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Evolution of the angle of obliquity of the femoral diaphysis during growth - Correlations

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Summary: Numerous studies of the bicondylar angle of the adult femur have been carried out in human anatomy, paleoanthropology and primatology. The aim of this paper is to study the evolution of this angle in relation to age and acquisition of walking in young children. Seventy-seven radiographs of children, ranging from 5 months to 17 years postnatally, and of four dead newborn were analysed. The measurements concern the bicondylar angle (A.O.F.), the collo-diaphyseal angle (A.C.D.), the length of the femoral neck (L.N.) and of the femur (L.F.) and the interacetabular distance (D.I.A.). Some children were x-rayed at different ages, which permits a longitudinal as well cross-sectional study. The results show that there is no sexual dimorphism and that the increase in the angle is closely related to the age of the child. The bicondylar angle starts at 0° at birth and then increases progressively with growth to reach adult values of at least 6°-8° between 4 and 8 years postnatally. In adults, the mean values are between 8° and 11° and the maximum range is between 6° and 14°. The obliquity angle corresponds to an angular remodeling of the femoral diaphysis, which is independant of the growth and shape of the distal femoral epiphysis. The tibiofemoral angle measures the evolution of a physiologic phenomenon, from the load "in varus" to the load "in valgus" of the lower limb. It is linked with the bicondylar angle but is different from it.

Evolution de l'angle d'obliquité de la diaphyse fémorale au cours de la croissance. Corrélations

Résumé : L'étude de l'angle bicondylaire du fémur a fait l'objet de nombreux travaux en anatomie humaine, en paléoanthropologie et en primatologie. Le but de cet article est d'en étudier l'évolution en fonction de l'âge et de l'acquisition de la marche. Soixante-dix-sept radiographies d'enfants âgés de 5 mois à 17 ans et de 4 nouveau-nés décédés ont été analysées. Les mesures ont porté sur l'angle bicondylaire (A.O.F.), l'angle cervico-diaphysaire (A.C.D.), la longueur du col (L.C.), du fémur (L.F.) et la distance interacétabulaire (D.I.A.). Certains enfants ont été radiographiés à différents âges, permettant une analyse longitudinale et transversale. Les résultats montrent qu'il n'y a aucun dimorphisme sexuel et que l'évolution de l'angle est étroitement corrélée avec l'âge de l'enfant. L'angle bicondylaire est nul à la naissance, augmente progressivement avec la croissance et atteint une valeur proche de la valeur adulte entre 4 et 8 ans. La valeur moyenne varie entre 8° et 11° et les valeurs extrêmes entre 6° et 14° dans les études faites chez les adultes. Cet angle d'obliquité correspond à un remodelage angulaire de la diaphyse distale, indépendant de la croissance et de la forme de l'épiphyse fémorale inférieure. Il est différent de l'angle tibio-fémoral dont l'évolution est un phénomène physiologique.

Key words: Femur — Knee-joint — Bicondylar angle — Pelvis — Growth

The adducted position of the knee-joint in humans positions this intermediate joint in an internal position in relation to the hip joint, which permits the knee and ankle joints to be placed almost directly under the center of gravity of the body.

In comparison with non-human primates, whose lower limb is in an abducted position during occasional bipedalism, the polygon of support is restricted. The static support is less efficient. In contrast, the displacements are more economical, since the load transmitted by the lower limb is closer to the vertical of gravity of the body, in the single stance phases of walking and running [6, 20, 26].

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The morphological skeletal feature, which permits this adduction of the whole lower limb in humans, is the bicondylar angle of the femur, also refered to as the obliquity, divergence, inclination or condylo-diaphyseal angle.

This angle was exclusively studied in adults and was compared between males and females [13]. Numerous primate and human paleontological studies were devoted to this angle among non human primates. The aim was to interprete the very high bicondylar angle, which is found on the femur of the first fossil hominids, the australopithecines, three millions years ago. This high angle was one of the main features which permitted the attribution of these fossils to the human lineage, since it indicates a clear adaptation to bipedal walking [4, 7, 8, 10, 16, 20, 23, 24].

This angular remodelling results in a drastic modification of the whole lower limb, during the passage from its "varus" position, characteristic of the newborn to its "valgus" position, characteristic of the adult. However few studies have been performed concerning the state of this feature in the newborn and its development in children, e.g. an anthropological and paleontological study [21, 23]. Salenius and Vanka [17] measured the evolution of the tibio-femoral angle in a sample of children distributed between birth and twelve years. Pauwels, in his biomechanical investigations [14], devoted some pages to the bone remodelling of the lower limb in children.

Independently, many measurements of the growth of the femoral neck, the collo-diaphyseal angle, the torsion of the lower limb, were collected in young children [1, 2, 3, 5, 9, 11, 18, 19, 25, 27].

The aim of our work was firstly morphogenetic: to measure and understand the evolution of the angle of obliquity of the femur. We then investigated correlations between the evolution of this angle and the one of the collo-diaphyseal angle, the length of the femoral neck and of the femur, and the interacetabular distance.

