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ORIGINAL RESEARCH REPORT

Reliability and Validity of a Novel Approach to Measure Hip Rotation

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Context: Currently, hip-rotation range of motion (ROM) is clinically measured in an open kinetic chain in either seated or prone position using passive or active ROM. However, during activities of daily living and during sports participation the hip must be able to rotate in a loaded position, and there is no standard measurement for this. ***Objective:*** To determine if a novel method for measuring hip rotation in weight bearing will result in good to very good reliability as demonstrated by an intraclass correlation coefficient (ICC) of >.80 and to investigate if weight-bearing hip measurements will result in significantly reduced hip ROM compared with non-weight-bearing methods. ***Design:*** Repeated measures. ***Setting:*** Outpatient sports physical therapy clinic. ***Participants:*** 20 healthy participants (10 men, 10 women) recruited for hip-rotation measurements. ***Methods:*** Three trials of both internal and external rotation were measured in sitting, prone, and weight bearing. Two therapists independently measured each participant on the same day. The participants returned the following day to repeat the same measurements with the same 2 therapists. ***Main Outcome Measures:*** Degrees of hip internal and external rotation measured in prone, sitting, and loaded positions. ***Results:*** In general, the measurement of hip ROM across the different conditions was reliable. The intrarater reliability was .67–.95, while interrater reliability was .59–.96. Interrater reliability was improved when values were averaged across the measures (.75–.97). ICCs for active loaded ROM were .67–.81, while interrater ICCs were .53–.87. In general, prone hip ROM was greater than supine and supine was greater than loaded. ***Conclusions:*** Loaded hip rotation can be measured in a clinical setting with moderate to good reliability. The rotation ROM of a loaded hip can be significantly decreased compared with unloaded motion.

Keywords: weight bearing, closed chain, range of motion

Traditionally, hip-rotation range of motion (ROM) has been measured using 1 of 2 goniometric methods: seated and prone.[1–7] Both of these methods may also be performed passively. These measures have been found to have good reliability, with intraclass correlation coefficients (ICCs) ranging from .76 to .97.[4] Each of these measurements assesses hip-rotation ROM in a non-weight-bearing position. According to the American Academy of Orthopaedic Surgeons, the amount of hip rotation measured in both seated and prone should be the same—45° of external rotation and 45° of internal rotation.[1] However, it has been reported that active external rotation is significantly greater in the prone position than in the seated position with the hip flexed 90°.[7] While that study[7] did show a difference between hip external-rotation measurements in seated in comparison with prone for active ROM, it did not test passive ROM. Knowing the full amount of passive motion available at the hip is important when considering athletic demands placed on the hip joint at the limits of available range. In addition, no measures were taken with the hip in a weight-bearing position that more closely reflects the functional demands of the joint.

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Because the hip is a weight-bearing joint used to pivot the acetabulum over a fixed femoral head during closed kinetic chain activities, it may prove functionally useful to assess both hip strength[8] and motion during weight bearing. Loaded-hip-rotation ROM has been previously assessed using 3-dimensional motion analysis during equal weight bearing in standing. This method does not limit motion at the pelvis, tibia, or ankle joints and is also difficult to reproduce in a clinical setting.[9] Establishing a means to assess ROM at the hip in a weight-bearing scenario in the clinical setting may provide greater functional insight to clinicians. To date, there has not been any reported clinically effective method to measure hip rotation in a weight-bearing position, which is required in many athletic movements.

Two aims were developed for the current study. The first was to determine the reliability of measuring hip-rotation ROM across the traditional seated, prone measures and a novel loaded-joint method, and the second was to compare 2 traditional methods (seated and prone) to the loaded position to identify differences in the recorded ROM.

Methods

Subjects

Twenty individuals between the ages of 18 and 35 years were recruited by word of mouth to participate in this

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study. The 20 subjects included 10 men (average age 27.1 ± 3.6) and 10 women (average age 28.4 ± 3.6). This group was assumed to represent a nonspecific cohort of healthy subjects with hip ROM in normal limits without specificity of sport or functional demands. Participants were excluded if they reported a history of diagnosed hip pathology or other current lower-extremity injury. The study protocol was approved by the institutional review board at Duke University Medical Center, where the study was conducted.

