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Clinical assessment of tibiofemoral angle and its relationship with body mass index

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Abstract

Background: Few studies have investigated BMI as a factor that might influence the physiological development of knee alignment in otherwise healthy normal weight and overweight children and adolescents.

Objective: This study set out to determine the relationship between tibiofemoral angle and body mass index in normal children and adolescents in Enugu metropolis.

Methodology: This cross-sectional study was done in Enugu metropolis with 3147 school children and adolescents aged 3-17years. The tibiofemoral angle was measured clinically using standard goniometer with extendable arms. The weight, height, BMI percentile-for-age, were determined for all the subjects. The association between tibiofemoral angle and body mass index was then analyzed.

Results: Majority of the subjects (97.6%) had valgus TFA. The maximum knee valgus angle was $6.8^{o}\pm0.80^{o}$ at 4 years which then declined to a mean of 2^{0} at 17 years. 91.2% of the subjects examined were normal weight(5th-85th percentile), 6.2% underweight(< 5th percentile) and 2.5% overweight(85th - 95th and > 95th percentile). The tibiofemoral angle was found to have a significant negative correlation with BMI in normal weight and overweight subjects.

Conclusions: We found a significant negative correlation between TFA and BMI in normal healthy weight and overweight children and adolescents. Thus, increasing BMI does not cause a corresponding increase in the magnitude of the knee angle.

Keywords: Tibiofemoral angle; Body mass index; Varus; Valgus

1. Introduction

Tibio-femoral angle (TFA) refers to the angle between the anatomical axis of the femur and the anatomical axis of the tibia[1]. It is commonly measured using the clinical method, which has a wide acceptance because it is non-invasive, easy to perform and reproducible[2]. Genu varum and valgus deformities are commonly encountered in children, and they represent a great source of apprehension amongst parents. These angular deformities may be physiologic; arising from sequential physiologic changes in knee alignment or pathologic; due to genetic factors, intra-uterine posturing, nutritional deficiencies and adaptive changes to weight bearing[3].

The clinical TFA represents one of the most reliable measures of angular alignment of the knee, and correlates with anatomical TFA which is determined radiologically[4]. Its use is mainly in the determination of the degree of angular

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deformity of the knee and also to differentiate physiologic conditions from pathologic angular malalignment of the knee[4].

Axial loading as represented by body mass index (BMI) has been linked to exaggeration of TFA in normal children with high BMI[5].

Recent studies have found a greater prevalence of lower limb malalignment, mainly valgus in subjects with high BMI (Overweight and obese)[6]. However, since elevated BMI increases the magnitude of joint loading, joint position and alignment are also known to influence knee joint forces and theorized to play a pivotal role in the onset of secondary osteoarthritis of the knee by altering stress distribution within the joint[7]. This emphasizes the need to investigate the relationship between TFA and BMI. Such a relationship, when validated, will aid in designing efficient prevention protocol to avoid progression to pathological deformities requiring surgical intervention and also help in developing timely intervention programs.

Of the number of studies performed to date, the majority have focused on the normal values and pattern of TFA for various populations[8].

However, there is a paucity of studies both local and international that investigated the relationship between body mass index and magnitude of knee angle in children[9]. This study aims to determine the relationship between TFA and BMI in children and adolescent subjects aged 3-17yrs in Enugu Metropolis using clinical methods.

2. Materials and method

The study area was Enugu metropolis, which serves as the capital of Enugu State in South-East Nigeria, and is made up of three local government areas; Enugu East, Enugu North and Enugu South.

It was a cross-sectional descriptive study conducted in fourteen Nursery, primary and secondary schools from April 2020 to March 2021; involving measurement of tibiofemoral angle, as well as obtaining the biodata of all patients.

2.1. Inclusion criteria

Children between the ages of 3 and 17 years.

2.2. Exclusion criteria

Those with obvious musculoskeletal disorder affecting the lower limbs (such as skeletal dysplasia, cerebral palsy, neuromuscular disorder and foot deformities.

- Those with windswept deformity of the knee.
- Those who have lower limb length inequality.
- Those who had undergone surgery of the lower limbs.
- Those whose parents or guardians declined.

