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Concurrent Criterion-Related Validity and Reliability of a Clinical Test to Measure Femoral Anteversion

Femoral anteversion is the term used to describe the relative rotation (twist) that exists between the shaft and neck of the femur.[13] At birth, the angle of femoral anteversion averages greater than 30°. Throughout development, however, femoral anteversion decreases, averaging approximately 15° by adulthood.[4] It is generally accepted that angles of femoral anteversion greater than 30° are considered "excessive."[2] An abnormally small angle of femoral anteversion (ie, ≤8°) is referred to as "retroversion."[13]

Excessive femoral anteversion is not uncommon and has been associated with several neurologic and orthopaedic conditions. Children with cerebral palsy have received considerable attention in this area, owing to the high prevalence of excessive femoral anteversion in this population.[1,8,12] Recently, abnormal femoral anteversion has been speculated as being contributory to several orthopaedic conditions, such as hip osteoarthritis,[26] hip labral tears,[7] and patellofemoral pain.[17] For this reason, femoral anteversion is commonly assessed when evaluating patients with lower extremity dysfunction.

Various imaging techniques have been described to measure femoral anteversion. The first description involved radiographs. However, the use of a projection image to quantify a transverse-plane entity led to large inaccuracies.[18] The radiographic method was replaced with computed tomography (CT) in the late 1970s, which was subsequently found to be more accurate when compared to an anatomical reference.[9] More recently, magnetic resonance imaging (MRI) has been used to measure femoral anteversion. The ability to alter the image plane gives MRI an advantage over CT, which is only capable of axial views. By orienting the image plane parallel to the femoral neck, visualization of the femoral neck

• **STUDY DESIGN:** Clinical measurement, criterion standard.

• **OBJECTIVES:** To determine if the clinical measure of femoral anteversion is comparable to measures obtained from magnetic resonance imaging (MRI). An additional purpose of this study was to assess the intertester and intratester reliability of the clinical test.

• **BACKGROUND:** Femoral anteversion is commonly assessed as part of the physical examination; however, limited and inconsistent data exist on the validity and reliability of the clinical test.

• **METHODS:** Eighteen healthy adults (9 males, 9 females; mean ± SD age, 25.4 ± 3.3 years; body mass index, 22.9 ± 3.4 kg/m^2) participated. Each underwent 3 data collection sessions: (1) MRI to measure femoral anteversion, (2) clinical testing of femoral anteversion, measured independently by 2 physical therapists, and (3) repeated clinical testing. Validity and reliability were assessed using intraclass correlation coefficient (ICC$_{2,3}$) and standard error of measurement (SEM).

• **RESULTS:** Moderate agreement was found between the clinical test and MRI measures of femoral anteversion (ICCs of 0.69 and 0.67 for examiners 1 and 2, respectively). The SEM was similar for both examiners (5.8° and 6.0°). Both intratester (ICCs of 0.88 and 0.90 for examiners 1 and 2, respectively) and intertester (ICC = 0.83) reliability was found to be substantial.

• **CONCLUSIONS:** In persons with a low body mass index, the clinical test to assess femoral anteversion was shown to exhibit substantial reliability, but only moderate agreement with MRI measurements. When performing the clinical test, one can be 95% confident that the true value of femoral anteversion will fall within 11.8° of the clinically measured value. This relatively wide confidence interval calls into question the clinical utility of the clinical test for assessing femoral anteversion. *J Orthop Sports Phys Ther 2009; 39(8):586-592. doi:10.2519/jospt.2009.2996*

• **KEY WORDS:** *femur, hip morphology, medical imaging, physical examination*

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axis is improved. The MRI method has been investigated by several authors and has been shown to be reliable (r = 0.97) and comparable to CT (r = 0.77).[25]

To date, only 1 clinical method has been described to measure femoral anteversion. Commonly referred to as "Craig's test,"[5] or the "trochanteric prominence angle test,"[3] the method involves positioning an individual prone and flexing the knee to 90°.[19] The greater trochanter is then palpated as the thigh is internally and externally rotated (using the leg of the flexed knee as a lever arm), until the greater trochanter is at its most prominent position laterally (**FIGURE 1A**). Femoral anteversion is measured as the angle formed by the long axis of the lower leg and the vertical, and is quantified using a goniometer or inclinometer (**FIGURE 1B**).

