

Femoral anteversion in normal adults

Ultrasound measurements in 50 men and 50 women

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The femoral anteversion (AV) angles were measured by ultrasound in a normal group of 100 adult subjects to find the normal range of anteversion, to determine the normal left/right difference, to assess the interobserver variation, and to find the correlation between AV angle and clinical hip rotation. All the ultrasound measurements were performed independently by 2 observers.

The mean AV angle was 18° in the women and 14° in the men. The mean left/right difference in AV was

3.8°, and the upper normal limit of side difference (mean + 2 SD) was 9.8°. The mean (SD) interobserver variation was only 1.9° (1.3°). The correlations between AV angles and internal and external hip rotation were significant, but not very high ($r = 0.49$ and -0.49 , respectively). We conclude that ultrasound is appropriate for measurement of femoral anteversion. Our results could be used as a basis when evaluating patients with clinically suspected rotational disorders of the femur.

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The femoral anteversion (AV) angle is important in conditions such as congenital hip dysplasia, intoeing gait in children, and torsional deformity after femoral shaft fracture. The AV angle can be reliably measured by radiographic methods, which include biplanar radiography (Dunlap et al. 1953, Rippstein 1955, Høiseth et al. 1989), and computed tomography (Weiner et al. 1978, Høiseth et al. 1989); but these examinations expose the patients to radiation. Consequently, in recent years, ultrasound has been employed for these measurements (Moulton and Upadhyay 1982, Berman et al. 1987, Terjesen et al. 1990).

We have developed a technique based on tilting of the transducer, and the results have proven reliable by comparison with biplanar radiographic methods (Terjesen and Anda 1987, Anda et al. 1988, Terjesen et al. 1990). However, further information regarding normal values and interobserver variation is required.

The aims of the present investigation were (1) to find the normal range of the AV angle in adults measured by ultrasound, (2) to find the upper limit of normal left/right (L/R) difference in AV angles, (3) to assess the interobserver variation in ultrasound measurements, and (4) to assess the correlation between AV angle and clinical hip rotation.

Subjects and methods

We examined 50 women, mean age 35 (20–60) years, and 50 men, mean age 35 (16–65) years; all of them

were without previous or present hip disease or femoral fracture. During the ultrasound examination, the subjects were lying in the supine position with the knees flexed 90° over the edge of the table. Their lower legs were strapped in the vertical position (Figure 1); thus, the posterior tangent of the femoral condyles was assumed to be horizontal.



Figure 1. The patient is correctly positioned with the knees flexed 90° over the edge of the table and the lower legs strapped in the vertical position. The tilt of the rectangular transducer is measured with a clinometer attached to the side of the transducer.

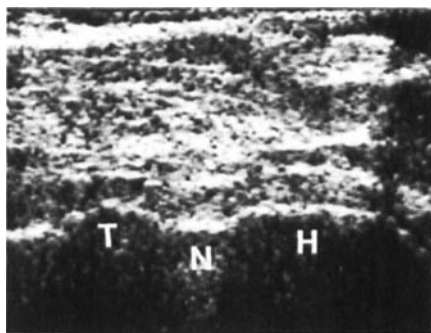


Figure 2. Ultrasound image showing the anterior outline of the femoral head (H), femoral neck (N), and the greater trochanter (T). The HT tangent appears horizontal on the monitor screen.

An ultrasound scan of the anterior outline of the femoral head, neck, and greater trochanter was obtained (Figure 2). The linear 5 MHz transducer was tilted until the anterior tangent of the central part of the femoral head and the proximal area of the greater trochanter (head-trochanter tangent) appeared horizontal on the screen. In this position the tilt of the transducer was measured with a clinometer attached to the side of the transducer (Figure 1). The real AV angle in adults was obtained by subtracting 10° from the measured angle (Terjesen et al. 1990). All the ultrasound measurements were performed independently by 2 observers. For measurements of hip rotation, the patients were lying in the prone position. With extended hips and the knees flexed 90° , passive rotation was measured with a goniometer as recommended by the American Academy of Orthopaedic Surgeons (1972) (Figure 3).

The Student's *t*-test and Pearson's coefficient of correlation (*r*) were used.

Results

The mean AV angle was 14° in the men and 18° in the women ($P < 0.001$; Table 1). The range of normal variation (mean ± 2 SD) was 3° - 33° in women and -2° - 29° in the men.