2.3. Sample size

The sample size was calculated using the formula[51]: $n = z^2 \sigma^2 / e^2$

Z = value for selected alpha level of 0.05 = 1.96

σ = standard deviation of the outcome variable from previous study [14] = 1.4

$e = acceptable\ margin\ of\ error = 0.05.$

$$n = \frac{(1.96)^2 \times (1.4)^2}{(0.05)^2} = 3011.81$$

The minimum sample size for the study was 3011.81

This was rounded up to 3240

2.4. Procedure

Body mass index was derived from weight and squared height of the individual and is represented by the formula: BMI = $\frac{WT}{HT^2}$

WT is weight measured in kilograms and HT is height measured in meters. Body mass index percentile indicates the relative position of a child's BMI among children of the same sex and age because the amount of body fat changes with age and varies by sex. Percentiles are the most commonly used indicator to assess the size and growth patterns of individual children[10]. After the BMI was calculated for the children, the BMI number was plotted on the US centre for disease control and prevention (CDC), BMI-for-age growth charts (for either girls or boys) to obtain a percentile ranking. Percentile specific to age and sex classify children into underweight, healthy weight, overweight and obesity. Body mass index that is less than 5th percentile is underweight, BMI that lies between 5th and 85th percentile is a healthy weight, BMI that is between 85th to less than 95th percentile is overweight and BMI equal to or greater than the 95th percentile is obesity[10].

