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ORIGINAL ARTICLE

Clinical evaluation of hip joint rotation range of motion in adults

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Summary

Introduction: Data on hip joint rotation range of motion (ROM) are rare; the methods of measurement vary and reproducibility has not been evaluated, in particular in relation to the subject's position (prone or supine, seated).

Hypothesis: Hip joint rotation ROM is symmetrical, and ROM is not modified by the patient's position when data is obtained.

Patients and methods: This series included 120 adults between 20 and 60 years old (71 women, 49 men), who had no hip, spine or lower extremity disorders. External (ER) and internal (IR) rotation ROM was obtained using a photographic method by two observers. Measurements were obtained with the patient in three positions: the dorsal decubitus (supine) (P1), and ventral decubitus (prone) (P2) with the hip in extension and seated with the hip in flexion (P3).

Results: Hip rotation ROM was P1: 68.1° (ER = 38.5°; IR = 29.6°); P2: 77.1° (ER = 41.8°; IR = 35.2°); P3: 78.5° (ER = 78.5°; IR = 37.9°) with no significant difference among the three positions. Interobserver reproducibility was satisfactory (concordance correlation coefficient (ccc) 0.7) and was comparable in the three positions with a ccc of 0.7072 (P1), 0.7426 (P2) and 0.7332 (P3), respectively. Hip rotation ROM balance was ER predominant in 47.5%, neutral in 39.5% and IR predominant in 13%. Hip rotation ROM balance was symmetric in both hips in 73 subjects (61%). Hip rotation ROM was reduced with age ($P < 0.0001$), and was 4.7° less in men ($P = 0.0078$), and in overweight subjects ($P < 0.0006$).

Discussion: Our values are probably lower than those in the literature because of the difference in study population. In our series, age, BMI and gender seemed to be determining factors. Hip rotation ROM balance is usually ER predominant or neutral. Hip rotation ROM can be measured in the three positions with no significant difference, with satisfactory interobserver reproducibility for each.

Type of study: Diagnostic prospective study: level III.

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Introduction

Internal (IR) and external (ER) rotation of the coxofemoral joint play a central role in the combined rotation of the leg and the pelvis during walking [1] and during various other activities of daily life [2]. Expectations for the functional results of hip arthroplasty have increased in patients who are younger and younger. Hip rotation range of motion (ROM) as determined during surgery for total hip arthroplasty is an important issue. The most important goal is stability [3—5]. It is difficult to determine and restore functional hip rotation with a prosthesis if reliable physiological data are not available. Existing data and methods of clinical measurement are outdated. They are usually found in studies on polyarticular ROM, or reported in specific populations. Measurement techniques vary, and are usually based on goniometry [6—12].

The aim of this study was to update the data on passive hip rotation ROM in adults using a more reliable method of photographic measurement. Our hypothesis was that hip rotation ROM was symmetric, and that ROM measurements were not influenced by the patient's position during measurement (prone, supine, seated).

Patients and methods

Patients

One hundred and twenty healthy Caucasian adult volunteers were included from the hospital were recruited randomly. Each volunteer received information and signed an informed consent form, in accordance with ethical laws related to research. Subjects with a history of hip, dorsolumbar or sacroiliac pain were not included because of the possible influence on hip rotation ROM [13—16]. For a reliable comparison of our results with those in the literature, and to obtain a homogeneous population by excluding stiff hips, we chose to exclude patients whose goniometric ROM was less than 110° in flexion, 30° in abduction and 25° in adduction [7—9]. However, none of the tested subjects were excluded based on these criteria. None of the subjects had a history of pelvic or leg surgery which could influence the results.

Data obtained included: age, gender, body mass index (BMI), and the practice of competitive ''pivot-contact'' sports (Table 1), which included the following: soccer, handball, volleyball, rugby, judo, karate, tennis as well as golf or dance.

Measurement techniques

For reliability and reproducibility the same protocol was performed on all subjects, in the same room and in the same way. Hip rotation ROM values were calculated with the patient in three positions (Fig. 1):

- position 1: dorsal decubitus (DD) (hip in flexion at 0° and knee at 90°);
- position 2: ventral decubitus (VD) (hip in flexion at 0° and knee at 90°);
- position 3: seated (hip in flexion at 90° and knee at 90°).

