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Developmental Pattern of Tibio-Femoral Angle in a Cohort of Nigerian Children: A Preliminary Report

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ABSTRACT

A cohort measurement of tibio-femoral angle (TFA) is more meaningful and reliable than a cross-sectional survey in investigating TFA pattern of development. This study reports the pattern of knee angle development in a cohort of 152 normal Nigerian children during the first 12 months of life. The infants' tibio-femoral angle, inter-condylar, and inter-malleoli distances were measured at monthly intervals using clinical methods. Age-reference values were generated. Results showed that the developmental pattern of tibio-femoral angle is extreme varus at birth with values ranging from 5° to 25°. The mean varus at birth (13.2±3.7°) decreased to reach the lowest value (5.6±0.7°) at nine months and then rose slightly to (6.9±1.2°) at 12 months. None of the infants exhibited a measurable valgus angle. In conclusion, the chronological development of TFA in these cohort Nigerian infants was varus, maximal at birth and decreasing during first 12 months of life. The age-reference values herewith generated may serve as a useful guide in evaluating lower limb alignment in Nigerian children, age 0 to 12 months.

INTRODUCTION

The developing child is the centre of potential adoration as well as a point of critical evaluation by well meaning relatives and friends. Any abnormality observed in the overall appearance of the child is certain to arouse comments and become a source of worry to the parents.¹ Apparent bowing appearance (physiological genu varus) of the lower extremities is a common condition seen in children in the first few years of life, particularly after they begin to walk. Pediatricians, family physicians, orthopaedists, and physiotherapists are frequently called on to evaluate these children for excessive bowing.² Age-reference values usually derived from investigations of TFA developmental patterns in children are important in guiding these clinicians in such evaluations. Age-reference values may also facilitate the diagnosis of pathological conditions such as Blount's disease.

The patterns of tibiofemoral angles (TFA) in children from different parts of the world have been studied using various measuring methods such as roentgenographic, photographic measurement, and clinical methods.³⁻¹¹ Clinical methods, which have been shown to be reliable enough for day to day practice, include goniometric measurement and intermalleoli and intercondyli distances.^{6,12-15} These studies have reported differences in the patterns of development and in the normal limit of tibiofemoral angles of children from different populations suggesting racial differences.^{5,6} Chinese children were reported to present with varus angle at birth, maximal valgus angle at age 3 years, and neutral angle (0°) at age 8 years with a range indicating that children aged between 3 and 11 years exhibit a significant degree of varus ≤5°. American children were reported to exhibit maximal varus angle at age 6 months, neutral angle at age 18 months, maximal valgus of 8° at age 4 years followed by gradual decrease to less than 6° at 11 years.⁵ The developmental pattern observed in Korean children was varus angle before age 1

year, neutral at 1.5 years, increasing genu valgum with maximum value of 7.8° at 4 years, followed by a gradual decrease to approximately 5 to 6° of genu valgum of the adult level at 7 to 8 years of age.¹

Three cross-sectional surveys have documented the patterns and normal values of tibiofemoral angles in Nigerian children.^{7,15,16} Two of these studies used clinical methods in measuring TFA while the third one used a photographic method. The aforementioned three studies involved infants and children aged 0 to 5 years, 1 to 10 years, and 0 to 12 years.^{7,15,16} Omololu et al. reported varus angle (0.27° to 1.95°) at ages 1 to 3 years, and this reduces to neutral (0°) at age 5 years in girls and age 7 years in boys.¹⁶ Both sexes had no bowing after the age of 7 years. The valgus angle was found to be constant at about 11° at ages 7 to 10 years in both sexes. In another survey from Nigeria, Oginni et al reported that knees were maximally bowed in the first 6 months.⁷ At 21 to 23 months, the distribution of angles became strongly bimodal: about half were varus and half were valgus, with few in between. After this they were all valgus, with few exceptions. The authors therefore suggested that the change from varus to valgus in individual infants must be sudden (a few weeks), although the changeover of the whole population appears smooth and gradual. The knee angle became maximally and uniformly valgus ($-7.1^\circ \pm 1.4^\circ$) between 3 and 3.5 years, with little change thereafter. The chronological changes in knee alignment pattern in normal South-East Nigerian children demonstrated varus angle by the first year of life, valgus angle during second and third years, neutral (0°) by the fourth and fifth year.¹⁵ The findings from these studies are somewhat varied except for the fact that they all reported varus angle presentation during the first 12 months of life. With the intention of providing stronger evidence of the developmental pattern of TFA in Nigerian children, we proposed a cohort study during the first three years of life. Longitudinal cohort studies are more reliable than cross sectional studies and previous studies have shown that major changes in TFA pattern occur before age 3-years.^{1,4,5} This initial report presents findings from birth to 12 months.