The first attempt to validate the clinical test for femoral anteversion was performed by Ruwe and colleagues in 1992.[19] It was reported that the clinical measure highly agreed with intraoperative measures of anteversion (within 4°). However, a limitation of this study was that the intraoperative technique involved "eye-balling" a Steinmann pin on a radiograph to assure it was centered within the femoral neck. Given the subjective nature of the method employed, the appropriateness of using this approach as a gold standard could be questioned. Another limitation of this study was that the mean age of the subjects was 8 years old, with a majority having a diagnosis of cerebral palsy.

A second attempt to validate the clinical test for femoral anteversion was undertaken by Davids and colleagues in 2002.[3] These authors also evaluated children with cerebral palsy (n = 20) and compared the clinical method to established techniques using CT. They reported poor agreement between the 2 methods, with errors greater than 10° in 45% of their subjects. Several problems with the clinical test were discussed that may help to explain the lack of agreement with CT measures. In particular, it was illustrated that the prominence of the greater trochanter is considerably anterior to the subtrochanteric center (used in the CT measurement of femoral anteversion), which reveals an inherent flaw in the clinical exam. Furthermore, the authors cautioned that their study was performed on children and that greater amounts of soft tissue typically found in older individuals may lead to further inaccuracies with the clinical test.[3]

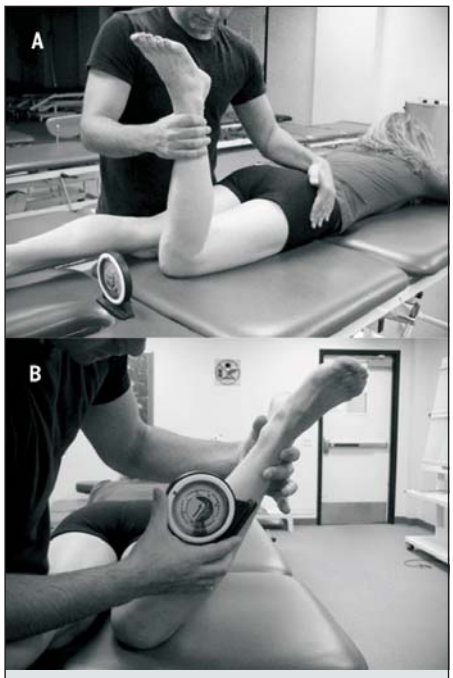

FIGURE 1. Clinical test for assessing femoral anteversion. The examiner palpated the greater trochanter at its most laterally prominent position (A), and then used an inclinometer (or goniometer) to measure the tibia inclination (B).

With respect to reliability, several investigations have assessed the interrater reliability of the clinical test for femoral anteversion.[10,14,15,19,23,24] The results of these studies vary considerably, as illustrated by the wide range of reported reliability coefficients (0.17-0.97) and measurement error (1.1°-8.4°). Of these studies, only 1 investigated intrarater reliability of the clinical test for femoral anteversion. These authors reported excellent within-tester agreement in 3 out of 4 examiners.[23] The discrepancies among reliability studies may be related to several factors, such as the diverse populations evaluated, slight variations in the methods to measure femoral anteversion, and the statistical approaches used to establish reliability.

Given the inconsistencies in the reported results of previous validity and reliability studies, further research is needed to assess the usefulness of the clinical test for femoral anteversion. More specifically, we sought to assess the concurrent, criterion-related validity of the clinical test for femoral anteversion using MRI. We elected to use MRI to assess validity as this modality gives the best direct visualization of the necessary landmarks with the least amount of invasiveness. An additional purpose of our study was to assess the interrater and intrarater reliability of the clinical measure of femoral anteversion.