The examining table was attached 1 m above the floor. Leg alignment was visualized with two reference points drawn with a dermographic pencil. The first on the anterior tibial tuberosity, the second at the intersection of the bimalleolar line and the anterior crest of the tibia. To avoid any movement artefacts from hip abduction or adduction the patient was placed in a device with four parallel cylindric supports where his/her two thighs were placed. The pelvis was stabilized with a strap attached to the table and during movements, the examiner kept his arm controlateral to the thigh to prevent any hip flexion.

Table 1 Characteristics of the population including age, Body Mass Index (BMI), competitive pivot a/o contact sports.

	Variables	Nb (NbTot. = 120)	Percentage (%)
Number of subjects	Men	49	41
	Women	71	59
Age (years)	Mean	39.1	
	Standard deviation	10.8	
	Range	22—60	
	Under 30	29	24
	30—40	30	25
	40—50	35	29
	Over 50	26	22
BMI	Mean	22.8	
	SD	3.2	
	Range	17.7—30.9	
Sports	Yes	52	43
	No	68	57

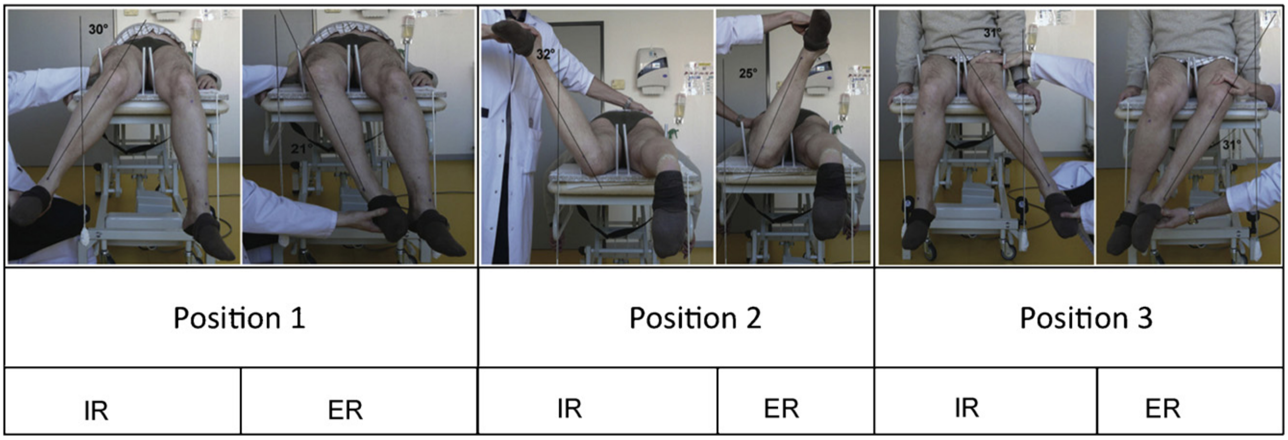

Figure 1 Measurement technique of hip rotation range of motion. IR: internal rotation, ER: external rotation, Position 1: dorsal decubitus hip in extension d. Position 2: ventral decubitus hip in extension. Position 3: seated hip in flexion.

A digital camera, Panasonic DMC-FZ18, was installed on a 1 m high tripod, 1 m 80 from the center of the examination table. Two plumb lines were attached to the table, to obtain a reference angle measurement, or 0° of axial rotation. The examiner performed passive ROM movements while the assistant took photos. This protocol was followed for both hips in each subject twice, by two independent examiners, resulting in 2X12 photos per subject. Several parameters were defined and calculated:

- the angles of external rotation (ER) and internal rotation (IR) articular ROM;
- total articular rotation ROM or $TAR = ER + IR$;
- the angle of hip rotation ROM balance in a particular hip ($EqR = ER - IR$), to define hips whose rotation was balanced (G1 with EqR between -10° et +10°), a hip with predominant external rotation (G2 with $EqR > +10°$) or predominant internal rotation (G3 with $EqR < -10°$);
- symmetry of both hips in the same subject, defined as both hips being in the same group (G1, G2 or G3).

Analysis of data

Angles were measured using Osirix software. A detailed descriptive analysis was performed. Quantitative variables were expressed as means, standard deviations ($m \pm SD$) as well as medians sorted at the 25th and 75th percentiles (interquartile intervals). Qualitative variables were expressed by group and percentage (*n*, %). Comparison of quantitative variables in the different groups was performed with the Student t test. When the validity of these tests (normal distribution, equal variance) was not confirmed, non-parametric tests were used (Wilcoxon or Kruskall-Wallis test). The relationship between two qualitative variables was tested with the Chi^2 test or the Fisher's exact test when the conditions for the Chi^2 test were not met (theoretical population ≥ 5). The value for one hip was the mean of two observations.

