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ORIGINAL PAPER

Correlation between clinical tibiofemoral angle and body mass index in normal Nigerian children

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Abstract
Purpose The tibiofemoral angle (TFA) is a reliable tool for determining lower-limb axial alignment and defining the degree of deformity in pathologic angular malalignment of the knee in children.
Methods We clinically examined 471 normal Nigerian elementary school children whose ages ranged from three to ten years to determine the clinical tibiofemoral angle and to establish its relationship with body mass index (BMI).
Results We found maximum knee valgus of 7.87° at three years, decreasing to 1° at ten years. We also found significant negative correlation between the tibiofemoral angle and BMI. All children examined had weights between the 5th and 85th percentile for age and sex.
Conclusion We conclude that in normal healthy-weight children, BMI does not cause an increase in tibiofemoral angle.

Introduction

The clinical tibiofemoral angle (TFA) represents one of the most reliable measures of angular alignment of the knee, as it has been found to give good correlation with the anatomical TFA, which is determined radiologically [1]. It has been used clinically to determine the degree of deformity in patients with pathologic genu varum or valgum. It has also been used to differentiate physiologic conditions from pathologic angular malalignment of the knee.

Several studies have been carried out to define the normal values of the knee angle in different populations [1–4], which serve as guides for the treatment of pathologic angular deformities of the knee. In certain pathologic states, axial loading has been suggested to play a role in the aetiopathogenesis of angular deformity [5–7]. There is, however, limited data worldwide on the effect of axial loading (body weight) on the values of TFA in normal children. This study aimed at establishing the mean TFA in Nigerian children and determining the relationship between TFA and axial loading in normal children.

Participants and methods

The study was conducted among 471 Nigerian elementary school children aged three to ten years comprised of 247 male and 224 female pupils.

Sample-size determination

The sample size for this study was determined using the Cochrane formula $n = Z^2pq/e^2$, where n = sample size, Z is the confidence level (in this case, 1.96 for a 95% confidence level), p is the estimated proportion of an attribute that is present in the population or the estimated percentage of success (50%, or 0.5 in this case), $q=1 - p$ *and* e is the desired level of precision or confidence interval (in this case 0.05). This gave us a sample size of 385. We then increased this figure by 20% to increase the accuracy of the results obtained, which gave us a final figure of 462 for sample-size

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Table 1 Means for tibiofemoral angle (TFA), body mass index (BMI), weight (WT), height (HT) and intermalleolar distance (IMD)

Age (years)	Sex	TFA	BMI	HT(cm)	WT(kg)	IMD (cm)
3	Females (n=20)	−7.40±0.53	16.66±0.33	94.40±1.20	14.77±0.17	1.810±0.192
	Males (n=25)	−8.24±0.48	16.77±0.20	97.48±0.78	15.94±0.25	1.736±0.248
	Total (n=45)	−7.87±0.36	16.72±0.18	96.11±0.72	15.42±0.18	1.769±0.161
4	Females (n=25)	−5.76±0.26	15.92±0.21	100.44±0.86	16.01±0.14	0.680±0.181
	Males (n=32)	−6.09±0.32	15.63±0.15	103.69±0.86	16.78±0.18	1.381±0.199
	Total (n=57)	−5.95±0.21	15.76±0.12	102.26±0.65	16.44±0.13	1.074±0.144
5	Females (n=27)	−5.28±0.39	15.36±0.31	105.44±0.57	17.167±0.50	0.426±0.143
	Males (n=28)	−5.63±0.27	15.61±0.28	108.04±0.52	18.29±0.46	0.643±0.117
	Total (n=55)	−5.45±0.233	15.49±0.21	106.76±0.42	17.74±0.34	0.536±0.093
6	Females (n=28)	−4.91±0.22	14.29±0.18	112.50±0.61	18.13±0.35	0.161±0.052
	Males (n=32)	−4.66±0.21	13.90±0.15	114.84±0.75	18.37±0.33	0.297±0.084
	Total (n=60)	−4.78±0.15	14.08±0.11	113.75±0.507	18.26±0.24	0.233±0.051
7	Females (n=28)	−4.50±0.24	14.72±0.25	117.29±0.69	20.34±0.51	0.143±0.067
	Males (n=32)	−4.63±0.20	14.47±0.23	117.69±0.60	20.09±0.44	0.203±0.100
	Total (n=60)	−4.57±0.15	14.59±0.17	117.50±0.45	20.20±0.33	0.175±0.062
8	Females (n=29)	−3.43±0.29	15.70±0.15	125.14±0.46	24.59±0.31	0.241±0.101
	Males (n=31)	−3.10±0.20	16.05±0.21	126.77±0.60	25.82±0.43	0.194±0.076
	Total (n=60)	−3.26±0.17	15.87±0.13	125.98±0.39	25.23±0.28	0.217±0.062
9	Females (n=34)	−1.28±0.12	17.14±0.15	130.82±0.44	29.33±0.29	0.061±0.047
	Males (n=34)	−1.81±0.19	16.78±0.16	131.32±0.33	28.93±0.26	0.132±0.090
	Total (n=68)	−1.54±0.11	16.96±0.11	131.07±0.27	29.13±0.19	0.097±0.051
10	Females (n=33)	−0.74±0.02	16.83±0.25	136.52±0.372	31.34±0.44	0.030±0.021
	Males (n=33)	−1.20±0.19	16.99±0.21	137.82±0.55	32.25±0.39	0.015±0.015
	Total (n=66)	−0.97±0.12	16.91±0.16	137.17±0.34	31.80±0.29	0.023±0.013

