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DEVELOPMENT OF TIBIOFEMORAL ANGEL IN CHILDREN OF SAUDI ARABIA

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Abstract:

Objectives: *Tibiofemoral angle (TFA), is anatomically formed by the intersection of the anatomical axis' of both the femur and tibia. The TFA differ according to age and ethnic groups. The aim of the current study is to determine clinically the mean value of the TFA, intercondylar distance (ICD) and intermalleolar distance (IMD) in children in Saudi Arabia for the age group 2 to 16 years and correlate the body mass index (BMI) to the lower limb alignment.*

Method: *A total of 469 Saudi children (280 males and 189 females) were included in this study. The age range of participants was 2-16 years. We clinically measured using a goniometer for the TFA and a measuring tape for ICD and IMD.*

Result: *The maximum mean TFA is found in the age group 13 years; in girls 9.70 degrees and in boys 11.75 degrees. There is a significant difference between the mean TFA of boys and girls in the age group of 13 years. The maximum valgus in girls was 16 degrees at age 5 and 6 years, and in boy was 18 degrees at age of 8 years. There is no varus alignment in the mean TFA in children older than 2 years. We found a statistically significant difference for the correlation coefficient of age with IMD. Both the ICD and IMD were variable with age. The BMI of the studied children has a negative correlation with the IMD [r = -0.086, P = 0.064]. There was no statistically significant correlation between the BMI and the mean TFA or the ICD.*

Conclusion: *The development pattern was found to be different in Saudi children studied from the international patterns. The mean TFAs of different age groups is provided in this study. We believe our data could be considered as one of the references for evaluating lower limb alignment in Saudi children.*

Keywords: *Bowlegs, intercondylar distance, intermalleolar distance, knee angle, tibiofemoral angle.*

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INTRODUCTION:

The knee angle, which is also called tibiofemoral angle (TFA), is anatomically formed by the intersection of the anatomical axis' of both the femur and tibia [1]. The development of the TFA has three phases: the first phase, through which knee alignment modulates from an infantile physiologic varus to maximum valgus after the child stands and walk at age 2-3 years; the second phase, through which the amount of valgus knee alignment decreases; and the third phase, through which knee alignment remains stable [2,3]. However, the range of ages, when children pass from phase to the other was found to be variable in different ethnic groups [11]. Engel and Staheli reported that Caucasian children aged less than a year showed genu varum, which was corrected spontaneously during the second year, they also found that the highest mean values of genu valgum at 2-3 years of life with no significant differences regarding the gender. [4].

It is important to know the normal variation of knee angels within a population to avoid unnecessary time-consuming and costly diagnostic procedures, repeated exposure to radiation and therapeutic measures, such as, medication, bracing, or even surgical intervention, which may be entirely unnecessary and in certain situations may prove harmful.[7] In addition, this understanding would help diagnose, evaluate, and treat pathologic conditions, such as infantile tibia vara or Blount's disease earlier when it is easier.[11] Knowing this will help physicians in determining if the child is in the normal range according to age and gender and hence, reassure worried parents and grandparents about their loved ones, and those outside the normal range to start treatments early. The TFA differ according to different age groups and ethnic variations. The treating doctor should, know these variations in their local population to use the applicable treatment options.

There are several studies that have been done around the world to set normal variation of knee angles for each ethnic group in a certain geographic location such as India [1], Korea [6], Nigeria [8, 9], Turkey [10] and Malaysia [2]. Most of the studies performed have had limitations such as being conducted in one hospital [6], narrow age groups [11], or small sample size [11]. Also, in Saudi Arabia, there is one study that was done in Riyadh. That study had many limitations such: narrow age group 2-12 years old only, the sample size was 300 and as they did not measure intercondylar distance (ICD)nor intermalleolar distance (IMD).

Several methods have been used to measure the TFAs in children [4,5,7]. Radiographic methods, which are commonly used, are time-consuming, costly and have an ethical problem related to needless radiation exposure in children [7]. A malrotation of the limb could lead to errors in the measurement of the TFA if left uncorrected. Clinical methods of measuring the TFAs are radiation free and cheap. Also, they are more acceptable to participants and could be repeated several times [5,10].