Radiographic and osteological materiel

The work is based on the study of available radiographic films and osteological specimens:

1) 73 pangonograms carried out on 20 children (12 girls and 8 boys), distributed between 5 months and 17 years. Among the 20 children, 12 children were x-rayed several times between 3 and 15 years, resulting in 65 x-rays.

- x-rays of the femur of 4 neonatal cadavers (2 girls and 2 boys): film without screen, mono-layer, voltage 50 Kv, permitting the observation of the cartilaginous structures.

As a whole, we used 77 radiographs of normal children.

2) 4 radiographs of three non walking children (12 years, 7 years and a half, 7 and 10 years) presenting a neurologic lesion: cerebro-motor palsy.

3) 5 femoral diaphyses of a fetus (7 monthes) and of 4 children (3, 5 and 7 years).

4) 2 femurs of a subadult orang-outan.

Methods

Measurements on the x-rays

The five measurements, shown in Fig. 1, were taken:

1) Bicondylar angle of the femur: angle α between the diaphyseal axis and the perpendicular line to the infracondylar plane. The diaphyseal axis links the middle of the infracondylar segment and the middle of the proximal diaphyseal segment, located 2 centimeters below the lesser trochanter.

2) Collo-diaphyseal angle: angle β between the diaphyseal and cervical axis.

3) Length of the neck: length between the summit of the collo-diaphyseal angle and the center of the femoral head.

4) Interacetabular distance: distance between the centers of the two femoral heads.

Methodological adjustments

Since the observed bicondylar and collo-diapyseal angles can be affected by medial or lateral rotation of the femur, relative to the radiographic plane, these rotations were appreciated by means of the observation of three views:

1) View of the head of the fibula: the visualisation of the superior tibio-fibular space translates into a medial rotation. At the opposite, the displacement of the head behind the tibia translates into a lateral rotation.

2) View of the lesser trochanter: It is clearly visible in lateral rotation and may be absent in medial rotation.

3) View of the patella: It may be moved inwards in medial rotation and outwards in lateral rotation.

To assess the degree of error due to rotation, a femur was x-rayed in 15° of medial and lateral rotation as well as in neutral position. On these films, we took the two angular measurements by means of the same landmarks as mentioned above. The rotations produced ± 1° of change in the bicondylar and collo-diaphyseal angles. These variations can be explained by the fact that the diaphyseal axis is displaced towards the lateral side in case of medial rotation or towards the medial side in case of lateral rotation (Fig. 2). Consequently on those several x-rays, for which rotation was observable, the measured bicondylar and collo-diaphyseal angles were corrected by +1°, when the femur was in medial rotation and by -1°, when the femur was in lateral rotation.

Osteological measurement

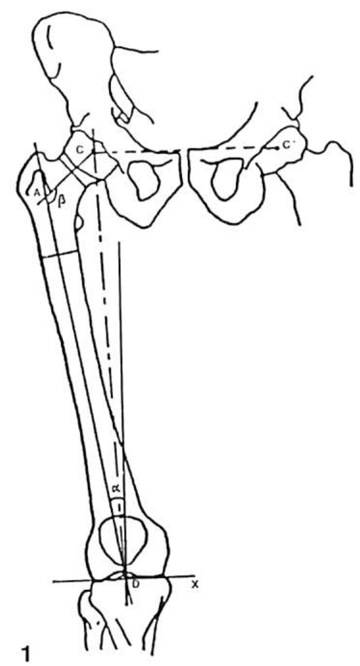
On dry bone, the epiphysis can be separated from the diaphysis. So both bicondylar and diaphyseal obliquity angles can be measured. This latter angle is measured in relation to the physeal plane and not to the infracondylar one (Fig. 3).

Results

Formation of the bicondylar angle in children

1) *Analysis of the x-rays of the newborn and of the 5 immature femurs:* X-rays of the femurs of the newborn show that the physeal plane, which separates the cartilaginous epiphysis from the diaphysis, is horizontal. The diaphysis is perpendicular to this plane and there is no angle of obliquity (Fig. 3a).

The osteological specimens (Fig. 3b) represent the diaphysis of a seven months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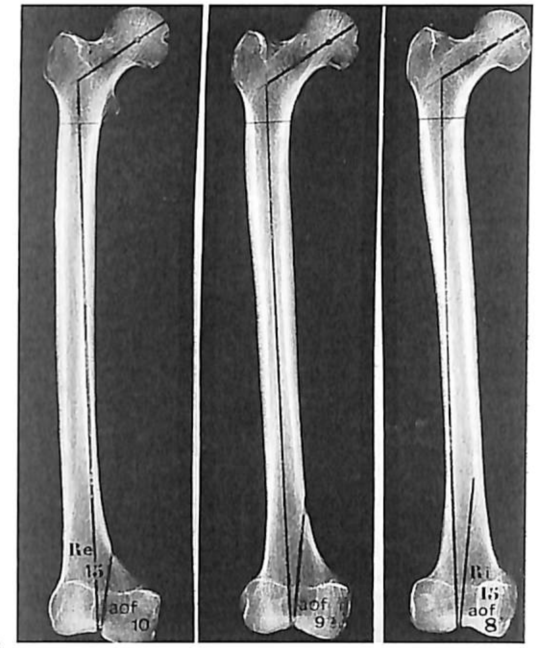
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Fig. 1
Drawing of the measurements carried out on the radiographs of the children: *C-C'*, Biacetabular distance, *A-C*, Length of the femoral neck, *C-D*, Length of the femur, α, Bicondylar angle, β, Collo-diaphyseal angle. The x-axis corresponds to the infracondylar plane

