DEVELOPMENT OF THE CLINICAL TIBIOFEMORAL ANGLE IN NORMAL ADOLESCENTS

A STUDY OF 427 NORMAL SUBJECTS FROM 10 TO 16 YEARS OF AGE

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We measured the clinical tibiofemoral (TF) angle and the intercondylar (IC) or intermalleolar (IM) distance in 427 normal European children (212 male and 215 female) aged from 10 to 16 years. In our study, girls had a constant valgus (5.5°) and displayed an IM distance of <8 cm or an IC distance of <4 cm. By contrast, boys had a varus evolution (4.4°) during the last two years of growth and displayed an IM distance of <4 cm or an IC distance of <5 cm. Values above these for genu varum or genu valgum may require careful follow-up and evaluation.

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Many studies have established that the tibiofemoral (TF) angle changes in healthy growing children. It may be expressed in degrees or as centimetres of either the intermalleolar (IM) or the intercondylar (IC) distance. The normal range of TF angle, calculated as two standard deviations (SD) about the mean, for normal children between birth and 12 years of age has been reported clinically (Cheng et al 1991; Heath and Staheli 1993) and radiologically (Salenius and Vankka 1975).

We agree that clinical evaluation is reliable and reproducible enough for day-to-day practice, but there are insufficient data for children between 12 and 16 years of age. In this adolescent period, knowledge of normal data is important to differentiate between physiological variation and pathological deformity which may require further evaluation and treatment.

We aimed to determine the mean values and normal range for the TF angle and IC and IM distances in European children aged from 10 to 16 years using clinical measurements.

MATERIAL AND METHODS

Of the 427 European children included in our study, 212 were male and 215 were female, ranging in age from 10 to 16 years. They were selected from four schools and none had any history of musculoskeletal disorders. The results were recorded in six age-specific groups (Fig. 1), and all measurements were made by the same examiner, using standard techniques. The clinical TF angle and the IC or IM distances were measured using a goniometer or a tape with the child standing with either knees or ankles just touching. The hips and knees were in full extension with the patellae straight ahead. The arms were placed behind the back to increase the stability of the posture.

The IC and IM distances were recorded as positive (varus) or negative (valgus) values, respectively. The TF angle was measured using the method of Heath and Staheli (1993). Skin markers were placed over the anterior and superior iliac spines, the centre of the patellae, and the mid-point of the ankle. A valgus angle was expressed in positive degrees.

Weight and standing and sitting heights were also measured; they were compared with the standard curve of Sempe, Pedron and Roy-Pernot (1979) and converted into standard deviations. The difference between the standing and sitting height measured was taken as the leg length. We tried to determine the relationship of the TF angle to weight, standing height and leg length.

To assess intraexaminer variability, ten children (20 measurements) each had repeated measurement with one month separating the examinations. The average SD for the measurements was 0.93° for the TF angle and 6.25 mm for the IC-IM distance.

Statistical analysis. We used linear regression and the determination coefficient to study the association between two morphological variables, and analysis of variance to compare the same variable in different age-specific groups. The null hypothesis was rejected at $p < 0.05$. To compare the same variable in boys and girls, independent sample t -

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Fig. 1

Number of children according to gender and age in years.

Fig. 2

TF angle of girls related to age in years.

Fig. 3

TF angle of boys related to age in years.

tests were used, and the null hypothesis was rejected at $p < 0.05$.

RESULTS

Tibiofemoral angle. The mean values and normal ranges are shown in Figure 2 (girls) and Figure 3 (boys). The girls had a stable valgus angle from 10 years (5.61°) to 16 years of age (5.53°). There were no significant differences between boys and girls until they were 14 years old ($p > 0.3$). Boys after 14 years of age showed a gradual and significant decrease of the valgus angle to 4.41°

($p < 0.001$). At 16 years old, boys were more bow-legged than girls ($p = 0.0004$).

IC and IM distances. The mean values and normal ranges are shown in Figure 4 (girls) and Figure 5 (boys). The girls showed no significant change with growth. In boys the IC distance increased from the age of 14 years (-2 cm) to the end of growth ($+0.5$ cm).

Tibiofemoral angle versus IC-IM distance. The correlation between these two measurements was significant, with a determination coefficient for boys of $r^2 = 0.82$, and for girls of $r^2 = 0.74$. The TF angle measurement was more accurate, however, because the SD of the IC or IM distance

Fig. 4

IC or IM distance of girls related to age in years.

Fig. 5

IC or IM distance of boys related to age in years.

was greater than the mean value.

Standing height, leg length and weight. We found no correlation between the TF angle and standing height ($r^2 = 0.031$), leg length ($r^2 = 0.004$) or weight ($r^2 = 0.064$). Similar results were found between the IC-IM distance and the three variables ($r^2 = 0.019$; $r^2 < 0.001$; $r^2 = 0.18$, respectively).

DISCUSSION

Various methods of measurement have been used to study the TF angle, but none has shown any significant differences between boys and girls; the data were combined for analysis (Cheng et al 1991; Heath and Staheli 1993). Salenius and Vankka (1975) used radiological measurements to demonstrate that both boys and girls have 5° to 6° valgus between 10 and 12 years of age. These examinations, however, are expensive and expose normal children to radiation; the results correlated directly with those of clinical examination (Salenius and Vankka 1975).

Engel and Staheli (1974) measured the angle formed by the midlongitudinal axis of the thigh and the tibia. They observed a constant valgus of 4° to 5° between 10 and 12 years of age for both sexes, and some decrease of this valgus angle between 12 and 14 years, but they did not perform a statistical analysis. Heath and Staheli (1993)

measured the TF angle on photographs and observed that white American children (boys and girls pooled) between 10 and 12 years old, had a valgus of 5.8° . Our results showed that until 13 years of age the valgus angle was 5.5° for boys and girls. Thus we found no significant gender difference, and our intraexaminer variability lies within the average range of other studies. Cheng et al (1991) measured the TF angle clinically and concluded that Chinese children between 9 and 12 years old have a valgus of 1° with a range of $\pm 8^\circ$ for both sexes. The discrepancy between the mean value reported by Cheng et al and our results could result from racial difference.

Our new finding was that after 13 years of age, the angle differed according to gender. Girls had a constant valgus angle of 5.5° , whereas the valgus decreased in boys to a mean of 4.4° . Shopfner and Coin (1969) noted a change from valgus to varus during adolescence and Cheng et al also noted that girls had a slightly greater IM distance than boys at all ages. At the end of growth, a varus pattern was more noticeable in boys than girls. Conclusions concerning the aetiology of the normal growth pattern in healthy adolescent boys cannot be drawn from this study.

We found no correlation between weight and the TF angle. Obesity did not increase the TF angle or IM distance significantly but we did find the largest IM distances in overweight children, possibly due to differences in soft-

tissue thickness at the knees.

Our study has established data for the varus/valgus profile of the legs in normal children between 10 and 16 years of age. Boys differed from girls showing a varus change during the last two years of growth. Normal girls had an IM distance of <8 cm or an IC distance of <4 cm. Normal boys had IM distance of <4 cm or IC distance of <5 cm. For

children showing greater values than these genu valgum or genu varum requires careful evaluation.

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