determination. In accommodating for subgroup analysis, we employed a multistage sampling technique, which included sampling at the local government level, at the school level and at the class level. To ensure that each of the minor subgroups (gender) had at least 20 participants, the sample size was increased to 471.

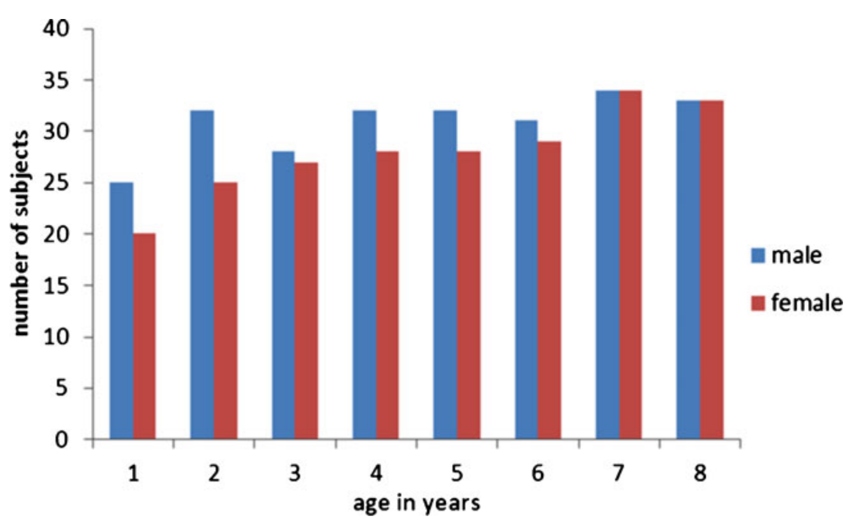


Fig. 1 Age and sex distribution of participants

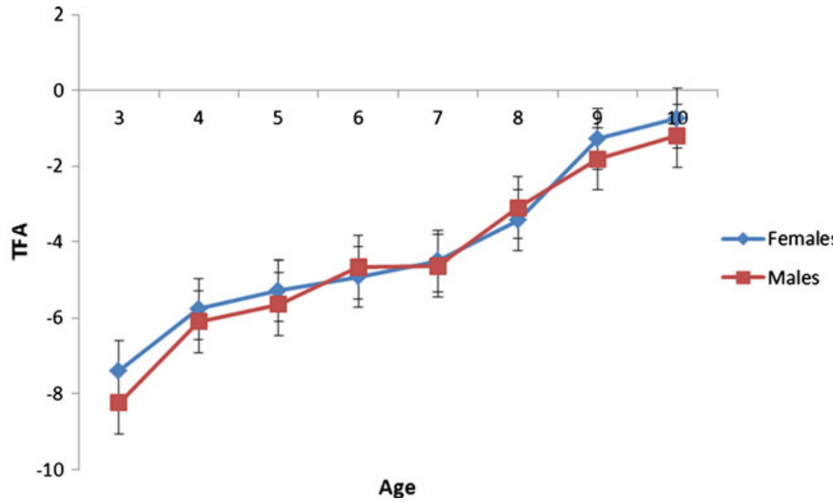


Fig. 2 Relationship between mean tibiofemoral angle and age

Participant evaluation

After obtaining approval from the school authorities for each school used, each participant was first examined clinically to exclude the presence of any pathology of the lower limbs. All participants were ambulant. The clinical TFA measurement was taken for both limbs and the average used for analysis. This was achieved using a standard goniometer. This method was chosen because it is relatively easy and inexpensive to perform, avoids the risk of exposure to ionising radiation and has been found to give good correlation with the anatomical TFA [1, 2, 4], which is determined radiologically and which offers the best modality for determination of the TFA. Each participant was examined standing with the hips and knees in full extension and neutral rotation, and with knees touching each other. The axes of the femora and tibiae were determined clinically by palpation. The femoral axis was defined as an imaginary line connecting the anterior superior iliac spine and the centre of the