Fig. 2
Comparative measurements of the bicondylar angle α (labelled here as A.O.F., femoral obliquity angle) and the collo-diaphyseal angle β of a dry femur, x-rayed under 3 different incidences: a) in lateral rotation of 15°, b) in neutral position, c) in medial rotation of 15°. The bicondylar angle is respectively 10°, 9° and 8° and the collo-diaphyseal angle 124°, 123° and 122°

fetus (0°) and of four children, respectively six months (2°), three years (5°), five years (9°) and seven years old (9°). One observes that the angular remodelling affects exclusively the diaphysis, independently from the growth of the distal epiphysis. Thus, in humans, the femoral obliquity is a diaphyseal character, whose reference is the physeal plane, located at the distal end of the diaphysis.

2) *Analysis of the x-rays of three non locomotor clinical cases:* The x-rays of two non walking children show a diaphyseal angle and a bicondylar angle of 0°. The first one, twelve years old, has a congenital hypotony of the trunk. His way of life is the sitting position in a wheelchair or the lying position. The second child has a palsy of the lower limbs. Seven and a half years old, he has also a mode of displacement in a wheelchair. The third child has a spastic diplegia. In the absence of a suited therapeutic treatment, he was non walking till the age of six years, at which time he was admitted to a center of re-education. Standing is undertaken, as well as learning to walk. The diaphyseal angle is 1.5° at the age of 7 years, as the bicondylar angle. At the age of 10 years, while he walks with an orthopedic walker one to two hours a day, the two angles reach 5°.

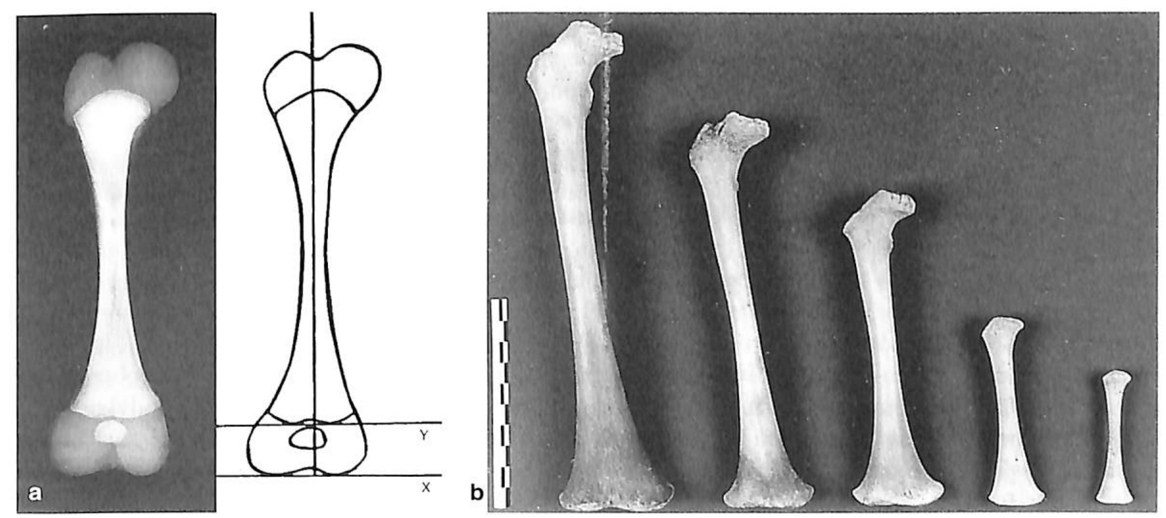

Fig. 3a, b
a Femurs of a human newborn: on the left, radiography; on the right, representation of the infracondylar (x) and physeal (y) planes. **b** Femoral diaphysis of a seven-months fetus and of four children, seven months, three, five and seven years old. The proximal and distal epiphysis are unfused at these ages and have been removed. One observes that the angle of obliquity of the femur remodelled the diaphysis in human children, independently of the distal epiphysis. The reference measurement of this angle is the physeal plane