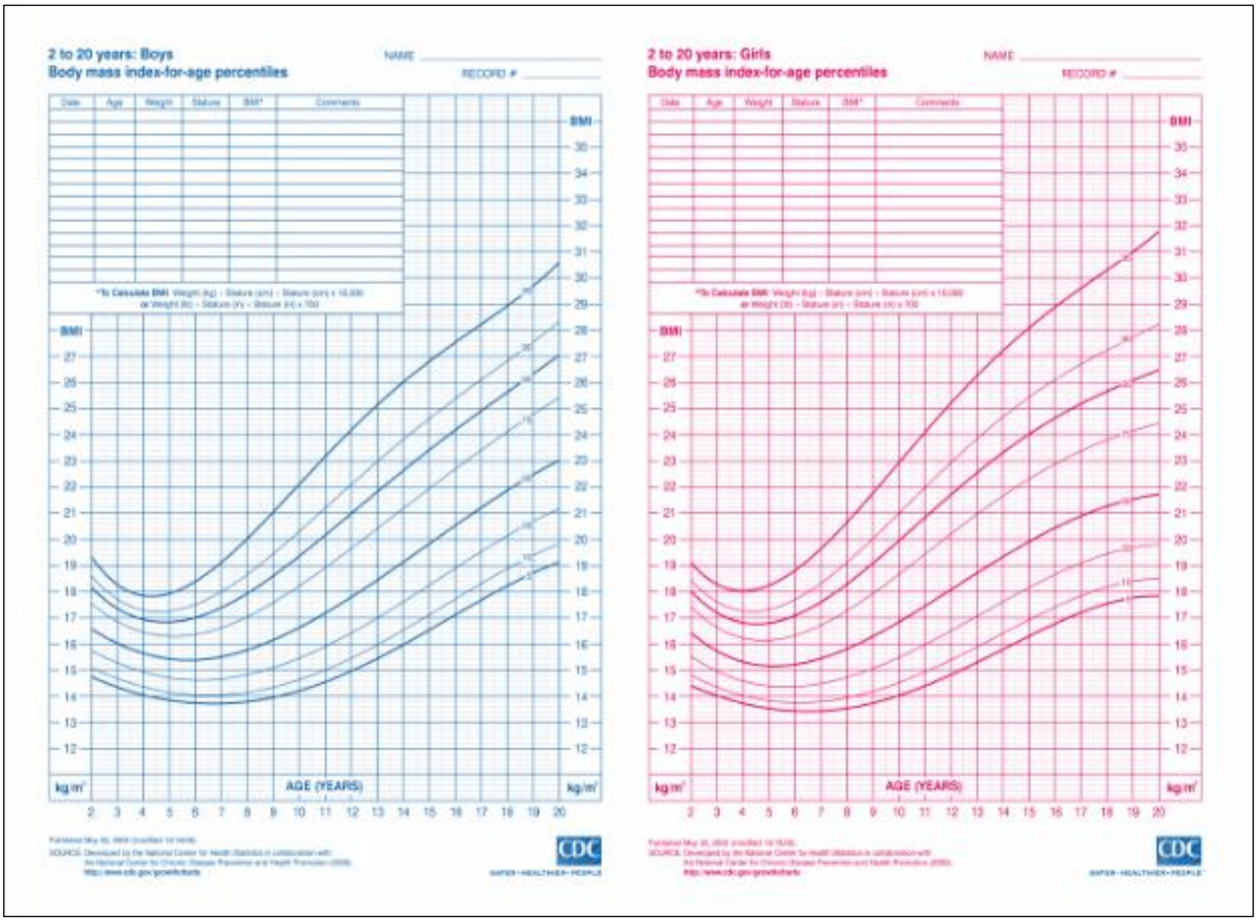

Figure 1 BMI – for-age percentile chart for boys and girls

2.5. Tibiofemoral angle

TFA was measured using the clinical method described by Matthew and Madhuri[11]. Each subject was made to stand with the hips and knee in full extension and neutral rotation, with the ankles or knees touching each other; a goniometer was then used to measure the angle

3. Results

A total of 3147 school children and adolescents aged 3-17 years participated in this study. Table 1 shows the age distribution of the subjects.

Table 1 Age distribution of the subjects

Age(years)	**N**	**%**
3	215	6.8
4	213	6.8
5	178	5.7
6	210	6.7
7	214	6.8
8	210	6.7
9	210	6.7
10	210	6.7
11	212	6.7
12	212	6.7
13	215	6.8
14	216	6.9
15	216	6.9
16	213	6.8
17	203	6.5
Total	3147	100.0

In table 1, a total number of 3,147 subjects were studied; the age with the lowest number of subjects was five years.

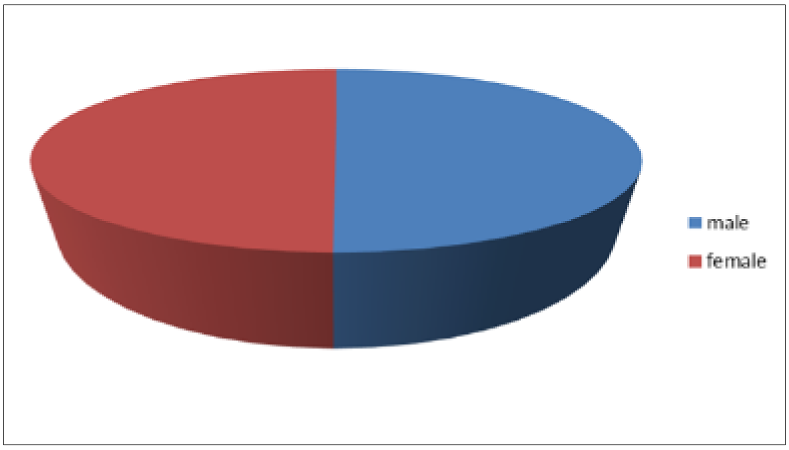

Figure 2 Gender distribution of the subjects

From figure 1, there were 1577 (50.1%) males and 1570 (49.9%) females that participated in the study.

Table 2 Mean height, weight, and body mass index (BMI) at different ages by gender.

AGE(years)	HEIGHT(cm)		WEIGHT(kg)		BMI(kg/m²)	
	Males	Females	Males	Females	Males	Females
3	94.89	93.81	14.41	13.25	16.01	15.06
4	104.08	101.65	16.05	15.67	14.82	15.17
5	108.44	107.85	17.53	17.34	14.92	14.92
6	114.36	114.18	18.62	18.47	14.24	14.17
7	121.88	120.09	21.22	20.76	14.28	14.40
8	126.81	124.53	24.75	24.43	15.39	15.76
9	131.94	131.12	26.90	27.31	15.46	15.90
10	136.42	137.60	30.88	32.30	16.59	17.06
11	139.54	141.66	31.60	32.83	16.23	16.36
12	145.32	146.21	35.27	36.64	16.70	17.14
13	151.29	148.08	38.84	41.85	16.97	19.08
14	157.63	153.93	46.09	47.71	18.55	20.13
15	164.74	160.36	51.19	52.19	18.86	20.30
16	168.05	163.24	55.10	52.56	19.51	19.72
17	175.66	164.93	62.42	54.35	20.23	19.98

Table 2; shows that height, weight and BMI gradually increases as age increases.

Table 3 Distribution of weight status based on BMI percentile.

Weight status	n	%
Normal weight	2871	91.2%
Overweight	80	2.5%
Underweight	196	6.2%
Total	3147	100%

In table 3; the weight status "overweight" is used for both overweight (85th – 95th percentile) and obese (> 95% percentile) subjects. Among the 80 subjects that were grouped into "overweight", 32 were obese and all the others were overweight. Majority 2871 (91.2%) subjects had normal weight (5th – 85th percentile) and the remaining 196 (6.2%) of the subject were underweight (< 5th percentile).

