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Digital-image analysis of the femoral shaft/neck angle in human foetuses

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Measurements were made of the femoral shaft/neck angle (CCD angle) in 106 human foetuses, aged from 16 to 38 hbd, using a "FEM-GEO_03" computer program. The values of the CCD angle in the group under examination were: mean = 140.48°, SD = 6.95°, max = 157.90°, min = 113.93°. No significant differences were found in CCD angle size between male and female foetuses or between left and right bones. Dispersion analysis showed a decrease in the CCD angle during foetal development, which suggests that adaptation to a vertical position and bipedal gait starts during pregnancy and is manifest as an inborn feature.

key words: femur, development, measurement, foetus

INTRODUCTION

The proper action of the hip joint depends on the congruence of the articular surfaces of the head of the femur and the acetabulum. One of the features determining this congruence is the femoral neck/shaft angle (CCD angle). In normal hips the CCD angle should cause the longitudinal axes of the femoral necks to cross at the point of body weight [1, 4]. Any deviation appearing during development which exceeds the normal values of the CCD angle may cause a number of disturbances, which are generally designated as developmental dysplasia of the hip [3].

Many authors have investigated CCD angle changes throughout postnatal growth [5–7] and the normal values of the CCD angle in newborns and children are well-known and commonly accepted. On the other hand, in the available literature only Dega, who published the normal values of the foetal CCD angle in 1932, has described the geometry of the proximal femur epiphysis in human foetuses [1].

The aim of the present study was to investigate changes in the femoral shaft/neck angle which occur during foetal development. A new computerised method of image analysis was applied.

MATERIAL AND METHODS

The research was performed on 106 human foetuses, 62 of which were male and 44 female. The age of the foetuses was established on the basis of femur length, using the norms supplied by Jeanty [2]. The range of foetal age in the material examined was from 16 to 38 weeks. The foetuses investigated were divided into five age-dependent groups (Table 1).

Table 1. Number of foetuses in the groups under examination

Group	Foetal age [weeks]	Sex	
		Male	Female
I	16–20	14	2
II	21–24	16	12
III	25–28	21	17
IV	29–32	7	10
V	33 and over	4	3

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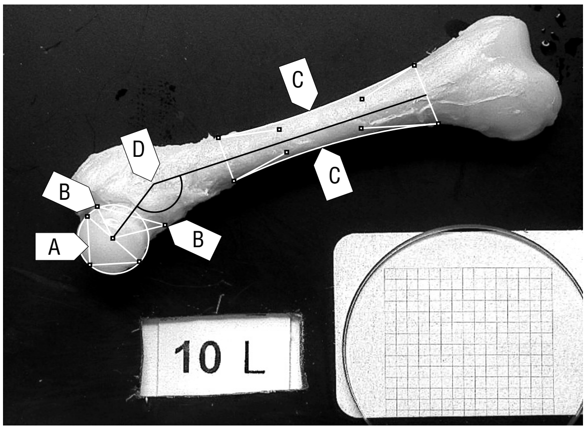

Figure 1. Method of evaluation of the CCD angle; A — triangle determining center of head of femur, B — points localized on superior and inferior margin of the neck (determining axis of the neck), C — Bezier's curves outlining borders of the shaft (determining axis of the shaft), D — the CCD angle.

The foetuses were prepared so as to form specimens composed of pelvis and both femurs with undamaged joints. The capsule of the hip joint was then cut around its attachment to the neck of the femur and the oval ligament was severed from the head. The separated femurs were photographed in anterior-posterior projection using the digital camera Olympus Camedia 4040. The images were stored in a 2272 × 1704-pixel BMP format and analysed by means of a "FEM-GEO_03" computer program. From a number of base-points and curves indicated by the program operator (Fig. 1), the computer determined the centre of the head of the femur and the axes of the femoral neck and shaft and calculated the angle between them.

Descriptive statistics, the t-Student test and Scheffe's test were used to analyse the data obtained.

RESULTS

The mean size of the CCD angle in the material investigated was 140.48° with standard deviation 6.95°. A maximal value of 157.90° was noted in a 23-week-old male foetus and a minimal of 113.93° in a 31-week-old female foetus.

A comparison of CCD angles in the right and left femurs (Fig. 2) showed no significant difference ($p = 0.083$) but in most cases (69.81%) the left angle was larger. No significant difference either ($p = 0.884$).was revealed in a comparison of male and female foetuses (Fig. 3).

In the further investigation CCD angle values were divided into groups according to foetal age. An analysis of dispersion (Fig. 4) showed a considerable de-

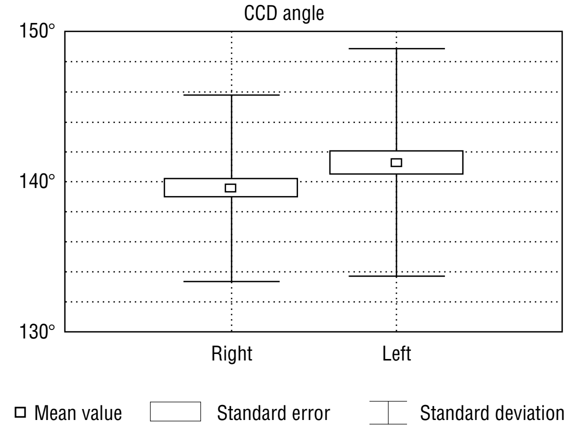

Figure 2. Comparison of CCD angles in right and left femurs.