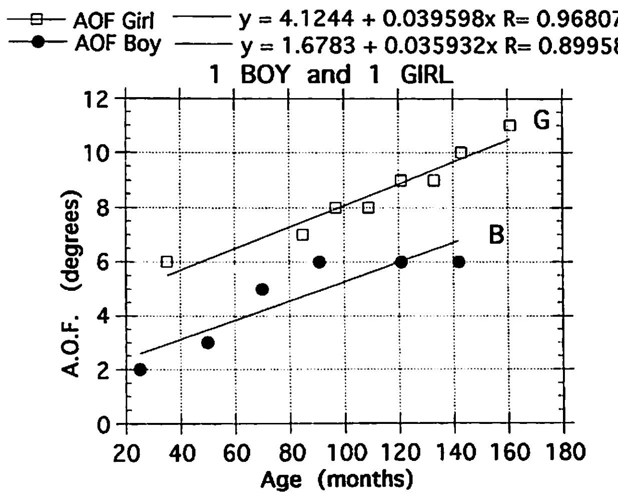

Fig. 4
Plot showing the increase of the bicondylar angle of the femur (A.O.F. in degrees) versus age (in months) in a boy, studied between 2 and 12 years on 6 successive radiographs, and in a girl, studied between 3 and 13 years on 8 successive radiographs. The equation of the line of regression is presented for each child. One observes that the coefficient of correlation is very high in both cases

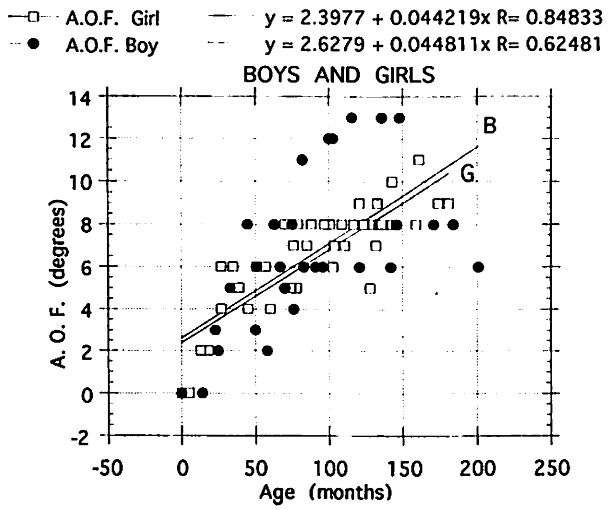

Fig. 5
Plot showing the increase of the bicondylar angle of the femur (A.O.F., in degrees) versus age (in months) for all the studied children. One observes that the coefficient of correlation between these two parameters is lower in boys than in girls and that these coefficients are globally lower than those observed in the longitudinal study, presented in Fig. 4. One notices that the lines of regression corresponding to boys and girls are parallel

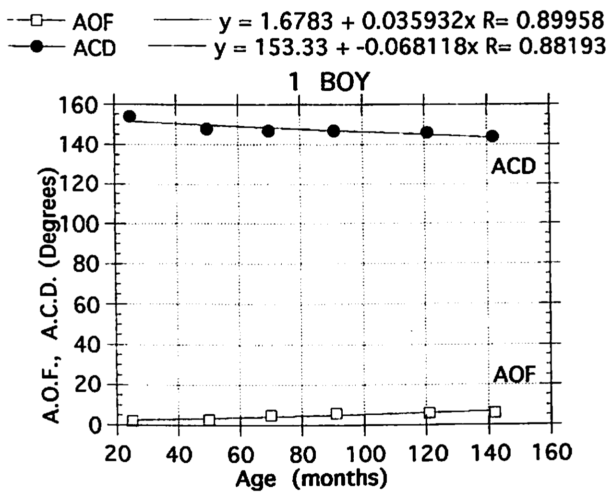

Fig. 6
Plot showing the decrease of the collo-diaphyseal angle (A.C.D., in degrees) and the increase of the bicondylar angle of the femur (A.O.F., in degrees) versus age (in months) in a boy studied between 2 and 12 years on 6 successive radiographs. One notices that the coefficients of correlation are almost identical

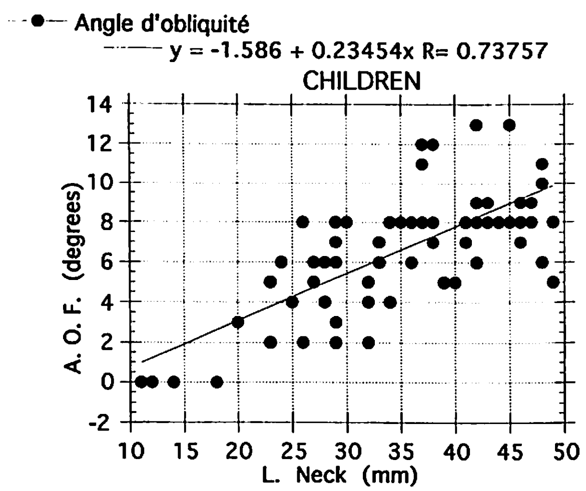

Fig. 7
Plot showing the increase of the bicondylar angle of the femur (A.O.F., in degrees) versus the lengthening of the femoral neck (in millimeters) for all the children studied

On the four radiographs, the physeal plane is clearly visible and shows that the diaphysis remained strictly straight in the first two cases and acquired a very slight and then a clear obliquity in the third case.