METHODS

The data was from part of an ongoing longitudinal research study of the tibiofemoral angle in Nigerian children. The study was approved by both institutional ethics review committees of the University of Ibadan/University College Hospital, Ibadan and Olabisi Onabanjo University Teaching Hospital, Sagamu. Parents' consent was obtained. A standard equation was used to determine the sample size using the standard deviation of previous studies carried out on Nigerian children with a 95% confident interval and the width of confident interval set at 2.^{7,16-17} The calculated minimum sample size was 96 to power the study. In order to cater for attrition, a total of 152 healthy infants (71 males and 81 females) without any obvious congenital deformity (such as congenital hip dislocation, club foot, calcaneo-valgus, pes planovalgus, pes planus) were recruited from 3 infant welfare clinics in Sagamu town using a consecutive sampling technique. They were followed up monthly from birth through 12 months to assess their knee angle development [TFA, Intercondylar distance (ICD), and Intermalleolar distance (IMD)].

MEASUREMENTS

Tibiofemoral angle was measured with a universal goniometer (Fieldtex product Inc, USA). Each participant was examined supine in the anatomical position. One arm of the goniometer was aligned to an imaginary line drawn from the anterior superior iliac spine to the middle of the patella (femoral alignment) and the second arm was aligned to a line joining the middle of the patella to the middle of the ankle (centre point between medial and lateral malleoli), tibia alignment. The centre of patella served as the fulcrum for the goniometer. The acute angle sustained between the femoral shaft (femoral alignment) and the tibial shaft (tibial alignment) was recorded as the tibiofemoral angle in degrees.¹⁶ The angles were assigned positive values for varus and negative for valgus.

Intercondylar distance and intermalleolar distance were measured with a Non-Elastic Tape Ruler (Butterfly brand, China). Each participant was examined in the supine anatomical position (without nappy) with the medial malleoli or medial condyles just touching with hip and knees in maximal extension.¹⁶ The values were recorded in centimeters -- intercondylar distance values for the varus angle and the intermalleoli distance for the valgus.

Standard methods were also used to assess body weight (kg), body height (m), and trunk and limb length (cm) with weighing scale (Docbel Industries, 3/17, Asaf Ali Road, New Delhi-110002), infantometer (Schafer, D-77656 Offenburg NR 120301), and non-elastic tape ruler (Butterfly brand, China) respectively.¹⁸ The same assessor took all the measurements.

DATA ANALYSIS

Statistical Package for Social Sciences (SPSS) version 15 was used to analyze the data using descriptive statistics of means, standard deviations, graphs, and charts. Pearson's correlation was used to determine the relationship between the TFA and the ICD while the t-test was used to assess the TFA differences between sexes.

RESULTS

Sixty eight infants were recruited for the study at age 0 to 7 days, 46 at age 8 to 14 days, and 38 at age 15 to 24 days. A total of 113 children were seen 13 times (initial contact and monthly visits for 12 months), 16 children were seen 10 to 12 times, 7 children were seen 3 to 7 times, and 16 were seen 1 to 2 times. By 12 months, 27 children defaulted, giving an attrition rate of 17.8%. The results from 1705 paired limb measurements of tibio-femoral angle of normal children (746 measurements from boys and 959 measurements from girls) aged 0 to 12 months are presented. The left and right knee angles were very highly correlated ($r=0.996$), so the average of both limbs was calculated for each subject and used for analysis.