To limit the statistical analysis, we chose the position which resulted in the best agreement between the two observers for total articular rotation ROM (TAR), IR and ER. This agreement was evaluated with Lin's concordance correlation coefficient (ccc) taking into account the effect of the patient, with the unit measured being the hip.

For the study of hip rotation ROM balance and symmetry, multivariate analysis using a mixed linear model was also performed to identify associated factors, taking into account factors of confusion and the effect of the patient, with the unit studied being the hip. Factors with up to a 20% degree of significance in univariate analysis were introduced into the model. Selection of variables introduced into the mulitvariate model was performed with a stepwise procedure using the report of resemblance. The results of logistic regression were presented in the form of an Odds Ratio.

$P < 0.05$ was considered to be significant. The statistical analysis was performed by the *Département hospitalo-universitaire de biostatistique, épidémiologie, santé publique et information médicale* with the SAS software version 9.1 (SAS Institute, Cary, N.C., USA).

Results

Total hip rotation ROM (TAR) was 68.1° in position 1, 77.1° in position 2 and 78.5° in position 3. Distribution was normal in all positions except for the TAR in position 1. Hip rotation ROM values in the different positions were (Table 2): in position 1, IR = 29.6°, ER = 38.5°, in position 2, IR = 35.2°, ER = 41.8°, and in position 3, IR = 37.9°, ER = 40.7°. Mean hip rotation ROM balance (EqRm) between IR and ER in position 1 was 7.83° of ER (SD: 13.98°), in position 2, 6.63° of ER (SD: 19.43°), and in position 3, 2.85° of ER (SD: 11.33°). There was no significant difference in TAR values, ER, IR or EqRm in the different positions.

Overall interobserver reproducibility (Table 3) was satisfactory ($ccc > 0.7$) whatever the position with $ccc = 0.742$ for position 2, $ccc = 0.733$ for position 3 and $ccc = 0.7072$ for position 1. Agreement was better for ER than for IR, whatever the subject's position (Table 3). For simplicity and reliability, we therefore used the values in position 2 for the other statistical calculations.

An increase in age of one year corresponded to a reduction in TAR of 0.32° (odds ratio) ($P < 0.0001$). TAR in men was 4.73° (odds ratio) ($P = 0.0078$) less than women subjects. An increase in the BMI of one unit was associated with a

Table 2 Hip range of motion in relation to the different positions of measurement. IR: internal rotation, ER: external rotation, TAR: Total Articular Range of Motion. Position 1: dorsal decubitus, hip in extension. Position 2: ventral decubitus hip in extension. Position 3: seated and hip in flexion.

Variable	Mean (°)	Standard Deviation (°)	Minimal (°)	Median (°)	Maximal (°)
Position 1					
IR	29.6	9.0	2.5	29	70.5
ER	38.5	8.7	16.5	39	73
TAR	68.1	10	32.5	68	97
Position 2					
IR	35.3	11.9	4.5	33.5	75.5
ER	41.8	10.2	6	47.5	75.5
TAR	77.1	10.5	37.5	77	105
Position 3					
IR	37.9	8.4	12.5	37.5	60
ER	40.7	7.6	17	40.5	70.5
TAR	78.5	11.3	35.5	77.5	107

reduction in the TAR of 0.98° (odds ratio) ($P < 0.0006$). On the other hand practicing a sport did not influence TAR.

Three groups, G1, G2 and G3, were defined before hip measurements based on the calculation of hip rotation ROM balance, with differences in rotation of up to 10° considered to be equal in accordance with the literature [6,8—10,14]. Indeed Ellison et al. [6] only found a statistical difference when IR and ER varied by more than 10°.

Thus, there were 95 hips in group G1 (balanced hips), 114 in group G2 (external predominance) and 31 in group G3 (internal predominance). We found three factors predictive of predominant external rotation (G2): increased age ($P = 0.0384$), BMI ($P = 0.0035$) and male gender ($P < 0.001$).