METHODS

Subjects

Eighteen healthy individuals (9 females, 9 males) between the ages 23 and 36 years participated in this study (mean ± SD age, 25.4 ± 3.3 y; height, 1.69 ± 0.36 m; body mass, 66.0 ± 12.0 kg; BMI, 22.9 ± 3.3 kg/m^2). Study participants were recruited from the University of Southern California student population. All subjects participated in the validation and reliability portions of the investigation. Prior to participation, all subjects were informed as to the nature of the study and informed consent was obtained as approved by The Institutional Review Board of the University of Southern California. Subjects were excluded if they had undergone any bony surgical realignment of the lower extremity or failed to meet any of the MRI safety requirements (ie, presence of metal implants, pacemakers, etc).

Instrumentation

Imaging was performed using a 1.5-T magnetic resonance system (General Electric Medical Systems, Piscataway, NJ). T1-weighted images of the proximal and distal femur were acquired using the following pulse sequence: repetition time, 450 milliseconds; echo time, 8.1 milliseconds; field of view, 24 × 24 cm; matrix,

256 × 256; slice thickness, 5 mm.

For the clinical measure of femoral anteversion, an industrial inclinometer was used (Magnetic Polycast Protractor; Empire Level Manufacturing Co, Mukwonago, WI). This device makes use of gravity and a pendulum mechanism to measure inclinations.

Procedures

Subjects underwent 3 separate testing sessions. The first session involved MRI assessment to determine femoral anteversion. The second session involved measurement of femoral anteversion using the clinical method. Two physical therapists independently measured each participant to establish interrater reliability. The third session involved the same procedures as session 2 and was used to establish intrarater reliability. For all testing sessions, only the right side of each subject was evaluated.

MRI Assessment of Femoral Anteversion Subjects were positioned supine on the imaging table, and the hip joint was supported by pillows in a neutral position (0° rotation, 0° abduction, 0° flexion). Two image series were obtained. First, an axial oblique image was acquired parallel to the femoral neck, bisecting its superior and inferior borders. Next, a second axial oblique image was acquired through the epicondylar axis. Total imaging time was approximately 10 minutes.

Images were analyzed using Image J, Version 1.36b, software (National Institution of Health, Bethesda, MD). First, the image oriented parallel to the femoral neck was analyzed to determine the femoral neck angle with respect to the image field of view. The femoral head was outlined with an ellipse and the centroid was determined. Next, the femoral shaft was outlined with an ellipse and its centroid was established. A line connecting the centroids was used to define the femoral neck axis in the transverse plane (**FIGURE 2A**). Next, the angle between the femoral neck axis and a horizontal line drawn in the image field of view was measured (**FIGURE 2A**). The angle was considered positive if the femoral head was anterior to the femoral shaft and negative if it was posterior to the femoral shaft.[25]