The mean interobserver variation of 200 hips was 1.9° , (range 0° - 8° , SD 1.3°). Thus, the 95 percent confidence interval was 0° to 4.5° .

The women had greater internal rotation and smaller external rotation than the men (respectively $P < 0.0001$ and < 0.001 ; Table 2). Although there were significant correlations between AV angle, internal and external rotation (Figure 4), the coefficients were only 0.49 and -0.49 , respectively.

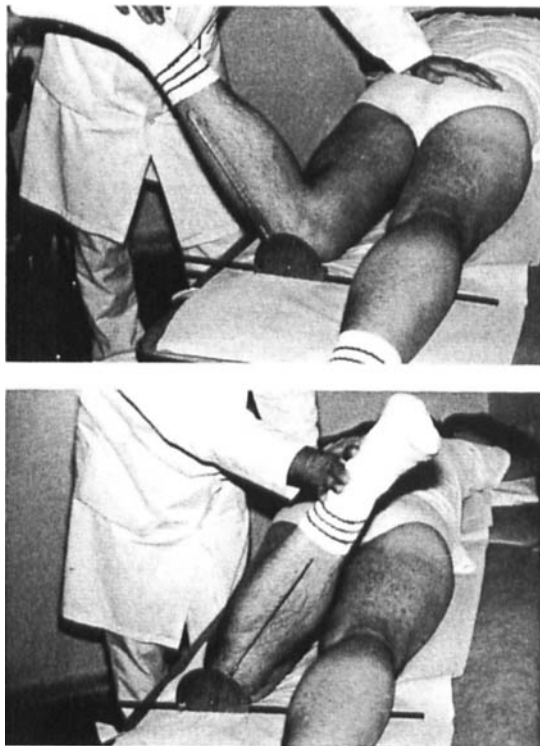


Figure 3. Measurement of internal (above) and external (below) hip rotation by means of a goniometer.

Table 1. Femoral anteversion (AV) angles measured by ultrasound in 100 normal adults

Sex	AV angle		
	Mean	SD	Mean ± 2 SD
Females	18°	7.4°	3° - 33°
Males	14°	7.8°	-2° - 29°

Table 2. Internal and external hip rotation (degrees). Mean SD

Sex	Internal rotation		External rotation	
	Mean	SD	Mean	SD
Females	48°	10°	38°	7.3°
Males	36°	8.3°	43°	9.6°

The upper normal limit of the L/R difference (mean $+ 2$ SD) was 9.8° (Table 3). Only 3 of the 100 subjects had a side difference of 10° or more. Many subjects with a L/R difference in internal and external rotation of 15° or more had a L/R difference in the AV angles within the normal range (Table 4).

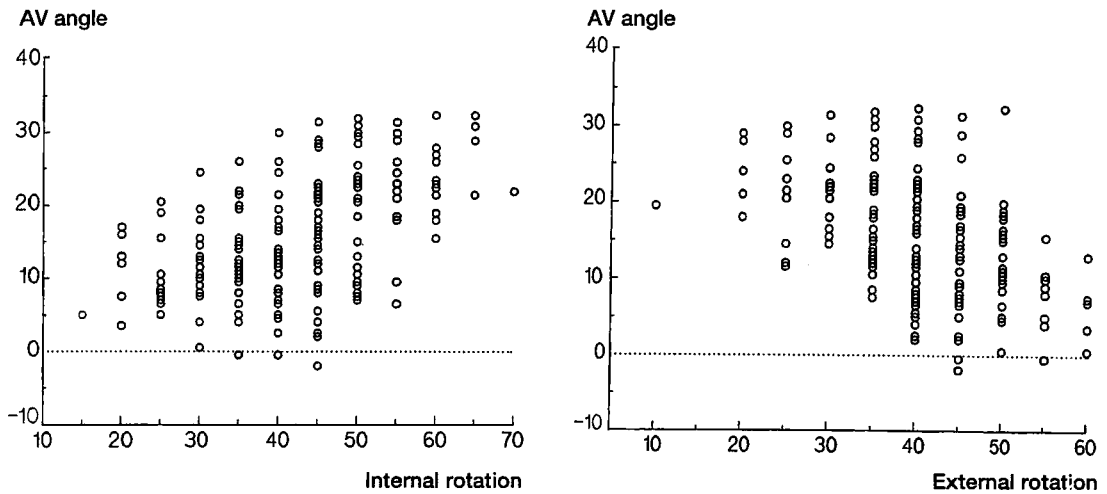


Figure 4. The relationship between AV angles and internal and external hip rotation in 200 hips.