patella. The axis of the tibia was defined as an imaginary line connecting the centre of the patella to an imaginary point midway between the medial and lateral malleoli. The acute angle subtended at their point of intersection at the centre of the patella represented the TFA. Valgus TFAs were recorded as negative values; varus angles were recorded as positive values. The intermalleolar distance (IMD) was recorded as the distance between the left and right medial malleoli, measured with both knees touching each other. Measurement was effected using a simple tape rule, and values were recorded in centimetres. Height was measured with all participants standing without shoes against a wall-mounted chart. The occiput, buttocks and heels were all confirmed to be touching the wall before readings were taken. With each participant clad in underpants only, and in the presence of a male or female chaperone as necessary, weight was recorded using a simple bathroom scale. Body mass index (BMI) was calculated using the formula weight/height^2 where weight is in kilograms and height is in metres.

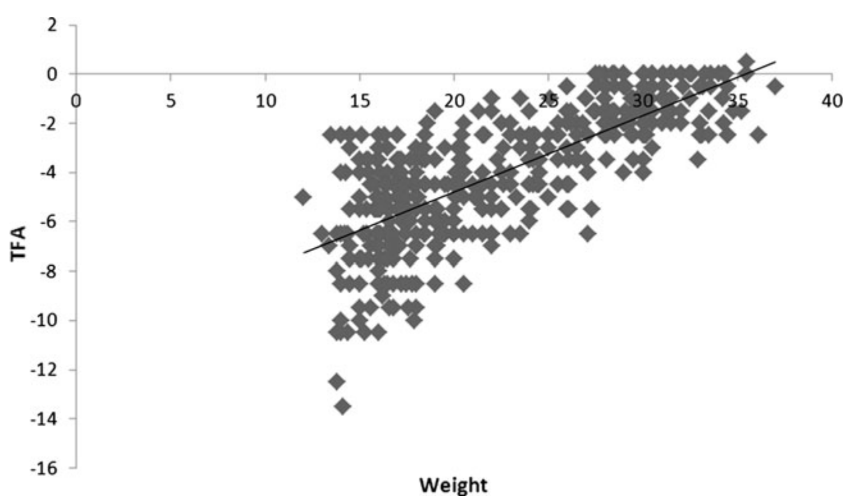


Fig. 3 Relationship between mean tibiofemoral angle and weight for all participants

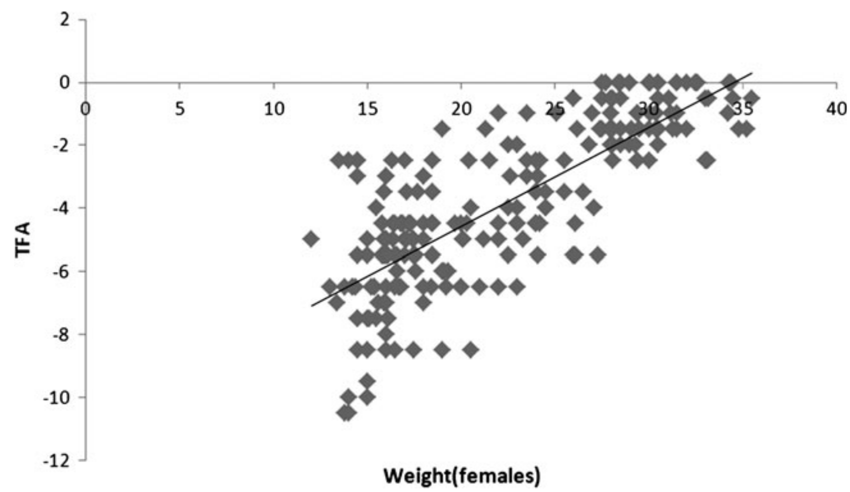


Fig. 4 Relationship between mean tibiofemoral angle and weight for girls

All measurements were carried out by the second author (OB) to minimise interobserver differences; however, intra- or inter-observer variation studies were not carried out for logistic reasons.