Procedures

Subjects participated in 2 data-collection series over a period of 2 consecutive days. Each series of measurements was collected by 2 physical therapists on both days (days 1 and 2) to establish both intrarater and interrater reliability. The order of therapists was randomized for each day. The order of measurements was not randomized. Seated positions were performed first, followed by prone and then loaded positions. No warm-up or stretching activities were performed before data collection. Each series of bilateral measurements included 3 trials of both internal and external rotation measured actively and passively in both the seated and prone positions. Bilateral measurements of internal and external rotation during the weight-bearing position were only measured actively. Single values were recorded each day for the measurement taken.

Seated and Prone Hip-Rotation ROM Measurements

The traditional measurements for hip ROM were taken using a handheld goniometer (Sammons Preston, IL) that provided measurements to the nearest full degree. A mobilization belt, as well as a 6-in (~15-cm) towel roll, was used to minimize unwanted motion in the sagittal and transverse planes.

Seated hip rotation was measured at the edge of a treatment table with both hips and knee flexed to 90° (Figure 1). The participant was instructed to internally or externally rotate the hip until a firm endpoint was achieved. The therapist visually monitored this posture. The goniometer was then positioned such that the moving arm aligned with the long axis of the tibia and the stationary arm was perpendicular to the table. The passive procedure was then performed in the same manner with the therapist rotating the hip until a firm end feel was attained. Once this position was attained the goniometer was positioned as described (Figure 1).

Prone hip rotation was measured with the subjects' knees placed just distal to the edge of the plinth (Figure 2). The knee for the measured lower extremity was flexed to 90° and the participant was instructed to internally and externally rotate the hip as far as he or she was able without compensating. The goniometer was then positioned such that the moving arm aligned with the long axis of the tibia and the stationary arm remained perpendicular to the table. The participant was then taken through the same measurements passively by the therapist until a firm end feel was attained. Then the correct position of the goniometer was verified and the ROM recorded (Figure 2).

Figure 1 — Setup for the measurement of active range of motion for hip internal rotation in the seated position. Same setup used for external rotation.

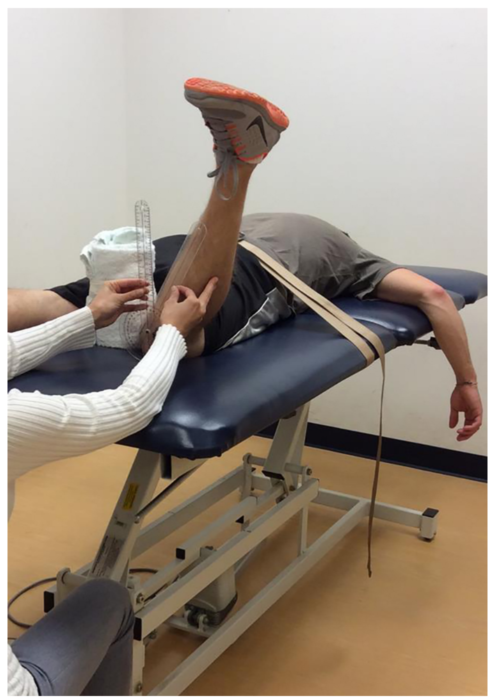

Figure 2 — Setup for the measurement of active range of motion for hip internal rotation in the prone position. Same setup used for external rotation.

Loaded-Hip-Rotation ROM Measurement

Loaded-hip-rotation ROM was assessed with the participant in a half-kneeling position on the edge of a plinth.