3) *Longitudinal and cross-sectional analysis of the plots of evolution of the bicondylar angle in children:* Before this analysis of growth, let us mention that the extreme range of variation of this angle is from 6° to 14° and that the means of different populations are between 8° and 11°. The sexual dimorphism can be significant or not significant according to the different populations, the angle being higher in the women in this case [13, 23].

On the Fig. 4 (plot 1), we present, for two children, a longitudinal observation of the growth of the bicondylar angle versus age. It concerns a girl, studied between 3 and 13 years on 8 successive radiographs and a boy, studied between 2 and 12 years on 6 successive radiographs.

These two growth curves show that the coefficient of correlation is very high between the age of the subject and the bicondylar angle: $R = 0.96$ for the girl and $R = 0.90$ for the boy.

We also calculated the correlation between the growth of the angle and the one of the length of the femur, measured at each age for each subject: the coefficient of correlation is also high: $R = 0.92$ for the boy and $R = 0.90$ for the girl.

If these two growth curves offer no statistical value, they are important however for the process under investigation, since they are longitudinal. Longitudinal studies are few for they are very difficult to obtain. The aim is to practice repeated radiologic examinations on the same child.

Thus sexual dimorphism observed between the boy and the girl must not be considered as significant. Particularly the higher value of the angle and its more continuous growth in the girl do not offer any statistical signification. On the basis of the curve displayed by the girl, let us keep in mind that the angle can rise very steadily between birth (0°) and 35 months, i.e. almost 3 years (6°).

The line of regression of the boy is interrupted at 12 years, since we do not have further information. This interruption does not mean a stop of growth of this angle.

On the Fig. 5 (plot 2), the cross-sectional study of the 77 radiographs of children ranging from birth to 17 years show that the correlation between the angle of obliquity and age is weaker than in longitudinal observations but remains significant: $R = 0.84$ in girls and $R = 0.62$ in boys. The two lines of regression corresponding to boys and girls are strictly parallel, showing the absence of sexual dimorphism for this angle in this sample.

This angle increases rapidly at the end of the first and during the second, third and fourth years to reach low adult values (6° to 8°) between four and eight years. From seven years onwards, the variability of the adult values (8° to 13°) is observed. The increase of the bicondylar angle occurs mostly during the first years of childhood between one and four years, which closely parallels the developmental chronology of the acquisition of standing and walking.

The coefficients of correlation calculated between the length of the femur and the bicondylar angle, for the same sample, are very close to the preceding ones: $R = 0.87$ in girls and $R = 0.58$ in boys.

Table 1. Coefficients of correlation (R) obtained between the five studied parameters and age (top) and between each parameter taken two to two (bottom). In the first and second columns, R corresponds to 6 and 8 successive radiographies taken respectively in a boy and in a girl (longitudinal study). In the third column, R corresponds to all the studied children (cross-sectional study). R is presented in decreasing order for the boy (first column)

Parameters	R (1 boy)	R (1 girl)	R (children)
Age/femur length	0.998	0.977	0.957
Age/biacetabular dist.	0.991	0.967	0.872
Age/neck length	0.969	0.937	0.827
Age/obliquity angle	0.899	0.968	0.722
Age/cervico-diaph. angle	0.881	0.945	0.686
L. femur/DIA	0.992	0.915	0.945
L. femur/L neck	0.969	0.980	0.908
DIA/L neck	0.949	0.844	0.881
L. femur/AOF	0.921	0.905	0.706
DIA/AOF	0.913	0.973	0.558
L. neck/AOF	0.907	0.839	0.737
L. Femur/ACD	0.896	0.951	0.712
DIA/ACD	0.893	0.888	0.650
AOF/ACD	0.865	0.914	0.698
L. Neck/ACD	0.788	0.900	0.635

DIA, biacetabular distance; *AOF*, bicondylar angle; *ACD*, collo-diaphyseal angle

Correlations between the five studied parameters: longitudinal study

In the first part, we focused our study on the femoral bicondylar angle, one of the five radiographic measurements. In the second and third part, we present both longitudinal and transverse studies of the four other parameters: their evolution with growth and the correlations between each parameter. The bicondylar angle is present as a parameter of comparison and an element of these correlations.

1) Evolution of the four parameters with growth: We present on Table 1 (Top), for the five studied parameters, the coefficient of correlation with age, for one girl, studied between 3 and 13 years on six successive radiographs and for one boy, studied between 2 and 12 years on 6 successive radiographs.

The coefficient of correlation is very high in all the cases.

On Fig. 6 (plot 3), the evolution of the cervico-diaphyseal and bicondylar angles are presented for the boy. The slope (a) of the line indicates the speed of growth of each parameter.

2) Growth correlations between the 5 studied parameters: We present on Table 1 (Bottom) the coefficient of correlation for all the pairs of parameters. It is high in most cases.

The pair of parameters, interacetabular distance versus bicondylar angle presents a significant coefficient of correlation in this longitudinal study ($R = 0.97$ for the boy and $R = 0.91$ for the girl), while this coefficient is not significant in the cross-sectional study ($R = 0.56$).

We must notice that, in this longitudinal study, children could not be studied soon after birth, but only from the age of two or three years. On the other hand, the maximum studied age is 13 years. So this longitudinal study must be completed by the following cross-sectional study, including four newborn and children reaching the age of 17 years.