Figure 1. TFA Related to Age for Males and Females

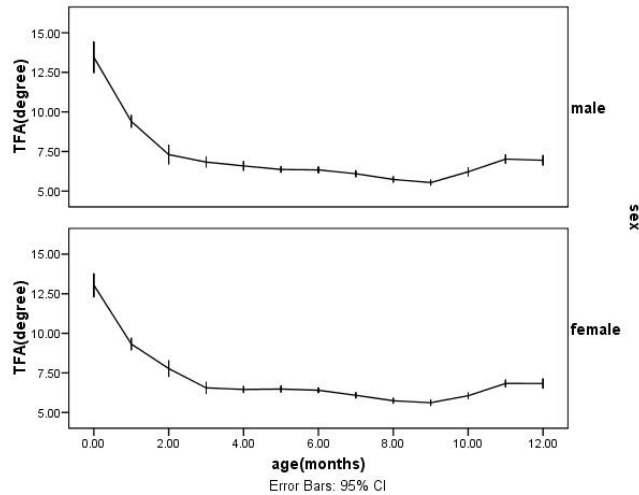
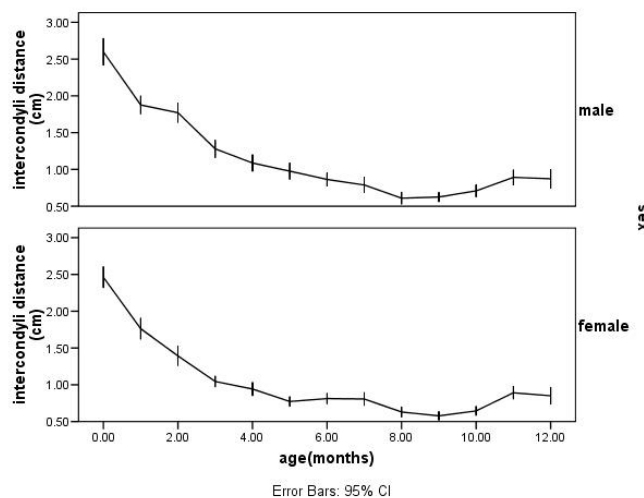


Figure 1 shows the pattern of development of tibio-femoral angle in our sample. All children presented with varus angles. The varus angle ranged from 5° to 25° at birth. Majority (80.9%) of the children had TFA value between 10° and 15°. Six participants had extremely low values (5° to 6°) and 16 children (10.6%) had extremely high values (20° to 25°). The mean varus angle fell steeply from 13.5±4.2° (boys) and 13.0±3.5° (girls) at birth to 6.8±1.2° (boys) and 6.6±1.5° (girls) at 3 months, then more slowly to 5.5±0.6° and 5.6±0.8° at 9 months after which it rose to 6.9±1.1° (boys) and 6.8±1.3° (girls). At 12 months, the majority (94.4%) had TFA of 6° to 10°. Only six (4.8%) children had TFA values <6° (5°) and one child had TFA values >10° (12°). Since there was no significant difference between boys' and girls' TFA ($t=1.108$, $p>0.05$), we proposed single set of reference values for both sexes (Table 1).

Figure 2. ICD Related to Age for Males and Females



Measurement of intercondylar distance showed a similar course of development from extreme varus at birth ($2.6\pm 0.8\text{cm}$ for boys and $2.5\pm 0.6\text{cm}$ for girls) that reduced gradually to $0.6\pm 0.3\text{cm}$ at age 8 months for boys and girls at age 9 months (Figure 2), then slightly rose again to $0.9\pm 0.5\text{cm}$ at age 12 months for boys and girls. The intercondylar distance was significantly higher in boys between ages 2 and 5 months. Thus, the reference values are presented for each month of the first year of life (Table 1). Most children (1699) recorded 0 cm of intermalleoli distance at age 0 to 12 months. Only six children recorded $\leq 0.5\text{cm}$ intermalleoli distance at age 12 months. The correlation between tibiofemoral angle and intercondyli distance measurements was significant, with a Pearson correlation coefficient for boys of $r = 0.69$ ($p=0.00$) and for girls of $r = 0.75$ ($p=0.00$).

Table 1. Reference Ranges for Knee Angle in Infants During Development

Age group (Month)	Tibiofemoral angle ($^{\circ}$)			Intercondyli distance (cm)		
	Mean	-2SD	+2SD	Mean	-2SD	+2SD
0	13.23	12.63	13.83	2.53	2.41	2.64
1	9.36	9.09	9.63	1.81	1.72	1.91
2	7.57	7.19	7.95	1.56	1.46	1.66
3	6.68	6.44	6.92	1.15	1.08	1.22
4	6.51	6.34	6.68	1.01	0.93	1.08
5	6.43	6.29	6.57	0.86	0.80	0.92
6	6.37	6.25	6.50	0.83	0.78	0.89
7	6.09	5.96	6.22	0.80	0.73	0.86
8	5.74	5.61	5.86	0.62	0.57	0.67
9	5.58	5.46	5.70	0.60	0.56	0.64
10	6.13	5.97	6.28	0.67	0.62	0.72
11	6.91	6.74	7.08	0.89	0.83	0.96
12	6.88	6.66	7.10	0.86	0.78	0.94