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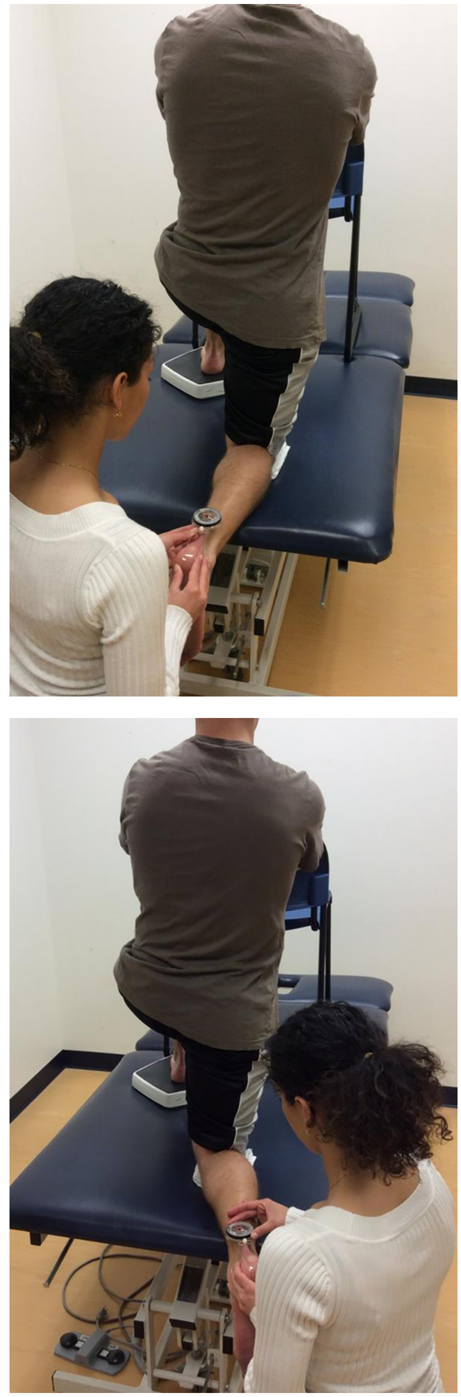
To minimize the effect that poor balance in this posture could play, a chair was placed on the plinth for the subject to hold onto to maintain balance (Figure 3[a]). The weight distribution was visually monitored and checked by the therapist. To assist with positioning, a chair was placed in front of the subject that could be held onto while getting into position for the testing. The foot of the forward limb rested on a scale (Healthometer, Bridgeview IL). The participant was directed to limit the amount of weight on the scale to less than 20% of his or her body weight. The participant was asked to monitor this during the measurement as he or she was in view of the scale. This would ensure that at least 80% body weight was being placed on the limb being measured. Before measurement, the pelvis was manually aligned parallel to the surface of the table. The knee of the measured limb was flexed to 90° and the lower extremity (femur and tibia) was visually aligned in the sagittal plane. The therapist visually monitored adherence to this position. To complete the measurement, a cervical ROM compass (Performance Attainment Associates, St Paul, MN) was aligned with the midline of the calf, the Achilles tendon, and the heel of the participant. Once in position, the compass was calibrated to zero (Figure 4). The participant was then instructed to internally and externally rotate the loaded leg as far as possible without moving the rest of the body ("While keeping the rest of your body still, move your lower leg inward/outward as far as you can by rotating at your hip") (Figure 3[b]). The participant was verbally cued ("Do not bend or point your foot and ankle") to ensure that the heel of the foot was maintained in a neutral position to minimize the effect of the subtalar joint on altering the recorded measurement.

Statistical Methods

Statistical analysis was completed using SPSS version 22 (IBM Corp, Raleigh, NC). The initial analysis that was completed on the measures was conducted to assess reliability of the measures. This analysis was completed using ICCs to examine intrarater reliability (2,1) by comparing the single measures on days 1 and 2, interrater reliability (2,1) by comparing the single measures between raters on days 1 and 2, and interrater reliability (2,*k*) by comparing the average of the 2 measures across days 1 and 2. ICC values were interpreted using the following as described by Altman: very good (.81–1.0), good (.61–.80), moderate (.41–.60), fair (.21–.40), and poor (<.20).[10] After the reliability analysis, repeated-measures ANOVAs (side × position) were conducted to examine differences between left and right sides and the different testing positions. This was completed independently for the active (2 × 3, side by position) and passive (2 × 2, side by position [did not test passive in loaded position]) tests for internal and external rotation. A critical alpha level of .05 was used to identify statistical significance. When appropriate, post hoc statistical analysis was carried out used Tukey honestly significant difference tests.