Table 4 Correlation between valgus TFA with age, weight and height

Parameter	Correlation coefficient(r)*	P-value
Age	-0.725	0.000**
Weight	-0.676	0.000**
Height	-0.727	0.000**

*=Pearson's correlation coefficient.; **=significant correlation.

Table 4; shows that valgus TFA had a significant negative correlation with age, weight and height.

Table 5 Correlation between valgus TFA and BMI in normal weight, overweight and underweight subjects.

Parameter	Correlation coefficient(r)*	P-value
Normal weight	-0.577	0.000**
Over weight	-0.479	0.000**
Under weight	-0.006	0.986

*=Pearson's correlation coefficient.; **=significant correlation.

In table 5; there is a significant negative moderate correlation between valgus TFA and BMI in normal weight subjects. There is also a significant negative low correlation between valgus TFA and BMI in overweight subjects and an insignificant negative very low correlation between valgus TFA and BMI in underweight subjects.

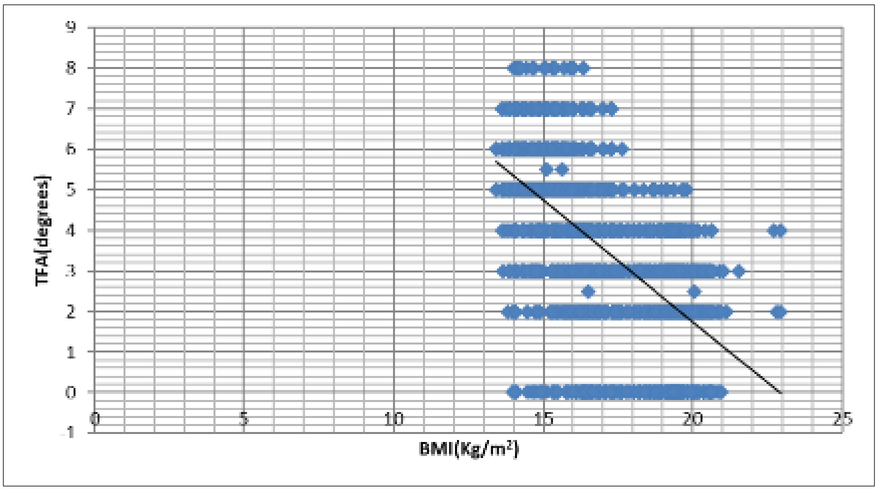

Figure 2 Relationship between valgus TFA and BMI in normal weight subjects.

In fig 2; the scatter plot shows a negative correlation between valgus TFA and BMI in normal weight subjects.

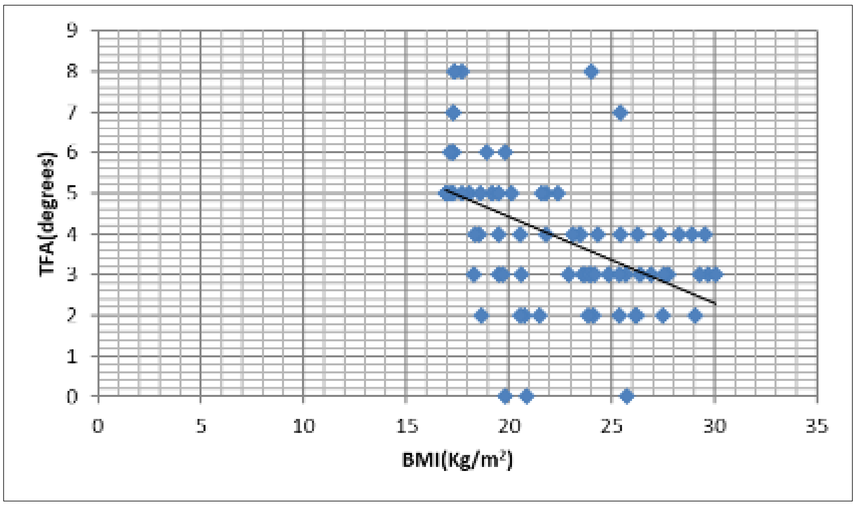

Figure 3 Relationship between valgus TFA and BMI in overweight subjects.

In fig 3; the scatter plot shows a negative correlation between valgus TFA and BMI in overweight subjects.