Statistical analysis

Participants were divided into eight groups according to their age. Mean weight, BMI, TFA and IMD were calculated for each group, with variance expressed as standard error of mean (SEM). For the purpose of correlation, Pearson's correlation coefficient was used, with significance level set at $p<0.05$.

Results

A total of 942 limbs from 471 participants comprising 247 boys and 224 girls were examined. The mean values for all measurements taken are represented in Table 1. Age and sex distribution is represented in Fig. 1.

We noticed a steady decline in TFA from a maximum of 7.87° of valgus at age three years to about 1° of valgus at age ten. There was no significant gender difference in TFA ($p=0.088$). The relationship between TFA and age is demonstrated in Fig. 2.

We also noticed a gradual decline in IMD from 1.8 cm at three years of age to 0.02 cm at ten years of age, with boys having significantly higher values than girls ($p=0.031$). We found a generally significant negative correlation between TFA and weight ,as well as between TFA and BMI, more so for weight (r values −0.754 for weight and −0.210 for BMI). This is represented in Figs. 3, 4, 5, 6, 7, 8.

Discussion

The normal limits of the knee angles have been documented in different races and populations [1–4]. Vankka and Salenius [1], in their radiographic evaluation of 1,279 Caucasian children, found maximum valgus angulation of 12° at three years of age. This was comparable with clinical studies

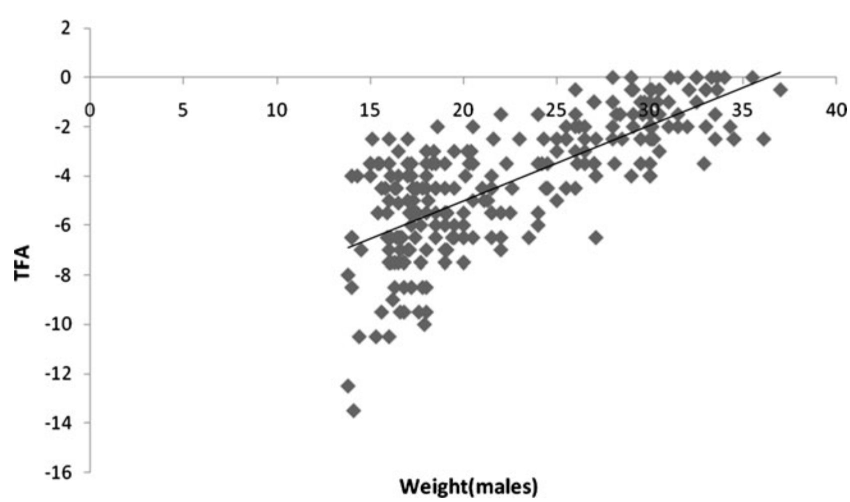


Fig. 5 Relationship between mean tibiofemoral angle and weight for boys

Fig. 6 Relationship between mean tibiofemoral angle and body mass index for all participants

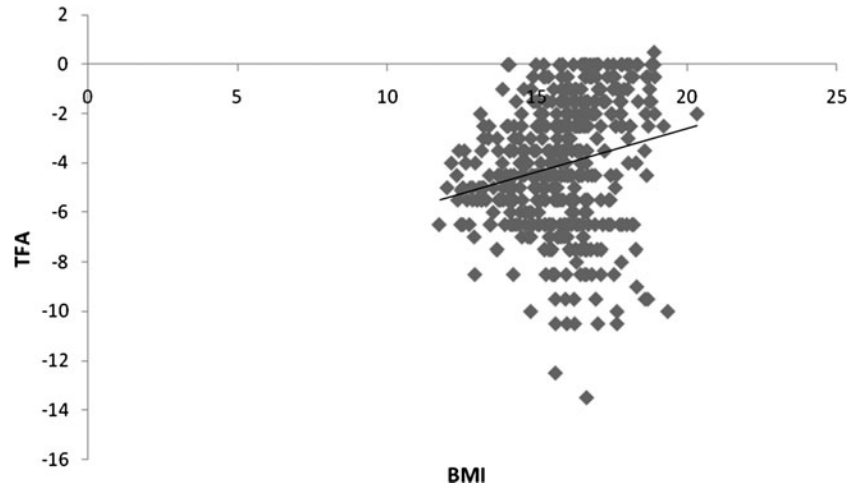


Fig. 7 Relationship between mean tibiofemoral angle and body mass index for girls