Table 3 Comparison of indicators of agreement (Lin's concordance correlation coefficient (ccc)) between the two examiners in relation to the subject's position (0.8—1: good agreement; 0.7—0,8: satisfactory agreement; < 0.7: poor agreement). IR: internal rotation, ER: external rotation, TAR: total articular rotation ROM. Position 1: dorsal decubitus hip in extension. Position 2: ventral decubitus hip in extension. Position 3: seated hip in flexion.

Measurement	ccc	Global ccc
Position 1		
IR	0.7998	0.7072
ER	0.6679	
TAR	0.6538	
Position 2		
IR	0.8343	0.7426
ER	0.6627	
TAR	0.7307	
Position 3		
IR	0.7707	0.7332
ER	0.6896	
TAR	0.7393	

Table 4 Comparison of hip rotation range of motion balance (right/left). Group 1: IR = ER. Group 2: ER > IR. Group 3: IR < ER.

	Right side		
	Group 1	Group 2	Group 3
Left side			
Group 1	25	15	3
Group 2	19	39	1
Group 3	8	1	9

Symmetric hip rotation ROM balance in both hips in the same individual was found in 73 subjects or 61%. Forty-seven subjects or 39% presented with asymmetric hip rotation ROM balance between the two hips. Of the latter, and depending on which of the three groups their hips were classified in (Table 4), 34 patients were found in G1 and G2, 11 in G1 and G3, and 2 in G2 and G3. Two factors were associated with the notion of hip symmetry: age and BMI. There were statistically more subjects with lateral symmetry in the population older than 50 ($P = 0.019$). The median BMI of subjects presenting with symmetric hips was significantly higher than those of others ($P = 0.013$).

Discussion

Very few authors have specifically studied normal hip rotation ROM in adults. The most frequent referential values are therefore based on old studies whose methodology is not clearly defined [7,11]. Chevillote et al. [17] reported a lack of inter- and intraobserver reliability for physical examinations of hip ROM. Our study shows that hip rotation ROM in the VD position is reproducible.

There is a slight mean predominance of external rotation compared to internal rotation, and the mean balanced hip rotation ROM position was between 2.85° and 7.83° of ER, depending on the subject's position. Hips are balanced

Table 5 Comparison of hip rotation range of motion in the literature by photographic (P) or goniometric (G) measurement. NbT: total number of hips tested.

Authors	Year	Meas.	Population				IR (°)		ER (°)	
			NbT	Age	Sport	Gender	Mean	ET	Mean	ET
Position 3										
AAOS [7]	1965	G					45		45	
Kapandji [11]	1970	G					45		60	
Boone et Azen [8]	1979	G	109	1—53		H = 109	47	6	47	6.3
Hu et al. [18]	2006	P	85	65—85		H = 51	23	7	25	8
Kouyoumdjian	2010	P	120	20—60		H = 49	38	8.4	41	7.6
Position 2										
Kapandji [11]	1970	G					20—30		40—45	
Roaas et Anderson [9]	1982	G	105	30—40		H = 105	33	8.2	34	6.8
Ahlberg et al. [12]	1988	G	15	30—40		H = 15	37	12.2	73	10.7
Kouyoumdjian	2010	P	120	20—60		H = 49	35	11.9	42	10.2
Ellenbecker et al. [21]	2007	P	64[a]		Tpro	H = 64	27	9.8	37	9.3
			83[a]		Tpro	F = 83	37	10.1	36	8.9
			101[a]		Bpro	H = 101	23	8.3	35	9.1

[a] Dominant hips tested alone; Tpro: professional tennis, Bpro: professional baseball; Gender M/W men/women.

(ER = IR) in 39.5% of cases; external rotation is usually predominant (47.5% of cases), while predominant internal rotation is rare (13% of cases). Finally rotation of both hips is symmetric in the same subject in 61% of cases. The tendency for ER predominance and symmetric hip rotation ROM balance is more sensitive in older subjects and/or in those with higher BMI.