The aim of the current study is to determine the mean value and assess the change of the knee joint angle, ICD and IMD in children in our region (Almadinah Almunawwarah, Saudi Arabia) for the age group 2-16 years clinically and correlate the body mass index (BMI) to the lower limb alignment

MATERIALS AND METHODS:

A total of 469 Saudi children participants (280 males and 189 females) were included in this study. They were clinically examined to measure the TFA, ICD and IMD. The age range of participants was 2-16 years of age.

During data collection, we specifically looked for healthy children such as the children in schools, children participating in summer camps and children with health problems that were not affecting the lower limbs, in order to make sure that the measurements were not affected by pre-existing health issue.

Participants with any of the following were excluded from the study:

- Non-walkers, because of the position that had to be maintained in order to get accurate measurements.
- Having a personal or a family history of inherited musculoskeletal deformities.
- A suspicion of having rickets or other metabolic diseases influencing the musculoskeletal system. A metabolic panel and appropriate radiographs were done in suspicious cases.
- Children with disorders affecting the lower limbs (skeletal, extra skeletal, neuromuscular disorders, and lower limb deformities).
- A current or a history of fractures of the lower limbs.

All examiners had a training session on the examination by a pediatric orthopedic surgeon to standardize the examination.

Each participant was checked twice; each time by a different examiner and cases with a discrepancy in the results were reexamined.

A sample of 35 children was chosen to be tested four times, two times by an examiner (for intra-examiner variability with one week between measurements)

and two times by other two examiners (for inter-examiner variability) to minimize the range of errors. We used a goniometer to measure the TFA and a measuring tape for ICD and IMD. The measurement technique is simple and practical. Also, it is less likely to be erroneous, even in overweight children and children who have marked femoral bowing, which might prevent detecting the exact location of the femur [1]. The children were positioned upright with their upper limbs placed behind their back to increase the stability of the posture while maintaining full extension and neutral rotation of hips and knees with both ankles and knees just touching each other at a close proximity with patellae facing forward. A pen was used to pinpoint the anatomical landmarks (the anterior superior iliac spines, the center of the patella and the midpoint of the ankle joint), then both the femoral and tibial axes were examined and marked. [1]

While one examiner measured the TFA, another examiner kept the child in the correct position then the examiners exchange their positions for a recheck. A knock-knee or a valgus TFA was considered as positive, while a bowleg or a varus angle was considered as negative. If the child had a varus angle the bony ICD was measured by positioning the bony prominences of both limbs against each other (the medial malleoli) and measuring the distance between the medial condyles, thus assuring the measurements are accurate even in obese children. In children with a valgus angle, the IMD was measured by positioning the medial condyles of both knees against each other and measuring the distance between the medial malleoli.

Then height, weight and body mass index (BMI) of each child were documented to look for a possible correlation between BMI and TFA, ICD and IMD. A millimeter scale was used; however, all the figures were rounded to the closest 0.5 cm, and the weight was measured in grams and also rounded up to the nearest 0.5 kg.

Analysis of the data was conducted by IBM SPSS version 21. A paired t-test was used to assess the differences between the right and left TFAs. Student's t-test was used to assess the variables for differences within each demographic. Pearson's correlation test was used to study the correlation between TFA, IMD, and ICD with age, and BMI. To be of statistical significance a P-value of less than 0.5 was needed.

RESULT:

Age	Male	Female	total	No. of limbs	Mean TFA (±SD)	95% CI of TFA
2	10	6	16	32	8.41 ± 4.03	0.75
3	8	16	24	48	8.54 ± 2.97	0.51
4	16	20	36	72	7.74 ± 2.93	0.43
5	32	38	70	140	8.57 ± 3.38	3.42
6	123	34	157	314	7.55 ± 2.43	0.2
7	8	12	20	40	7.75 ± 3.2	3.2
8	14	13	27	54	8.87 ± 2.62	2.62
9	9	13	22	44	7.79 ± 3.63	3.63
10	8	5	13	26	7.5 ± 3.29	3.29
11	11	5	16	32	7.47 ± 3.44	3.44
12	11	7	18	36	8.69 ± 3.55	3.55
13	6	5	11	22	10.82 ±2.17	0.81
14	7	5	12	24	8.63 ± 2.37	0.83
15	9	5	14	28	8.21 ± 1.58	0.75
16	8	5	13	26	5.92 ± 1.55	0.61
Total	280	189	469	936	7.99 ± 3.09	0.18