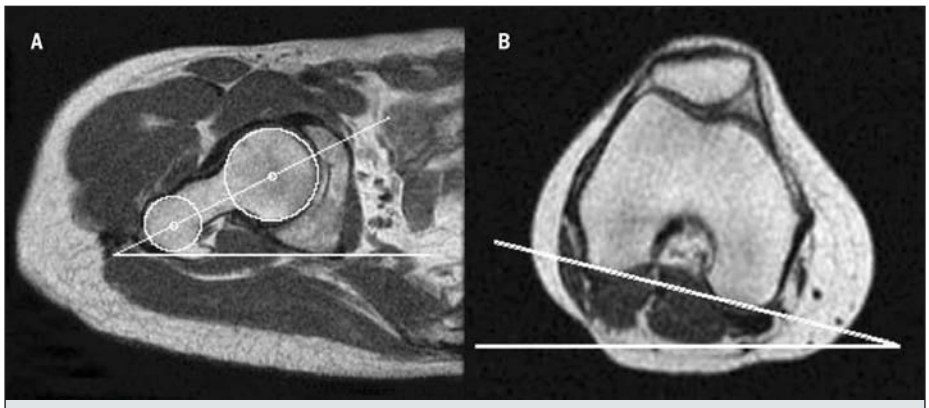

FIGURE 2. Femoral head and femoral shaft were outlined and centroids were determined. A line connecting the centroids, defined the femoral neck axis in the transverse plane, was compared to a horizontal line drawn in the image field of view (A). Axial oblique image through the femoral condyles used to determine the femoral epicondylar axis. The posterior femoral condyle line was referenced to a horizontal line in the image field of view. To determine femoral anteversion, the femoral neck axis angle (with respect to the image field of view) was added to the femoral condylar angle (with respect to the image field of view) (B).

The axial oblique image through the femoral condyles was used to determine the femoral epicondylar axis. The most posterior aspect of each femoral condyle was defined and a line connecting the 2 was drawn (**FIGURE 2B**). This line defined the femoral condylar axis in the transverse plane and was referenced to a horizontal line in the image field of view (**FIGURE 2B**). The epicondylar axis angle was positive if the lateral condyle was anterior to the medial condyle (indicating an internally rotated position) and negative if the lateral condyle was posterior to the medial condyle (indicating an externally rotated position).[25] Pilot imaging using a plastic level with phantom tracers revealed that the horizontal reference lines used in the 2 sets of images to quantify anteversion reflected the same orientation.

To determine femoral anteversion, the femoral neck axis angle (with respect to the image field of view) was added to the femoral condylar angle (with respect to the image field of view).[25] All measurements were made by 1 investigator (R.S.), who was not one of the 2 clinical examiners. This individual demonstrated excellent reliability in a pilot study on 5 subjects ($ICC_{2,3}$ = 0.99). For statistical analysis, an average of 3 measurements was used.

Clinical Assessment of Femoral Anteversion Two physical therapists with 3 and 16 years of clinical experience in outpatient orthopaedic practice performed the clinical tests for femoral anteversion. Neither routinely performed this test as part of their clinical practice. Prior to testing, both examiners underwent a training session to review the procedures and methods. The examiners practiced on 3 volunteers who had previously undergone MRI assessment of femoral anteversion. The MRI results were revealed to the examiners as a form of feedback. These subjects were not included in the current study. The training session lasted approximately 1 hour.

The clinical test was performed as described by previous investigators.[3,5,19] First, participants were positioned prone on an examination table, with the thigh of the test extremity in neutral abduction/adduction. The examiner stood on the contralateral side to the subject's hip being examined. While stabilizing the sacrum with the forearm, the greater trochanter was palpated with the hand that was more cranial. The knee of the test extremity was flexed to 90° using the hand that was more caudal. The hip was then internally and externally rotated until the

TABLE 1 Femoral Anteversion Angle Measured by MRI and 2 Testers*

Subject	Gender	BMI (kg/m²)	MRI†	Examiner 1†	Absolute Difference‡	Examiner 2†	Absolute Difference‡
1	F	21.2	23.3	16.7	6.6	21.7	1.6
2	F	20.3	12.0	13.3	1.3	21.0	9.0
3	F	21.9	36.5	29.3	7.2	30.3	6.2
4	F	17.8	21.7	15.0	6.7	18.7	3.0
5	F	23.0	8.6	7.7	0.9	10.7	2.1
6	F	18.8	33.4	20.7	12.7	19.7	13.7
7	F	22.6	13.9	11.0	2.9	21.0	7.1
8	F	12.6	3.7	9.0	5.3	16.0	12.3
9	F	20.7	23.6	15.7	7.9	19.0	4.6
10	M	24.4	8.1	15.3	7.2	4.7	3.4
11	M	24.7	17.9	11.0	6.9	7.7	10.2
12	M	25.2	12.7	4.7	8.0	8.3	4.4
13	M	20.3	6.5	10.0	3.5	6.0	0.5
14	M	23.6	19.6	1.7	17.9	6.7	12.9
15	M	23.9	12.8	8.7	4.1	10.0	2.8
16	M	23.0	18.8	13.3	5.5	10.6	8.2
17	M	33.6	19.8	6.0	13.8	1.0	18.8
18	M	24.4	15.8	8.3	7.5	12.0	3.8
Mean		22.9	17.1	12.1	7.0	13.8	6.7
SD		3.4	8.4	6.4	4.2	7.6	5.1