A comparative analysis of our results with those in the literature (Table 5) remains difficult. Indeed, the populations are quite different and it is at times difficult to determine the methodology in the reported studies. Boone and Azen [8] studied active rather than passive hip ROM. They also included children which could explain the higher ROMs reported in their study. Although the more recent study by Hu et al. [18], used a protocol of photographic measurement similar to ours, they only included subjects over 65, which explains the comparatively lower hip ROMs. In the same way, the generally lower values found by Roaas and Anderson [9] could be explained by the highly selected population of men alone, between 30 and 40 years old. Ahlberg et al. [12], included subjects from the Middle East and found very high ER values: in this particular case, daily postures associated with the cultural environment could explain these differences. The subjects in our study were all Caucasian, and ethnic origin has a significant influence on hip rotation. Variations may be secondary to congenital skeletal torsion (for example the Japanese have predominant external rotation) or inherent in the way of life (sitting cross-legged) [19,20]. Ellenbecker et al. [21], found variations or even limitations in TAR depending on the types of sports practiced by high-level athletes. They emphasize the importance of stretching exercises to develop or maintain hip rotation ROM. In a comparison of junior and senior soccer players and a control population, Manning et al. [22] found a reduced TAR in seniors, which may be explained by repetitive microtraumas associated with their athletic activity, causing capsular degeneration. Thus, some of the differences found may be explained by the variability of the studied populations.

Historically, joint ROM has been measured by different methods, including goniometer, inclinometer, potentiometer, photometer or X-ray. Our technique of photographic measurement seems rapid and precise. In the literature, hip rotation ROM and balance measurements are usually obtained by goniometry. We only found three studies that used digital photo techniques and computerized analysis—the study by Ellenbecker et al. [21] as well as the studies by Hu et al. [18] and Lavigne et al. [23] in patients who underwent arthroplasty. Although there was less interobserver variability in the study by Ellenbecker et al. [21] than in that by Ellison et al. [6] et Simoneau et al. [24] using goniometric measurement, there are no studies that statistically confirm the superiority of the former measurement technique. Cutaneous reference points are reliable and movement on the skin of less than 3 mm does not affect angles of measurement for rotation below 1°. Measurement positions were chosen to obtain the most reliable data for digital photos. No significant difference was found among the different positions, in particular between hip flexion and extension measurements. However, because this is a clinical study there are no data on variations in pelvic version in the different positions, which can influence hip rotation ROM values. [25].

Since the AAOS in 1965 [7], the seated position has become the reference for the measurement of hip rotation. For Kapandji [11], the higher hip rotation values found in flexion can be explained by a capsuloligamentary release. In a study on the influence of the examination position in the evaluation of active hip internal and external rotation, Simoneau et al. [24] found that there was a significant difference in ER in the prone position, but none for IR. In our population, hip rotation ROM was lower in position 1 by there was no significant difference between positions 2 and 3. In most recent publications, authors have preferred position 2 for a better control of the pelvis. For comparative purposes, and because of the lower interobserver variability, we consider position 2 as a reference.

The factors influencing hip rotation ROM balance in our study seem to be identical to those found in the literature. Age, gender and BMI are determinant, as shown by Roach and Miles [26], Svenningsen et al. [10] and Gilleard and Smith [27]. Unlike Ellenbecker et al. [21], practicing a pivot sport did not influence the results of our study. Nevertheless, the influence of practicing a sport is difficult to interpret in a population with a majority of amateur athletes.

Hip rotation ROM balance was predominantly in external rotation or symmetrical. These tendencies are similar to those found in the literature. In a population similar to ours, Cibulka et al. [28] found ER predominant hips in 52% of cases, symmetrical in 29% and IR predominant in only 19% of the cases. We also found that hip rotation ROM balance was symmetrical in both hips in the majority of cases.

At the same time, however, this is a purely clinical study. Radiological criteria were not included for the tested hip (femoral head, neck, anteversion ratio), the leg (skeletal torsion), the pelvis, or the spine, in particular the angles of frontal and especially sagittal lumbopelvic balance. When a total hip arthroplasty is being performed, the position of the acetabular component and the femoral stem determines not only stability, but also articular ROM of the implant and its limits. In their study on the influence of the CCD angle on ROM and the position of the implant, Widmer and Majewski [29], defined ideal hip rotation ROM balance for the implant of 60° IR and 40° ER. In the report of their computer assisted navigation results Miki et al. [30] found mean asymmetric hip rotation ROM balance results such as IR = 75° et ER = 36°. These reports differ from the physiological hip rotation ROM findings described here. Based on our results, a more physiological approach to obtain balanced hip rotation ROM during total hip arthroplasty would require ER predominance in most cases, especially in older subjects and those with higher BMI. This probably supports the use of dynamic computer assisted navigation for positioning of THA [31]. In practice, the symmetric hip rotation ROM found in both hips in most healthy subjects in our study seems to validate the necessity of a controlateral reference examination in the presence of a unilateral pathology during the preoperative clinical evaluation of THA patients.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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