(a)

(b)

Figure 3 — (a) Initial setup for the measurement of range of motion (ROM) for hip rotation in the weight-bearing hip position. (b) Final position for the measurement of ROM for hip internal rotation in the weight-bearing hip position.

Results

Overall, the measurement of hip ROM across the different positions was found to exhibit good reliability (Table 1). In addition, the level of reliability was similar between

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Figure 4 — Compass calibration position for the weight-bearing hip-position measurements.

sides and directions of motion (internal vs external rotation). The overall point estimate of the reliability for all measures improved when single measures were averaged across the 2 days to identify the point estimate of the mean. Specifically, reliability of the seated active-rotation measures yielded good to very good intrarater (.82–.93) and interrater (.78–.92, .91–.94) values. Seated passive values for the hip-rotation measures were good to very good for intrarater (.87–.93) and interrater (.80–.89, .87–.94), as well. Similar good to very good reliability measures were found for intrarater (active, .74–.95; passive, .82–.95) and interrater (active, .75–.96, .90–.97; passive, .74–.93, .91–.94) of the prone measures, as well. Finally, moderate to good reliability was found for the intrarater (.67–.81) and interrater (.53–.87, .75–.90) analysis of the loaded-hip-ROM measures.

Average values were compared between sides across the different testing positions for the active and passive ROM measures. There was no significant interaction for position and limb for any of the test positions. The data collected showed no difference in hip-rotation measurements in right versus left hip across all tested positions (P = .15–.64, Table 2). A statistically significant main effect for position was observed, which suggested that the position tested makes a difference in

Table 1 Intraclass Correlation Coefficients (ICC) for the Different Intrarater and Interrater Comparisons for All of the Tested Measures for the Study

				Intrarater ($ICC_{2,1}$)		Interrater ($ICC_{2,1}$)		
Position	**Motion**	**Side**	**Rotation**	**Tester 1**	**Tester 2**	**Day 1**	**Day 2**	**Interrater average of days 1 and 2 ($ICC_{2,k}$)**
Seated	Active	Left	Internal	.82	.84	.83	.87	.94
			External	.89	.89	.78	.86	.91
		Right	Internal	.93	.92	.92	.89	.94
			External	.93	.88	.82	.91	.91
Seated	Passive	Left	Internal	.89	.93	.80	.88	.89
			External	.89	.92	.81	.86	.87
		Right	Internal	.87	.88	.89	.89	.94
			External	.90	.83	.86	.82	.87
Prone	Active	Left	Internal	.87	.90	.75	.89	.90
			External	.81	.83	.85	.86	.91
		Right	Internal	.95	.93	.96	.93	.97
			External	.74	.76	.89	.89	.95
Prone	Passive	Left	Internal	.90	.85	.74	.92	.91
			External	.87	.93	.93	.85	.93
		Right	Internal	.95	.93	.93	.93	.94
			External	.83	.82	.88	.87	.92
Loaded	Active	Left	Internal	.71	.67	.59	.87	.85
			External	.70	.81	.73	.71	.75
		Right	Internal	.81	.74	.72	.85	.90
			External	.74	.74	.70	.53	.76

Note: Single measures were used for the initial intrarater and interrater reliability comparisons. Intrarater comparisons were made for the average measures of day 1 vs day 2 (2,1). Interrater comparisons were made using the data on days 1 and 2 using single measures on each day (2,1), as well as an average of the 2 measures (2,k).