Abbreviations: BMI, body mass index; MRI, magnetic resonance imaging.
** All values in degrees, unless otherwise indicated.*
† Values represent the average of 3 measurements.
‡ Difference between MRI value and tester value.

greater trochanter was determined to be at its most prominent position laterally (**FIGURE 1A**). The base of the inclinometer was then aligned on the subjects' tibial crest. The angulation of the tibia with respect to vertical was recorded (**FIGURE 1B**).

To assess the intratester reliability of the clinical measure of femoral anteversion, measurements were obtained from each subject on 2 different occasions. To prevent measurement recall, data were obtained at least 1 week apart. For intertester reliability, the first session data for each examiner was used. In all instances, measurements were taken 3 times and averaged for final analysis. Both investigators were blinded to each other's, as well as the MRI measurements of femoral anteversion.

Statistical Analysis

To assess the level of agreement between measures of femoral anteversion using MRI and the clinical test, the $ICC_{2,3}$ and the SEM were utilized. The SEM was calculated using the equation $\sqrt{\Sigma(ABS^2)/2}$, where ABS equals the absolute difference score.[20] This analysis was performed using the values obtained in the first clinical testing session and was repeated for each of the 2 examiners. Intertester and intratester reliability of measurements obtained with the clinical test was assessed using $ICC_{2,3}$. Intertester reliability was assessed using the values obtained during the first clinical testing session. Intratester reliability was assessed using the values obtained during the first and second clinical testing sessions for each tester. Ninety-five percent confidence intervals were calculated for all ICC values. ICCs were interpreted using the following criteria: 0.00-0.10, virtually none; 0.11-0.40, slight; 0.41-0.60, fair; 0.61-0.80, moderate; 0.81-1.0, substantial.[22] All statistical analyses were performed with SPSS, Version 15.0 statistical software (SPSS, Inc, Chicago, IL).

RESULTS

Validity

The average (SD) angles of femoral anteversion, as measured by the clinical test during the first testing session, were 12.1° (6.4°) for examiner 1 and 13.8° (7.6°) for examiner 2. The average (SD) amount of femoral anteversion as assessed using MRI was 17.1° (8.4°) (**TABLE 1**). The ICCs assessing the level of agreement between the 2 methods were 0.69 and 0.67 for examiners 1 and 2, respectively (**TABLE 2**). The SEM values were 5.8° and 6.0° for examiners 1 and 2, respectively (**TABLE 2**).

Reliability

The ICC values representing intratester reliability for examiners 1 and 2 were

0.88 and 0.90, with SEM values of 3.2° and 3.1°, respectively. The ICC value representing intertester reliability was 0.83, with a SEM of 3.8° (**TABLE 2**).

TABLE 2 Validity and Reliability of Femoral Anteversion Measurements

Comparison	$ICC_{2,3}$ (95% CI)	SEM (deg)
Examiner 1 versus MRI	0.69 (0.08-0.89)	5.8
Examiner 2 versus MRI	0.67 (0.16-0.87)	6.0
Examiner 1 versus examiner 1 (intratester reliability)	0.88 (0.68-0.96)	3.2
Examiner 2 versus examiner 2 (intratester reliability)	0.90 (0.74-0.96)	3.1
Examiner 1 versus examiner 2 (intertester reliability)	0.83 (0.55-0.94)	3.8

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; MRI, magnetic resonance imaging; SEM, standard error of the measurement.