Table 1 Age and gender distribution with the mean tibiofemoral angle (TFA ± standard deviation [SD]) and 95% confidence intervals (CIs)

Table 1, showed the age and gender distribution of the 469 children, along with the mean TFA ± standard deviation (SD) at various ages and 95% confidence intervals (CIs).
The total number of our participants was 469 children; 59.70% boys (n=280) and 40.30% of them girls (n= 189). The ages were distributed between 2 and 16 years. Both girls and boys, reached a peak of valgus at the knees at the same age. In girls, maximum mean TFA was 9.70 degrees with the age group of 13 years, while in boys, the maximum mean TFA was 11.75 degrees and seen in the same age group (13 years).

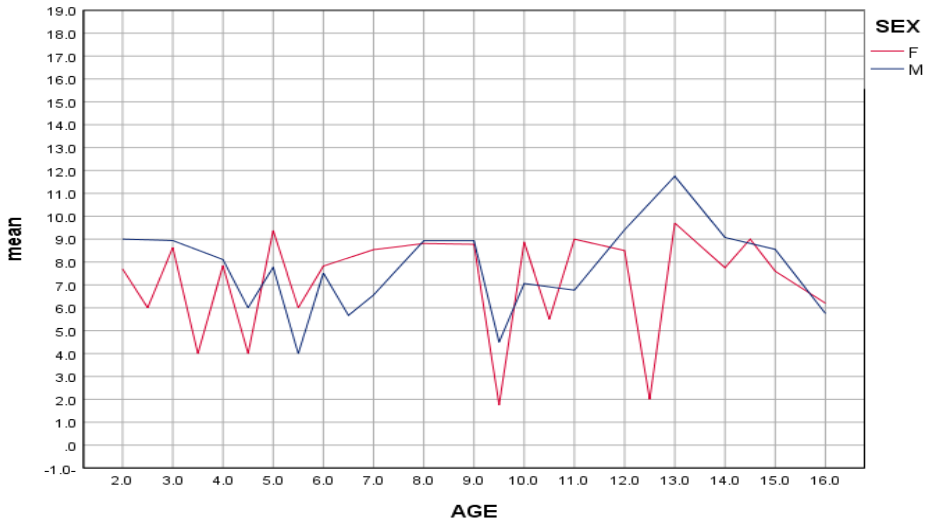

Fig. 1 Comparative chart showing development of the knee angle in males and females.

We noticed that the mean TFA was higher in girls than in boys (Table 2). There were no statistically significant differences between the mean TFA of boys and girls in the age except for the age group of 13.
The maximum valgus in girls was 16 degrees at age 5 and 6 years, and in boy was 18 degrees at age of 8 years. There were no negative values (varus knee) in the mean TFA in children older than 2 years. In the TFA there were no statistically differences in the right and left knees of the children as we have seen on paired t-tests.

Age	Mean TFA of female (±SD)	Mean TFA of male (±SD)	P value
2	7.42 ± 3.42	9 ± 4.33	0.079
3	8.34 ± 3.35	8.94 ± 2.05	0.647
4	7.65 ± 2.75	8.17 ± 2.88	0.868
5	9.08 ± 3.79	7.76 ± 3.04	0.072
6	7.82 ± 2.99	7.47 ± 2.49	0.092
7	8.54 ± 2.38	6.56 ± 4.10	0.098
8	8.81 ± 2.45	8.93 ± 3.38	0.569
9	7.69 ± 4.11	7.94 ± 3.24	0.486
10	8.2 ± 2.24	7.06 ± 3.89	0.189
11	9 ± 2.54	6.77 ± 3.90	0.110
12	7.57 ± 4.59	9.41 ± 3.11	0.181
13	9.70 ± 2.41	11.75 ± 1.54	0.046*
14	7.80 ± 2.74	9.21 ± 2.15	0.198
15	7.60 ± 1.58	8.56 ± 1.79	0.458
16	6.2 ± 1.75	5.75 ± 1.6	0.645
TOTAL	8.24 ± 3.24	7.83± 2.98	0.123