Table 3. Left/right difference in AV angles and comparison with previous radiographic studies in adults. (Upper limit of normal variation: Mean + 2 SD)

Authors	Method	Left/right difference		
		Mean	Range	Upper limit
Own study	Ultrasound	3.8°	0°-13°	9.8°
Brouwer et al. (1981)	Biplanar radiography	4.9°	0°-15°	11.5°
Reikerås et al. (1982)	Biplanar radiography			11.8°

Table 4. The relation between AV angle and hip rotation in patients with a side difference in internal or external hip rotation of 15° or more and/or in AV angle of 10° or more

Case	AV angle	Side difference (right-left)	
		Internal rotation	External rotation
17	-6°	-10°	15°
19	-6°	-20°	10°
42	-3°	-15°	5°
46	13°	15°	-10°
49	-5°	-10°	15°
57	1°	-5°	15°
62	-2°	-10°	15°
64	10°	0°	0°
65	13°	10°	-10°
77	-3°	-15°	10°
95	-2°	-15°	5°
97	-7°	-15°	10°

Discussion

With the subject supine and lower legs kept vertical, we measured the angle between the horizontal plane and the head-trochanter tangent. This angle is consistently higher than the real AV angle determined by biplanar radiographic methods, and previous studies on dry femora (Anda et al. 1988) and studies of patients with rotational disorders of the femur (Terjesen et al. 1990) have shown that 10° should be subtracted from the measured angle to obtain the real AV angle in adolescent and adult subjects. Using this correction factor, there was a good accordance between ultrasound and biplanar radiography.

A common assumption is that ultrasound measurements are rather operator-dependent, due to many sources of error concerning both positioning of the patient and ultrasound technique. By assessing the variation between different observers, Phillips et al. (1985) found less reliability of ultrasound measurements when compared with radiographic methods.

However, the interobserver variation in our present study was small, indicating that the tilted transducer technique is reliable in clinical use when measurements are performed following a standardized pattern.

There have been no previous reports on ultrasound measurements of AV angles in a normal group of adult subjects. Most previous investigations using biplanar radiographic methods have concluded that the average AV angle in normal subjects is between 10° and 15° (Brouwer et al. 1981, Reikerås et al. 1982, Terjesen et al. 1982), but somewhat higher values were reported by Hubbard et al. (1988). Thus, our results correspond well with those of radiographic studies. We found a higher average AV angle in the female than in the male subjects, which accords with radiographic studies (de

Jong 1968, Brouwer et al. 1981). The lower limit of the normal range was -2° in the males and the upper limit was 33° in the females. We therefore suggest that AV angles outside the range of 0° - 30° should be considered abnormal.

Knowledge of the normal L/R difference in AV angle is important when evaluating torsional deformities after femoral shaft fractures. Apart from one report (Sudmann 1973), torsional deformity after femoral fractures in adults has so far been assessed by clinical methods only (Winquist et al. 1984, Kempf et al. 1985, Thoresen et al. 1985). In a normal group of 100 subjects examined by biplanar radiography, 6 percent had a side difference in AV angle exceeding 10° (Brouwer et al. 1981). According to various radiographic studies, the upper normal limit of L/R difference (mean + 2 SD) is 11° - 13° (de Jong 1968, Brouwer et al. 1981, Reikerås et al. 1982), which is in keeping with our results. Because L/R differences up to 15° (Brouwer et al. 1981) and 17° (de Jong 1968) occurred in normal subjects, we propose that a side difference of 15° or more should be regarded as a true torsional deformity after femoral shaft fractures, whereas a difference of 10° - 14° should be regarded as a possible torsional deformity.

Previous authors have warned against the use of clinical hip rotation as an indicator of rotational deformity (Reikerås and Bjerkreim 1982, Svenningsen et al. 1989a). Similar conclusions can be drawn from our study, as the correlation between hip rotation and AV angle proved to be modest. Our results did not support the experience that external rotation seemed to be a somewhat better indicator than internal rotation (Svenningsen et al. 1989a). The pattern and magnitude of hip rotation in our study correspond well with the results of Svenningsen et al. (1989b) as regards the male group, whereas internal rotation, as well as external rotation, was somewhat smaller in the females in our study. This was probably due to a higher mean age of the subjects.

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