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Table 2 Mean and Standard Error (SEM) for All Positions for Active and Passive Rotation

Position	Motion	Side	Rotation	Mean	SEM
Seated	Active	Left	Internal#	31.1	1.7
			External#	33.9	2.2
		Right	Internal#	32.1	2.1
			External#	33.2	2.0
Seated	Passive	Left	Internal	40.6	2.1
			External	44.5	2.2
		Right	Internal	42.2	2.2
			External	44.4	2.2
Prone	Active	Left	Internal*#	34.3	3.0
			External*#	46.0	2.8
		Right	Internal*#	36.0	3.2
			External*#	46.5	2.5
Prone	Passive	Left	Internal	44.4	3.1
			External*	45.5	2.2
		Right	Internal	45.5	3.1
			External*	54.6	2.8
Loaded	Active	Left	Internal	21.1	2.1
			External	25.8	1.7
		Right	Internal	22.6	2.7
			External	27.8	2.1

*Significantly greater than seated position $P \leq .05$. #Significantly greater than loaded position $P \leq .05$.

the amount of hip rotation available ($P < .01$, Figures 5 and 6). Prone active internal rotation was greater than seated active internal rotation ($P < .03$), which was greater than loaded internal rotation ($P < .01$, Table 2, Figure 5). Similarly, prone active external rotation was greater than seated external rotation ($P < .01$), which was greater than loaded external rotation ($P < .01$, Table 2, Figure 6). A similar hierarchy of results was observed for passive ROM and active ROM (Figures 7 and 8). There was a significant difference in passive prone external rotation compared with passive seated external rotation ($P < .01$, Figures 7 and 8). The average seated passive external rotation for right and left leg was 45.0° ± 2.2°, while the average prone passive external rotation for the right and left leg was 54.7° ± 3.1° ($P < .01$, Figures 7 and 8).

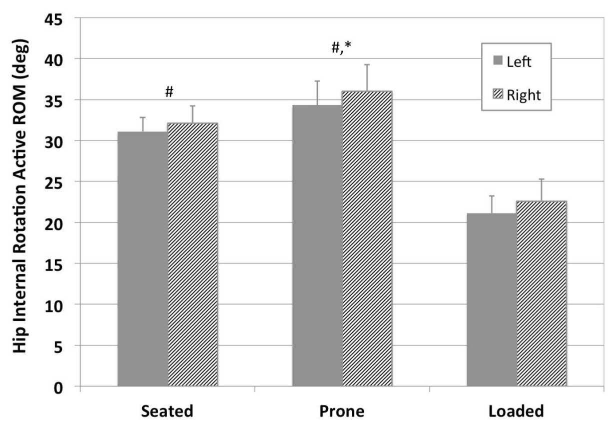

Figure 5 — Active hip internal-rotation range-of-motion (ROM) measurements on the left side across the different positions measured including standard error measures. #Significantly greater than loaded position, $P \leq .05$.

Discussion

Hip ROM is important to measure since a loss of rotation in either direction has been associated with prior lower-extremity injury and/or low back pain.[11–14] While measuring hip-rotation ROM provides an objective clinical value, current clinical applications of the traditional seated and prone methods may only offer limited insight into deficits.

Interrater and intrarater reliability of the hip-rotation measurements were moderate to very good for all of the hip-ROM measurements. This is similar to prior research examining reliability of traditional measures of hip rotation.[1–7] In general, the point estimate for the reliability

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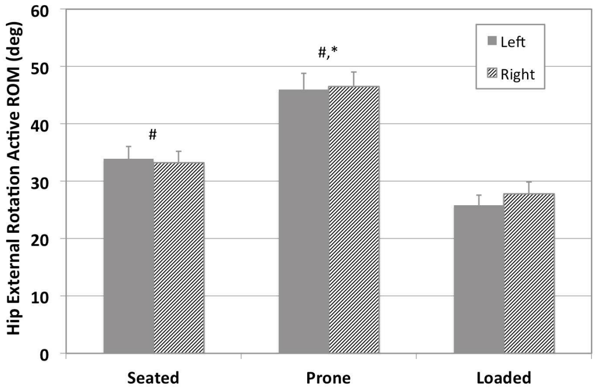

Figure 6 — Active hip external-rotation range-of-motion (ROM) measurements on the left side across the different positions measured including standard error measures. *Significantly greater than seated position, $P \leq .05$. #Significantly greater than loaded position, $P \leq .05$.