DISCUSSION

In the current study, we investigated the concurrent criterion-related validity and reliability of a clinical test used to measure femoral anteversion. Although commonly used by clinicians for a wide range of patients with varying clinical conditions, the reliability and validity of this test has not been clearly established. In the current study, the clinical test to assess femoral anteversion was shown to exhibit substantial reliability, but only moderate agreement with MRI.

In the validity portion of this study, the ICCs for the level of agreement between the clinical test and MRI were moderate (0.69 and 0.67). It should be noted, however, that the clinical test underestimated the true angle of femoral anteversion in 75% of the subjects evaluated. This observation is consistent with the data from Davids et al,[3] who created a 3-dimensional model of the proximal femur and noted that the location of the most prominent portion of the greater trochanter would likely lead to underestimations of femoral anteversion when using the clinical exam.

Although the average difference scores between each of the examiners and MRI were relatively small (5.0° and 3.3° for examiners 1 and 2, respectively), the average absolute difference scores were substantially larger (7.0° and 6.7° for examiners 1 and 2, respectively). Our average difference scores when comparing the clinical test and the MRI-measured values are consistent with those reported by both Davids et al[3] (5°) and Ruwe et al[19] (4°). However, average difference scores can be misleading, as large overestimations and underestimations will tend to cancel each other out. In the current study, the maximum differences between the MRI and clinical measurements were 17.9° and 18.8° for examiners 1 and 2, respectively. While we observed moderate agreement between examiners and MRI measurements of femoral anteversion, it should be noted that the 95% confidence intervals were fairly wide (**TABLE 2**).

The SEM gives a better approximation of the overall measurement error and is recommended as an estimate of measurement precision.[16] In the current study, the SEMs for examiners 1 and 2 were similar (5.8° and 6.0°, respectively). Given an overall average SEM of 5.9° for both examiners, our data suggest that one can be 95% confident that the true angle of femoral anteversion would fall within 11.8° of the clinically measured value. This relatively wide confidence interval calls into question the clinical utility of the clinical test, as classification of persons as having excessive anteversion or retroversion would only be possible in extreme cases.

The fact that 22% of our examiners' values for the difference between clinical and MRI measurements exceeded the 95% confidence threshold (11.8°) calls into question the accuracy of the SEM estimate. One possible explanation for this discrepancy may be related to the relatively small sample size used to establish the SEM in the current study. Perhaps a larger sample size (eg, greater than 100) would have resulted in a more accurate estimation of the SEM.

Despite limited utility of the clinical measure of femoral anteversion, the level of agreement observed in the current study represents an improvement over previous attempts to validate the clinical test. For example, 39% of our subjects had a clinical measurement value within 5° of the MRI-measured value and only 22% had a clinical measurement value greater than 10° compared to the MRI-measured value. Our findings are in contrast with those of Davids et al,[3] who reported that 23% of their subjects had a clinical measurement value that was within 5° of the femoral anteversion value as measured by CT, while 45% of subjects had a clinical measurement that was greater than 10° compared to the CT-measured value. Differences between the 2 studies may be attributed to study population differences (children with cerebral palsy versus healthy adults) and/or imaging methods (CT versus MRI).

The most likely source of error between MRI and clinical measurements of femoral anteversion is the soft tissue superficial to the greater trochanter. As palpation of the greater trochanter is critical for attaining an accurate clinical measurement, the soft tissue overlying the greater trochanter would likely lead to errors. The sample evaluated in the current study consisted of healthy young adults, with an average body mass index (BMI) of 23. This value falls within the normal limits for young healthy adults.[11] It should be noted that the largest errors were present in the subjects with the highest BMI. Given as such, our findings may not be generalizable to individuals with a higher BMI.