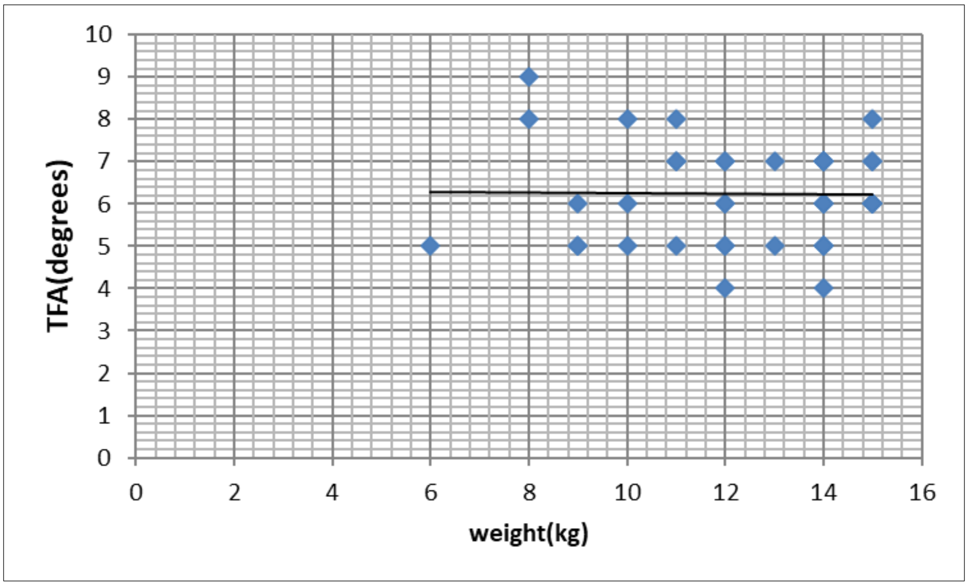

Figure 4 Relationship between valgus TFA and BMI in underweight subjects.

In fig 4; the scatter plot shows a very low negative correlation between valgus TFA and BMI in underweight subjects.

4. Discussion

The tibiofemoral angle in this study showed significant negative correlation (r = -0.577, p = 0.000) for normal weight (BMI within 15^{th} – 85^{th} percentile) and (r = -0.479, p =0.000) for overweight (BMI: 85^{th} – 95^{th} and > 95^{th} percentile) subjects. This implies that increasing BMI does not lead to a corresponding increase in TFA. Similarly, Bafor et al.[2] in their study on the correlation between tibiofemoral angle and body mass index in normal Nigeria children reported a significant negative correlation between TFA and BMI in normal healthy weight children, all the participants in their study were healthy-weights with BMI within 5^{th} – 85^{th} percentile. We expanded this earlier study by Bafor et al by showing a significant negative correlation between TFA and BMI in the overweight subjects. In keeping with the findings in our study, Taylor et al[11] on their evaluation of the correlation of MDA with BMI, they found a significant negative correlation (r= -0.10, p= .017) between MDA and BMI in the overweight participants. On the contrary, some studies reported a significant positive correlation between intermalleolar distance and BMI in the overweight subjects[12,13]. The finding of increasing valgus with obesity in these studies could have been due to the use of intermalleolar distance in the assessment of the degree of valgus, which could lead to overestimated angle in overweight persons due to excessive subcutaneous fat accumulation around the knees[13]. In this study, the majority of the subjects (97.6%) were found to have a valgus TFA. This was similar to other studies on Nigerian[14], Saudi Arabian[15], Turkish[16] and Indian[1] children that are three years and above. Maximum valgus angle was observed at 4 years of age with values of 6.56^0 in boys and 6.94^0 in girls and the valgus angle gradually decreased to 2^0 at 17 years of age. These findings can serve as a reference for further studies regarding malalignment in South-East Nigeria, where there is a paucity of data in this regard.

In this study, the assessment of angular alignment of the knee was based on clinical measurement of tibiofemoral angle using a goniometer with extendable arms. Although the gold standard for assessment of knee alignment is a standing knee radiograph, the clinical measurement of knee alignment angle with goniometer has been reported to have strong correlation (r=0.70, p<0.0001) with the knee alignment angle measured on a more cumbersome and costly full limb radiogragh[17].

5. Conclusion

In conclusion, there was a negative association between TFA and BMI in normal healthy weight and overweight children and adolescents. Therefore, increasing BMI does not cause a corresponding increase in the magnitude of the knee angle in normal children.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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