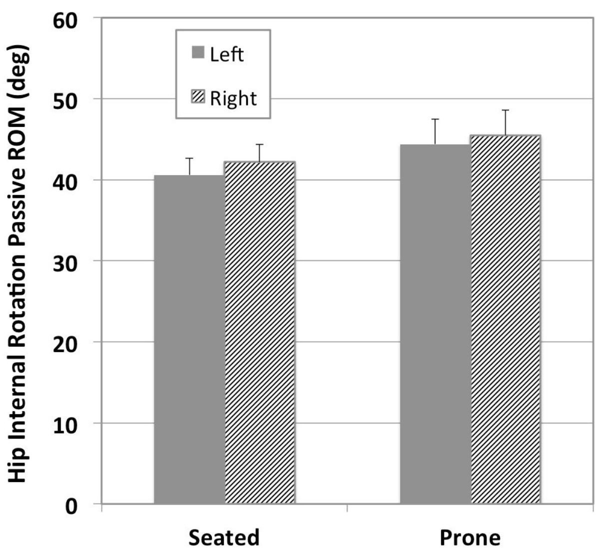

Figure 7 — Passive hip internal-rotation range-of-motion (ROM) measurements on the left side across the different positions measured including standard error measures.

was higher for the traditional measures than the newly proposed method that tested the hip in a loaded position. This was likely due to several factors attributed to the setup of the loaded-hip test. One primary factor was that there were fewer constraints placed on the tested subject during the initial positioning, which likely led to movement in undesired planes, that is, hip flexion/extension, hip abduction/adduction, or trunk deviation from neutral. Furthermore, the use of the cervical compass for hip-rotation ROM was a novel task, though not a novel instrument to the tester, which could contribute to less consistent measurements. This measurement is more demanding with regard to physical effort on the behalf of the subject, because the leg is rotated under 80% of

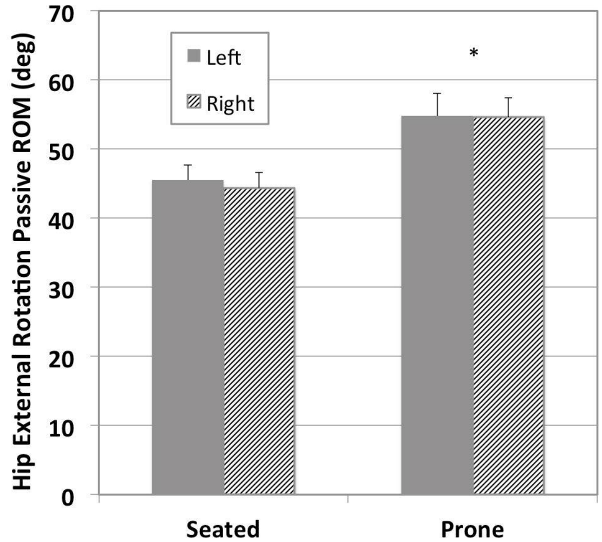

Figure 8 — Passive hip external-rotation range-of-motion (ROM) measurements on the left side across the different positions measured including standard error measures. *Significantly greater than seated position, $P \leq .05$.

body weight, which could elicit greater compensations that are observed through movement in undesired planes. The reliability improved to an acceptable level when the average of the 2 measurements was used. As a result of this finding, future use of this measure should include using an average of at least 2 single trials to optimize reliability.

As expected, differences in hip ROM were observed across the different testing positions in this study, as was found in other works.[7] In previous studies, external rotation was found to average 36° in seated and 41° to 45° in prone.[4,7] Internal rotation was reported as 33° in seated and 32° to 36° in the prone position.[4,7] In the current study, active ROM was greatest in prone, followed by seated and then loaded (Table 2, Figures 5 and 6). The passive ROM differences still existed in the same hierarchy between prone and seated; however, there was less discrepancy (Table 2, Figures 7 and 8). As with other studies, no consistent differences in values were observed between left and right limbs.[1,2,5–7] The observed lack of difference between limbs is likely associated with lack of symptoms in this set of subjects. Prior research has correlated asymmetric hip rotation with pathology.[2,12,14,15] Differences in hip rotation as a result of testing position have previously been reported by Simoneau et al.[7] Similar to the current study, they[7] observed that hip position played a significant role in hip-rotation motion. The current study shows less internal rotation than external rotation during the loaded measurement (Table 2), which becomes an important consideration when evaluating hip pathology due to the correlation between pathologies and lack of internal rotation.[12,14,15] Understanding that further hip internal-rotation limitations could be exposed when the joint is loaded versus unloaded, as