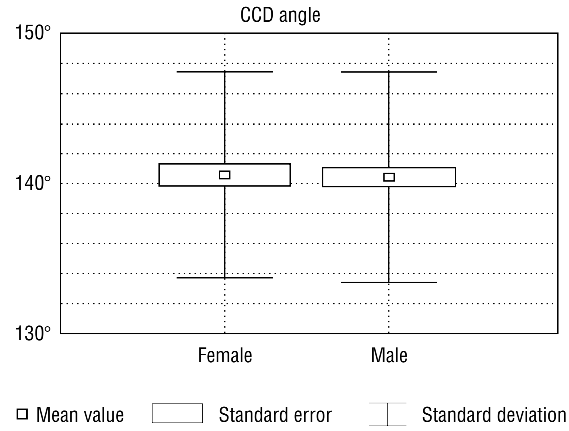

Figure 3. Comparison of CCD angles in female and male femurs.

crease in CCD angle size throughout the foetal development from a mean of 142.01° in the youngest to a mean of 137.58° in the oldest group of foetuses (Table 2). However, statistical analysis with the use of Scheffe's test of the differences between the groups examined showed them to be of no statistical significance.

DISCUSSION

In the literature reviewed [1, 3, 4] a number of factors are quoted which influence CCD angle size in postnatal life: epiphysial cartilage activity, perfusion of the femoral epiphysis, muscle action, hormones, static factors, body weight and, finally, disease. The most spectacular is the influence of age. During human growth from childhood to adulthood the CCD angle decreases significantly. This is a result of changes in body proportions followed by adaptation of the hip joint to vertical posture and gait in changed conditions.

The results of this research suggest that the process of adaptation to vertical posture and bipedal

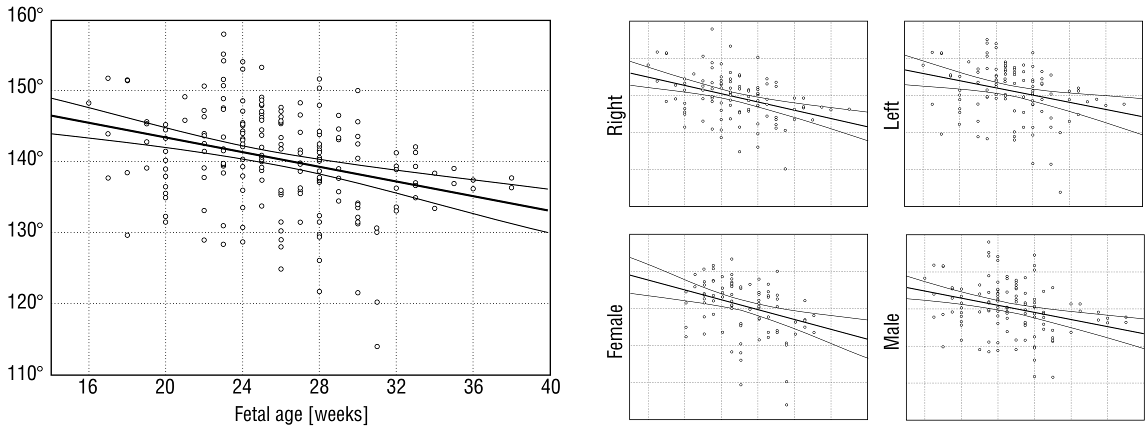

Figure 4. Analysis of dispersion of CCD angle values in the population investigated.

Table 2. CCD angle values in the groups examined

Group	Foetal age [weeks]	CCD angle (mean SD)				Total
		Male foetuses		Female foetuses		
		Right	Left	Right	Left	
I	16–20	142.35 ± 6.43	142.76 ± 6.76	139.68 ± 6.73	136.84 ± 6.50	142.01 ± 6.46
II	21–24	140.57 ± 7.24	143.68 ± 8.07	142.63 ± 5.47	144.94 ± 5.27	142.83 ± 6.80
III	25–28	138.70 ± 5.84	140.82 ± 7.94	140.31 ± 5.88	141.86 ± 6.69	140.35 ± 6.64
IV	29–32	134.57 ± 2.80	137.01 ± 8.42	137.10 ± 7.51	137.31 ± 10.30	136.62 ± 7.73
V	33 and over	137.14 ± 1.46	138.81 ± 1.77	135.66±1.97	138.42 ± 3.56	137.58 ± 2.30

gait starts during pregnancy and is manifest as an inborn feature.

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