to assess the reliability of measurements in rehabilitation. *Am J Phys Med Rehabil*. 2005;84(9):719-723. doi:[10.1097/01.phm.0000176452.17771.20](https://doi.org/10.1097/01.phm.0000176452.17771.20)
21. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res*. 2005;19(1):231-240. doi:[10.1519/15184.1](https://doi.org/10.1519/15184.1)
22. de Vet HC, Bouter LM, Bezemer PD, Beurskens AJ. Reproducibility and responsiveness of evaluative outcome measures. Theoretical considerations illustrated by an empirical example. *Int J Technol Assess Health Care*. 2001;17(4):479-487. doi:[10.1017/S0266462301107038](https://doi.org/10.1017/S0266462301107038)
23. Bazett-Jones DM, Tylinksi T, Krstic J, Stromquist A, Sparks J. Peak hip muscle torque measurements are influenced by sagittal plane hip position. *Int J Sports Phys Ther*. 2017;12(4):535-542.