Table 2 Mean TFA ± SD distribution amongst male and female children at different ages. *significant In this study, we found statistically significant difference for the correlation coefficient of age with IMD [r= -0.154, P= 0.001] and ICD [r= 0.133, P= 0.004]. Both the ICD and IMD were variable with age.

Also, we noticed that the BMI of the studied children has a negative correlation with the IMD [r = -0.086, P = 0.064]. But there was no statistically significant correlation between the BMI and the mean TFA or the ICD.

DISCUSSION:

Our study demonstrated that the maximum mean TFA was 10.8 degrees at the age of 13 years, followed by a gradual decrease to a mean of 5.9 at the age of 16 years. In another study, Samia et al. (2011) found that the maximum mean valgus of Saudi children was 9.5 degrees at 3 to 4 years and the lowest mean value was 3.5 degrees at 11 to 12 years [11]. A study involved 196 white European children reported that the maximum mean TFA was 8 degrees at an age of 4 years [5]. Another study from India [1] showed that the maximum valgus was 8 degrees at the age of 6 years, therefore, the ethnicity might have a major role in the pattern of knee development.

In our study, the maximum mean TFA was 9.70 degrees at the age of 13 years in girls, while in boys the maximum mean TFA was 11.75 degrees of the same age. In addition, the minimum mean TFA was 5.8 degrees in boys at an age of 16 years, and 6.2 degrees in girls of the same age.

We found that there is a significant difference in the TFA in age group 13 years, in which the TFA angle was higher in boys than girls. Comparing with Riyadh study [11] they found that there is a significant difference in the development of the TFA between boys and girls in the age group 5-6 years, in which the TFA was higher in girls than boys (7.98 and 7.24 degrees, respectively). The use of different techniques to measure the knee angle could be the reason behind this variation in the outcome.

Our results were contradicting with the study of Yoo JH et al. [6], in their study they demonstrated that larger peak valgus alignment at age 4 years in both genders. This is opposite to our findings in our study participants in whom the maximum valgus was noted to occur at the age of 5 and 6 in girls while in boys at 8 years. This difference could be because of using a different method to measure TFA. It is more likely due to the ethical and racial descent in the population groups.

In another study conducted in Nigeria by Omololu et al. [9], the knees were maximally bowed at ages 1-3 years and decreased to neutral of 0 degrees at the age of 5 years in girls and age of 7 years in boys. The valgus angle was noted to be steady at about 11 degrees between ages 1 and 10 years in both genders. We found that none of our subjects had a negative TFA in the 2 years age group. On the contrary, the Chinese study by Cheng et al. [12], found that the mean varus TFA at the age of 2 years. Also, they noted a rapid decrease in the mean IMD that reached 0 cm at 8 years, with an average range of ± 3 cm. Conversely, we observed both the ICD and IMD were variable with age.

In our study, there was no significant association between BMI and TFA at all age groups. This result resembled the Nigerian study [13] that demonstrated a negative correlation between TFA and BMI. They explained their findings that it could be because of the little number of obese children in the sample.

The varus knee in children older than 2 years was not observed in our population. This result resembles the results from 2 other studies, one of them was conducted in Riyadh [11], which found that there is varus phase to the age of 2 years and valgus phase between age 2 and 12. The other study in India [1], which demonstrated that the TFA was not negative (varus) at the age of 2.

The major limitation in our study is being cross-sectional in nature.

CONCLUSION:

We provided the data of normal development of the knee angle in a group of Saudi children through clinical measurements. The development pattern could be different in Saudi children from the international patterns. The mean TFAs of different age groups are provided in this study. We believe our data could be considered as a reference for evaluating lower limp alignment in Saudi children.

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