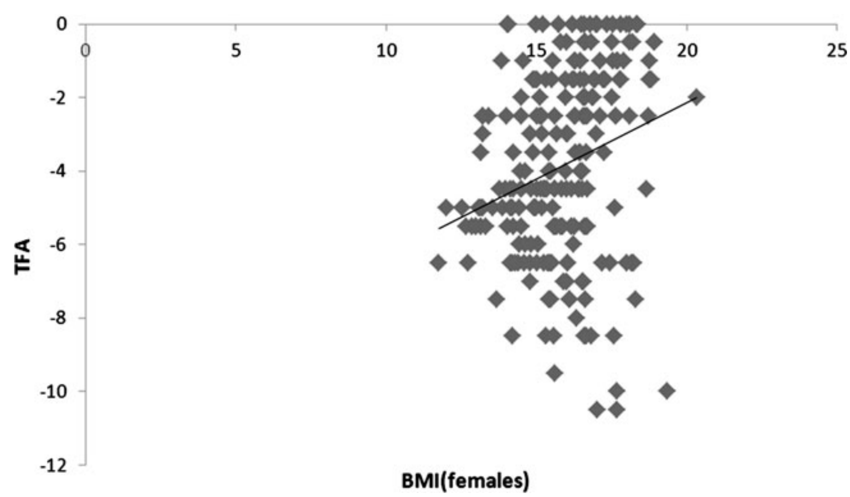
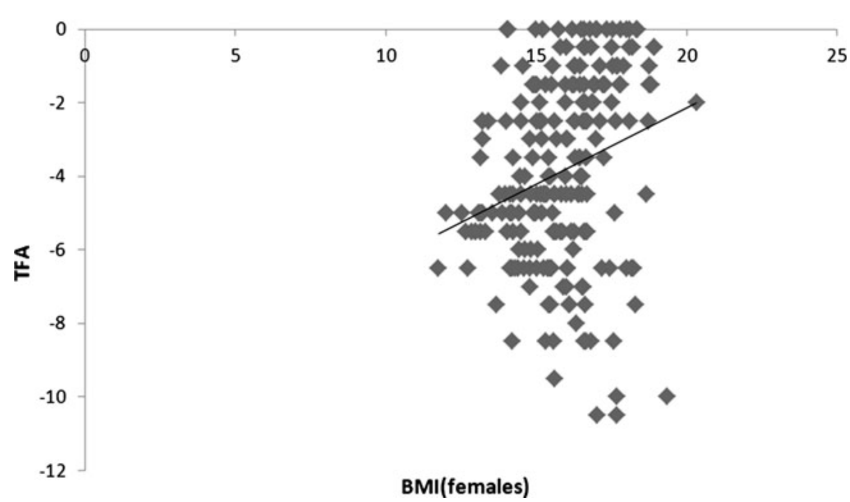


Fig. 8 Relationship between mean tibiofemoral angle and body mass index for boys



carried out in western Nigeria by Omololu et al. [3], who reported maximum valgus of 11°. Cheng et al. [2], examining 2,630 Chinese children, reported maximum valgus TFA of 8° at 3.5 years. This finding is in keeping with results of this study, which show maximum valgus angulation of 7.87° at three years. Heath and Staheli [4] photographically determined TFA and found maximum valgus angulation of 8.7° at four years. The discrepancy between values for maximum valgus alignment of the knee is not known. Racial differences have been suggested [3, 4], but even in the same geographical subregion, this study demonstrated differences in the same race and similarities in values in different races. Several methods of TFA determination have been used [1, 2, 4]. Perhaps a difference in the techniques for determining knee angles, as posited by Heath and Staheli [4], may account for this. It is generally accepted that radiological methods offer the most objective modality for determining TFA. This method was employed by Vankka and Salenius [1], who reported good correlation with clinical measurements. This seems a more plausible explanation for the slight differences observed. A closer look at the relationship between clinical and radiological measurements may shed more light on this issue.