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these data show, suggests that loaded testing positions should be considered so that it is not assumed by the clinician that the unloaded ROM is fully available during weight-bearing activities. If this motion is available, but not being used, there may be an opportunity for intervention. More information is needed to determine if the motion required during functional tasks better correlates to non-weight-bearing or weight-bearing rotation measures. There are a number of factors that may explain the difference in rotation motion between the traditional and loaded positions. First, this measurement was performed while bearing weight through the hip, likely causing muscle cocontraction at the hip joint to meet the postural demand of the position. Joint approximation during loading may alter proprioceptive input, which could influence tension within the joint, sacrificing mobility to remain stable. The lower limbs in the loaded position were aligned asymmetrically (1 hip at 0° and the other at 90° of flexion), possibly causing reciprocal muscle-extensibility limitations that decrease available ROM. Finally, the acetabulum typically rotates about a fixed femur, and, in this measurement, the femur rotates about a fixed acetabulum, perhaps decreasing the motor control necessary to complete this novel, less functional, task.

Currently, research suggests that hip injuries are caused from repetitive microtrauma to the joint, and this microtrauma is thought to occur during loaded activities.[11] The direct relationship between acute or chronic injuries and loaded rotational ROM has not yet been established. By taking hip-ROM measurements in a loaded position, clinicians may more accurately assess available motion at the joint during conditions in which it is likely being injured. The benefit of this loaded-hip measurement is that it provides clinicians with information as to the degree to which the femoroacetabular joint is able to rotate in a functional position. This can have important implications when treating patients with deficits in hip rotation because the clinician must realize that the motion measured in an unloaded position is likely 10° or more rotation than motion measured in a loaded position. While traditional methods of measuring hip rotation remain valuable, clinicians should consider that these measurements do not necessarily relate to the amount of motion that individuals use during functional and athletic tasks.

As with any study, there are limitations that should be discussed. The primary limitation is the size of the study—specifically, the use of only 2 raters and a small number of subjects. To fully determine the psychometric properties and normative values of this novel measure, additional clinicians and subjects should be included to provide a greater understanding of what information can be gained by examining hip ROM tested with this protocol. Reliability may have been affected by movement in undesired planes due to few constraints placed on the subject during initial positioning. Furthermore, the use of the compass for rotational ROM was a novel task that could contribute to less-consistent measurements.

Future investigations should include a larger and more diverse sample with regard to age, activity level, sport demands, and anthropometrics to establish normative data with a novel method before clinical use. Future iterations of the test should consider factors that improve stability by providing additional constraints to the pelvis to isolate the hip rotation. Another consideration would be to investigate hip-rotation ROM with a pelvis rotating on a fixed femur, as this condition aligns with closed-chain athletic activities. Reliability may be further improved in the loaded condition with decreased knee friction and improved trunk restraints. In addition, measuring the loaded position with the hips in a symmetric position, as was the case with the seated (both hips flexed) and the prone (both hips extended) positions, may provide a truer comparison with those positions. However, this would require the contralateral knee to be extended to allow clearance for the measured lower leg during external rotation—possibly decreasing the ability of the subject to maintain a consistent position. With further research, this novel measure may be included along with other functional assessments of movement patterns that could predict injury in athletic populations.

Conclusion

Loaded-hip rotation can be measured in a clinical setting with good intrarater and interrater reliability. No significant differences exist between right and left hip-rotation ROM in this healthy population. Differences in ROM do exist when the motion is influenced by the testing position. Loaded-hip-rotation ROM may be of greater relevance than unloaded ROM when functional and athletic demands are considered in the pathologic hip population.

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