Correlations between the five studied parameters: cross-sectional study

1) Evolution of the four parameters with growth: In Table 1 (Top), we present for

use of comparison with the longitudinal results, the coefficients of correlation obtained for the five parameters studied in the whole sample.

The three parameters presenting the most significant coefficients of correlation are the parameters of length of the femur, of the neck and of the interacetabular distance.

In contrast, we notice that the two angular parameters (bicondylar and collo-diaphyseal angles) do not offer an as significant correlation with age as in the longitudinal study. This indicates the variability of growth when one compares different children.

2) Growth correlation between the five parameters studied: We present in Table 1 (Bottom), for comparison, the coefficient of correlation for the 10 pairs of parameters studied.

The 3 pairs of length parameters are the first, followed by 4 pairs of parameters presenting very close coefficients of correlation, included between 0.74 and 0.70. By decreasing order, these pairs are: length of the neck/bicondylar angle, length of the femur/collo-diaphyseal angle, length of the femur/bicondylar angle and bicondylar/collo-diaphyseal angles.

We present on the Fig. 7 (plot 4) the growth of the length of the neck versus that of the bicondylar angle. The slope of the line indicates a mean rate of growth.

We must notice that the coefficient of correlation linking these parameters are higher in the longitudinal study, which again indicates the variability of growth of these parameters in children.

In the same manner, for the three other pairs of parameters, the coefficients of correlation are not significant, while they were significant in the longitudinal study, however less significant than for the seven anterior pairs.

Discussion

The formation of the femoral bicondylar angle and the role of the diaphysis in this angular remodelling during growth had never been shown. This study shows that:

1. *The femoral diaphysis of the fetus and newborn is vertical: there is no angle of obliquity.* The observation of radiographs, anatomical and osteological specimens shows that the physeal plane is horizontal and that the angular remodelling of the axis of the femoral diaphysis must be referred to the physeal plane which remains horizontal during growth, in the functional position. The infracondylar plane is the only reference to measure the angle of obliquity of the femur in adults, since the fusion of the distal epiphysis to the diaphysis eliminates the physeal plane.

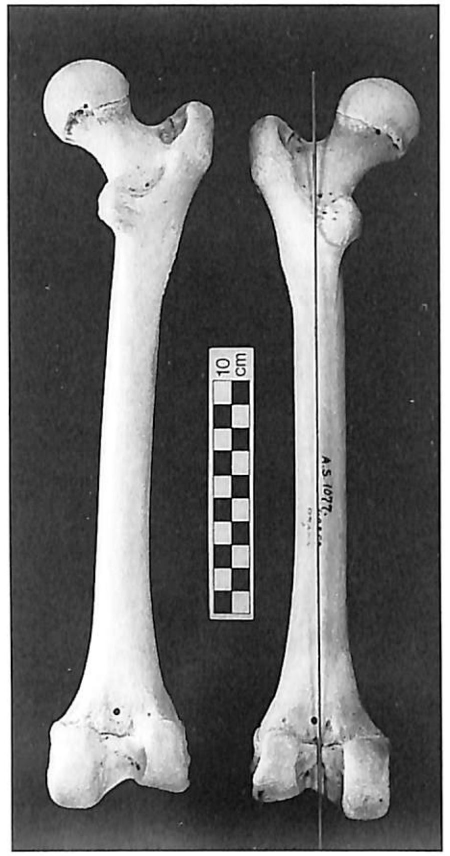

Fig. 8
Posterior view of the femurs of a subadult orang-outan. The higher internal condyle produces a high bicondylar angle (9°), measured in relation to the infracondylat plane. However the diaphysis is strictly vertical, as shown by the spine perpendicular to the epiphyseal suture

The femoral bicondylar angle is almost identical to the obliquity of the diaphyseal axis in humans, since the two femoral condyles display about the same height. Such is not the case in non-human primates: the medial condyle is far higher than the lateral condyle, which produces a high femoral obliquity angle. This angle is measured in relation to the infracondylar plane. Conversely, the obliquity angle of the diaphyseal axis is always zero (Fig. 8). The specificity of the human femur is precisely the presence of a high obliquity angle of the diaphyseal axis, which does not exist in any other primate [21].

It is well known that, in all the long bones, the growth of the epiphysis -distal and proximal- is independent from that of the diaphysis. The epiphyses are developed from a spherical growth cartilage, whose activity is centripetal. At the opposite, the diaphysis gets longer by the effect of a discoïd growth cartilage, whose growth is axial [15]. Thus the distinction that we establish, on the femur, between the two planes, infracondylar and physeal, conforms totally to this independence of growth.

Pauwels [14] suggested that increased compression on the medial portion of the distal femoral epiphyseal cartilage and the increasing valgus position of the knee as a child acquires an upright bipedal posture, would lead to additional medial metaphyseal apposition and the formation of a bicondylar angle.