We found no significant gender variation in TFA, which is in keeping with the generally observed trend. BMI, also known as Quetelet's index, is an accepted modality for routine screening of overweight adolescents in the USA [8]. It is derived from the weight and height of the individual and is represented by the formula

$$\frac{wt}{ht^2},$$

where *wt* is weight measured in kilograms and *ht* is height measured in metres. BMI as a measure of total body mass is superior to weight measures alone because it takes into consideration adjustments for height, age and gender. It has, however, been criticised as a tool for measuring underweight, overweight or obesity in children, who are not generally considered to have a medium frame. This is largely due to differences in bone density and the consequent ratio of bone to total weight, as well as to age and sex differences in amount of total body fat. The US Centers for Disease Control and Prevention (CDC) gives interpretation to calculated BMI figures in children on the basis of age and gender [9]. The CDC guidelines enable BMI conversion to percentiles based on age and sex. A BMI that lies between the 5th and 85th percentiles is determined to be a healthy weight. Values that lie between the 85th and 95th percentile are considered as at risk for overweight and values >95th percentile overweight [10]. In our study, all participants had a BMI within the 5th and 85th percentile for age and sex using the CDC charts, thus representing healthy weight.

There is a paucity of literature demonstrating the relationship between body mass and the magnitude of the knee angles in normal children. In a prospective study of the orthopaedic complications of overweight children and adolescents, Taylor et al. [11] using whole-body dual-energy X-ray absorptiometry (DEXA) scans found greater malalignment of the metaphyseal–diaphyseal and anatomic TFA measurements in overweight compared with normal weight children. These malalignments were mainly valgus. In that study, participants were classified as overweight if their BMI exceeded the 95th percentile for age, gender and race.

Pirpiris et al. [12], in a study aimed at determining whether or not BMI and percentile BMI were associated with an increased likelihood of being listed for surgery in patients with Blount's disease, retrospectively analyzed 102 consecutive patients with Blount's disease. They found significant correlation between BMI and percentile BMI and being listed for surgery. They concluded that a higher BMI was associated with more severe deformity in patients with Blount's disease. These findings were essentially in keeping with findings by Sabharwal et al. [5], who found a significant correlation between the magnitude of obesity and biplanar roentgenographic deformities in children with early-onset Blount's disease and in those with a BMI ≥40. In this study, a negative correlation was demonstrated between clinically determined TFA and BMI as well as weight. This correlation was more significant with weight and less so for BMI. The absence of overweight and at risk for overweight participants in this study makes it difficult to comprehensively evaluate the role of BMI in the magnitude of the knee angle in normal children.

Conclusion

In this study, we conclude that axial loading, as represented by BMI, does not contribute to the increasing magnitude of knee angles in normal, healthy-weight children. This may not necessarily be the case with overweight children.

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Conflict of interest The authors declare that there are no conflicts of interest.

References

1. Salenius P, Vankka E (1975) The development of the tibiofemoral angle in children. J Bone Joint Surg [Am] 57:259–261
2. Cheng JCY, Chan PS, Chiang SC, Hui PW (1991) Angular and rotational profile of the lower limb in 2,630 Chinese children. J Pediatr Orthop 11:154–161

3. Omololu B, Tella A, Ogunlade SO, Adeyemo AA, Adebisi A, Alonge TO, Salawu SA, Akinpelu AO (2003) Normal values of knee angle, intercondylar and intermalleolar distances in Nigerian children. West Afr J Med 22:301–304
4. Heath CH, Staheli LT (1993) normal limits of knee angle in white children – Genu varum and genu valgum. J Pediatr Orthop 13:259–262
5. Sabharwal S, Zhao C, McClemens E (2007) Correlation of Body Mass Index and Radiographic Deformities in Children with Blount Disease. J Bone Joint Surg Am 89:1275–1283
6. Kessel L (1970) Annotations on the aetiology and treatment of tibia vara. J Bone Joint Surg 52B:93–99
7. Cook SD, Lavernia CJ, Burke SW et al (1983) A biomechanical analysis of the etiology of tibia vara. J Pediatr Orthop 3:449–454
8. Himes JH, Dietz WH (1994) Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 59:307–316
9. BMI Percentile. [centers for Disease Control and Prevention Website] http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html AccessedAugust 5 2011
10. Dawson P (2002) Practice Guidelines: Revised Growth Charts for Children. Am Fam Physician 65(9):1941–1942
11. Taylor ED, Theim KR, Mirch MC et al (2006) Orthopaedic complications of overweight in children and adolescents. Pediatrics 117 (6):2167–2174
12. Pirpiris M, Jackson KR, Farng E et al (2006) Body Mass Index and Blount Disease. J Pediatr Orthop 26(5):659–663