DISCUSSION

Findings from both goniometric and intercondylar measurements of TFA in this cohort indicate that the pattern of TFA in Nigerian children is varus during the first 12 months of life. None of the 152 infants involved in this study presented a valgus angle. A measurable valgus angle during this period may be considered abnormal among Nigerian children. Our findings are similar to findings from earlier studies from Nigeria and other parts of the world.^{1,3,5,7,11} Despite the various methods used in measuring TFA (i.e. radiographic, photographic, goniometric, and distance measurements), all these studies agreed on the chronological pattern of knee angle in infancy and early childhood.^{1,3,5,7,11}

The mean value of TFA at birth (13.2°) in the present study was slightly higher than that reported for Korean infants (12°) but less than that of Finish infants (16.5°).^{1,3} It was also less than 15.9° reported for American children but higher than 10° reported earlier for Nigerian and Pakistani (10.01°) children at age 6 months.^{5,7,11} The slight differences might due to the way the data were presented in each study (this study presented the data at monthly intervals while some of the previous studies presented it in 6-months intervals). The slight rise in the values of TFA at age 10 months is noteworthy. Many of these children have started dependent walking around this age. It has been suggested that duration of the period of dependent walking is correlated with knee angle in children.¹⁹ The data in the present study suggest that having an extremely low or high value of TFA at birth does not determine the TFA value at age 12 months. In fact, none of those children with extremely low or high value of TFA values at birth demonstrated extremely low or high values at age 12 months. Significant sex differences were not found in the present study in their values of tibiofemoral angle values, though boys have presented with higher values. This may imply that the same reference can be used for both sexes. This observation was similar to the previous reports which reported no sex difference in knee angle of children less than 2 years.^{1,5,7,11} However, in adolescence, sex differences in the values of TFA have been reported.^{4,12,20,21}

Measurement of intercondyli distance showed a similar pattern of development in children from extreme varus at birth which decreases with age in the present study. A similar pattern was also reported by previous studies.^{5,14,15} Few previous studies that measured ICD reported values for age groups rather than specific ages.^{5,14} This makes it difficult to compare values from previous studies with the mean values for specific ages in this present study.^{5,14} However, the mean ICD value (2.5cm) at birth in this study was similar to that of American children (2.6cm) and Pakistani children (2.96cm) at 6-months.^{5,14} The mean ICD value

at 6 months (0.83 cm) in the present study is lower than that of these previous studies.^{5,14} This difference in the observed values may be due to racial differences.

We found a high degree of correlation between intercondyli distance and tibiofemoral angle, with a Pearson correlation coefficient for boys of $r= 0.69$ and for girls of $r=0.75$. Similar observations have been reported by previous studies.^{6,11,12} This interesting correlation indicates that either of these two measurements can be used to document the status and monitor the progress of the patient. However, there is controversy about which clinical measurement is more accurate and easier for routine physical examination to evaluate the knee angle in children. Cheng et al noted that the IC/IM distance measurement is easier to apply clinically and is as reliable.⁴ Qureshi et al reported that both methods were reliable because of high correlation between the TFA and IC/IM distances.¹¹ Conversely, Cahuzac et al reported that the TF angle measurement is more accurate than distance measurement because the standard deviation of the IC/IM distance is greater than the mean values, while Arazi et al shared the same opinion because of observed difficulties about regarding the positioning of the subjects when the distance measurement was performed.^{6,12} Our results suggested that both clinical measurements (TFA and ICD) were reliable because the two methods demonstrated high correlation between each other.

The age-reference values established in the present study are of increased importance in providing practical screening for Nigerian children. Such screening may influence decisions regarding the necessity for further clinical and/or radiological assessment to rule out or look for bone diseases. The age-reference values may help the surgeon to more confidently decide about the wait and watch policy for the knee angle to correct spontaneously or to more appropriately select the time and type of surgery. This may also help the clinicians or surgeons to differentiate between physiological bowing and Blount's disease. Moreover, a relevant and correct understanding of the development of the knee angle and limb alignment would prevent unreasonable apprehension by parents and relatives.

CONCLUSION

This paper concludes that the chronological development of the TFA in a cohort of Nigerian infants is maximal varus angle at birth, decreasing until age 9 months when it begins to rise again. For practical evaluation of Nigerian children, the age-reference values generated in this study can be utilized when evaluating lower limb alignment. A measurable valgus angle at this period of age may be considered as abnormal.

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KEY TERMS

Tibiofemoral Angle, Developmental Pattern, Nigeria Children