2. The obliquity angle is totally different from the tibio-femoral angle, which measures the evolution of a *physiological phenomenon* and not of an osteological angular remodelling. This angle between the axes of the femoral and tibial diaphysis shows the evolution of the load of the lower limb from varus to valgus. In the newborn, when the angle of obliquity is zero, the tibio-femoral angle is 20° on average. At birth, the lower limbs assume a marked genu varus position, with abduction of the thigh and adduction of the legs. As the child begins to stand and walk, the tibio-femoral angle decreases, passing 0° between 1.5 and 2 years on average and reaching a peak valgus position of about 10° around 3 years, only to decrease to a relatively constant of approximately 6° by 6-7 years [17]. Consequently, there is little loading of the leg in bipedal posture and locomotion prior to late in the first postnatal year and little loading with the knee in a valgus position until about 2 years postnatally, at which time the child is usually both actively bipedal and is maintaining the leg in a full, or even exagerated, valgus position. It is during this time period that there is most of the change in the bicondylar angle, although it continues to increase for several additional years. A low adult value is reached between 4 and 8 years (cf. Figs. 4 and 5, radiographic growth series and [23] osteological growth series).

3. The emergence and evolution of the bicondylar angle is thus proved to be dependent upon the levels and *especially patterns of biomechanical loading of the knee commensurate with a normal postural and locomotor development.* This angle does not appear in non-walking children. The age of stabilisation of this angle remains an open question. According to Salenius and Vankka [17], the tibio-femoral angle would stabilize around 6-7 years postnatally. The femur would increase its length, while maintaining a constant angle. Our study does not permit to answer precisely for the bicondylar angle. For one of the children, the angle continued to grow significantly from 7 until 13 years, for another child, it was not modified after 7 years.

4. The bicondylar angle of the femur and its mode of development are ignored in the medical litterature, while it plays an important role in the modifications of the different axes of the lower limb in children. The recent study of Mc Mahon et al. [12] proposes a mechanical pattern of growth of the lower limb of the child from birth to the age of 8 years. The authors only use the tibio-femoral angle and the collo-diaphyseal angle for the data of angular growth. We showed that that the bicondylar angle opens by about 8°-10° in the same time as the collo-diaphyseal angle closes by around 10°. The model offered by these authors would be more objective if the evolution of the bicondylar angle was taken into account. The very interesting mechanical results from a clinical point of view would gain in credibility and precision. Particularly, the authors observe that the femoral diaphysis retains always a high moment in varus, at the opposite of the other considered segments, femoral and tibial metaphysis, knee-joint and tibial diaphysis. This moment would be probably higher if the evolution of the bicondylar angle was taken into account. Anyway this result can be explained, in our point of view, if one admits the growth of this parameter, although it is not taken into account directly in this study.

Conclusion

The bicondylar angle of the femur is zero at birth and develops in relation to growth. This angular remodelling of the diaphysis develops on the internal part of the distal physis. Its value is highly correlated with the age of the subject and with the length of the femur. Its development is linked with the verticalisation and the acquisition of walking. Its reaches a value close to its definitive value around the age of 8 years, shortly after the stabilisation of the tibio-femoral angle.