In the intratester reliability portion of this study, it was found that both examiners demonstrated substantial reliability

in performing the clinical test for femoral anteversion (ICCs of 0.88 and 0.90 for examiners 1 and 2, respectively). The examiners had SEMs of 3.2° and 3.1°, indicating that one can be 95% confident that the clinical measurement made by a clinician on one day would fall within 6.3° of the measurement from that same clinician taken at a later date. Our intertester reliability results showed substantial agreement between our 2 examiners (ICC = 0.83). Given a SEM of 3.8°, one can be 95% confident that the clinical measurement taken by 1 clinician would fall within 7.6° of the measurement taken by a second clinician.

Our results for intratester reliability are similar to those of Shultz et al,[23] who reported ICC values ranging between 0.77 and 0.97. In contrast, our results for interrater reliability demonstrated a much higher level of agreement when compared to previous studies. In their study of children with cerebral palsy, Ruwe and colleagues[19] reported that the average measurement difference between a physical therapist and an orthopaedic surgeon was 5.2°. The average difference score in our study was 1.7°. Ruwe and colleagues[19] did not report ICCs or absolute difference, so direct comparisons are difficult. Similarly, our findings represent an improvement over 3 separate investigations that evaluated the interrater reliability of the clinical test for femoral anteversion in persons with patellofemoral pain.[10,15,24] More specifically, our interrater ICC (0.83) and SEM (3.8°) were substantially better than those of Sutlive et al,[24] Piva et al,[15] and Lesher et al,[10] who reported reliability coefficients of 0.17, 0.45, and 0.47, and SEMs of 8.4°, 4.5°, and 7.0°, respectively. Interestingly, after excluding subjects with BMIs greater than 24.5 kg/m^2, Piva and colleagues[15] reported that their interrater reliability improved to 0.81.

Aside from the low BMI of our subjects, another possible explanation for our improved reliability results may be related to the training the clinicians received as part of this investigation. In our study, the examiners underwent a training session where MRI measures of femoral anteversion were revealed to the examiners and they were allowed to retest a small group of prestudy subjects with this information in mind. This experience may have contributed to the higher level of reliability not evident in previous studies. To the best of our knowledge, the influence of training on the reliability of clinical measures has not been investigated and would appear to be an important direction for future research. Also, it should be noted that our reliability and validity results were based on an average of 3 measurements. Clinical estimates of femoral anteversion obtained from a single measurement may be expected to be less valid or reliable.

It could be argued that the generalizability of our findings may be limited due to the fact that only healthy individuals were studied. However, it should be noted that 33% or our subjects had MRI-measured femoral anteversion that could be considered abnormal (ie, $\leq 10°$ or $\geq 30°$ of femoral anteversion). An important factor when evaluating the reliability and/or validity of a structural characteristic such as femoral anteversion is to ensure that structural variability exists within the sample pool. From that perspective, we feel that our results can be viewed as being generalizable, as subjects in our study exhibited a range of anteversion values (3.7°-36.5°) that would be observed in most musculoskeletal conditions.

CONCLUSION

In persons with a low BMI, the clinical test to assess femoral anteversion was shown to exhibit substantial reliability, but only moderate agreement with MRI. When performing the clinical test, one can be 95% confident that the true value of femoral anteversion will fall within 11.8° of the clinically measured value. Our findings call into question the utility of the clinical test, as classification of persons as having excessive anteversion only would be possible in extreme cases. ◉

KEY POINTS

FINDINGS: In persons with a low BMI, the clinical test to assess femoral anteversion was shown to exhibit substantial reliability, but only moderate agreement with MRI.

IMPLICATION: Our findings call into question the clinical utility of the clinical test as classification of persons as having excessive anteversion or retroversion would only be possible in extreme cases.

CAUTION: The generalizability of our findings may be limited, due to the fact that only healthy individuals with low BMI (<25 kg/m^2) were studied. Also, it should be noted that our results were based on an average of 3 measurements. Clinical estimates of femoral anteversion obtained from a single measurement may be expected to be less valid or reliable.

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