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References

1. Bedouelle J (1982) Antétorsion des cols fémoraux. Rev Chir Orthop 68: 5-13
2. Cahuzac JP (1989) Vices de torsion des membres inférieurs. Cahiers d'Enseignement de la SOFCOT. Expansion scientifique, Paris. Conférences d'enseignement, pp 35-45
3. Fabry G, McEven GD, Shands AR (1973) Torsion of the femur. A follow-up study in normal and abnormal conditions. J Bone Joint Surg 55: 1726
4. Halaczek B (1972) Die Langknochen der Hinterextremität bei Simischen Primaten. Juris Druck und Verlag, Zürich
5. Harris NH (1976) Acetabular growth potential in congenital dislocation of the hip and some factors upon which it may depend. Clin Orthop 119: 99-106
6. Heiple KG , Lovejoy CO (1971) The distal femoral anatomy of Australopithecus. Am J Phys Anthrop 35: 75-84
7. Johanson D and Coppens Y (1976) A preliminary anatomical diagnosis of the first Plio/Pleistocene hominid discoveries in the Central Afar, Ethiopia. Am J Phys Anthrop 45: 217-222
8. LeGros Clark WE (1947) The importance of the fossil Australopithecinae in the study of human evolution. Sci Prog 35: 377-395
9. Lerat J L et Taussig G (1982) Les anomalies de rotation des membres inférieurs. Rev Chir Orthop 68: 1-74
10. Lovejoy CO, Heiple KJ, Burstein AH (1973) The gait of Australopithecus. Am J Phys Anthrop 38: 757-780
11. Lude L, Taillard W (1964) Le développement de la congruence articulaire de la hanche chez l'enfant. Rev Chir Orthop 50: 758-777
12. Mac Mahon EB, Carmines DV, Irani RN (1995) Physiologic bowing in children: an analysis of the Pendulum Mechanism. J Pediatr Orthop , Part B, 4: 100-105
13. Parsons FG (1914) The characters of the English thigh bone. J Anat Physiol 48: 238-267
14. Pauwels F (1979) Biomécanique de l'appareil locomoteur. Springer-Verlag, Berlin Heidelberg New York
15. Pous JG, Dimeglio A, Baldet P, Bonnel F (1980) Cartilage de conjugaison et croissance. Notions fondamentales en orthopédie. Doin, Paris
16. Robinson JT (1972) Early hominid posture and locomotion. University of Chicago Press, Chicago
17. Salenius P, Vankka E (1975) The development of the tibiofemoral angle in children. J Bone Joint Surg [Am] 57-A: 259-261
18. Shands AR, Steele MK (1958) Torsion of the femur. J Bone Joint Surg 40: 803
19. Taussig G, Delor M H, Masse P (1976) Les altérations de croissance de l'extrémité supérieure du fémur. Rev Chirg Orthop 62: 191-210
20. Tardieu Ch (1983) L'articulation du genou chez les Primates. Presses du C.N.R.S., Paris
21. Tardieu Ch (1993) L'angle bicondylaire du fémur est-il homologue chez l'homme et les primates non humains ? Réponse ontogénétique. Bull Mem Soc Anthrop Paris 5: 159-168
22. Tardieu Ch (1994) Morphogenèse de la diaphyse fémorale chez l'homme. Signification fonctionnelle et évolutive. Folia Primatol 63: 53-58
23. Tardieu Ch, Trinkaus E (1994) The early ontogeny of the human femoral bicondylar angle. Am J Phys Anthrop 95: 183-195
24. Vallois H (1920) L'épiphyse inférieure du fémur chez les Primates. Bull Mém Soc Anthrop Paris 10: 27-54
25. Von Lanz T, Mayet A (1953) Die Gelenkörper des menschlichen Hufgelenkes in der progredienten Phase ihrer umwegigen Ausformung. Z Anat 117: 317-345
26. Walmsley T (1933) The vertical axes of the femur. J Anat 67: 284-300
27. Watanabe RS (1974) Embryology of the human hip. Clin Orthop 98: 8-26

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Applied anatomy for the resection approach of glossopharyngeal nerve and tympanic nerve (P33) Ju Xuehong, Wang Xuehua, Zhu Shijie. Department of Anatomy, Weifang Medical College, Weifang 261042

Glossopharyngeal nerve and tympanic nerve was studied on 100 adult skulls and 24 sides of cadaveric head specimens. Some landmarks,such as mastoid process, the inferior border of tympanic plate and styloid process, could be helpful to decide the operative approach. The average distance and the shortest distance between the inferior border of tympanic plate and the tympanic cavity were 9.4 ± 1.9 mm and 5.3 mm respectively. The glossopharyngeal nerve can be easily separated from the carotid sheath at the anterolateral surface. The inferior ganglion is formed near the jugular foramen by glossopharyngeal nerve. The tympanic nerve leaves it from either the lateral (42.8%) or the posterior (42.9%) or the anterior (14.3%) side. The operative approch and technique are discussed.

Anatomical study and clinical application of superficial palmar digital veins in finger replantation (P39) Han Mingtao, Zeng Tao, Yu Xianjuan, Tan Xunxiang. Wendeng Orthopedic Hospital, Wendeng 264400

The superficial palmar digital veins were anatomized in 10 adult hand spcimens with methylene blue injection through the ulnaris or radialis artery. They originate from the veinlets of the finger-belly running proximately to form 2~3 tiny superficial veins at the distal end of the middle-segment of the finger. Connecting branches to the dorsal of the finger side were observed. The superficial palmar digital veins join together in wed and drain into the dorsal palmar veins or the marginal vein arch of the palm. The average diameters of the superficial palmar digital veins are 0.3~0.6 mm at the distal transversal stria. 0.4~0.7 mm at the middle point of the midsegment of the finger and 0.6~1.0 mm at the root of the finger. In clinical practice, 93 fingers of 68 patients were replanted with anastomosis of the superficial palmar digital veins, of which, 88 fingers were successfully replanted. These indicate that anastomosis of the superficial palmar digital veins is critical for the veinal drainage of replanted fingers.

Vascular communications between the left ventricular wall and the chamber in fetal heart (P45) Zhang Xiaodong, Tao Ping, Xia Jialiu, Tian Long, Chen Li. Department of Anatomy, Peking Union Medical University, Beijing 100005

Objective:To study the mechanism of myocardial reascularization from the aspect of embryology. **Methods**: The coronary arteries of 13 fetal hearts aged various months were perfused with Chinese ink. Histologitical sections were made to study communications between the left ventricular wall and the chamber under microscope. **Results**: The ventricular wall was built like the spongy structure with many communicating channels with the chamber. The arrangement, distribution and relative proportion of these channels including intertrabecular spaces and myocardial sinusoids underwent remarkable changes during appositional growth and structural reconstruction. It showed that fetus repeated certain stages of phylogenesis in its ontogenesis. **Conclusions**: Direct myocardial revascularization by laser was similar to the mode of bringing blood from heart cavity into the myocardium in early period of fetal heart.

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