Estimation of the Predictive Effect of Body Mass Index-Percentile on Skeletal Maturation in a Nigerian Population.

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Abstract

Aim: *To determine the predicting effect of BMI-index percentile on the skeletal maturation of Nigerian children.*

Materials and Methods: *A cross-sectional descriptive study. This study was conducted in a tertiary health care facility in North-Central Nigeria. Participants were children between the ages of 5-17 years consisting of 44 males and 30 females who presented in the child dental clinic over a period of eight months were recruited for the study. Skeletal maturation was assessed using the middle phalanx of the third finger (MP3), while the standard WHO growth chart specific for age (2-20 years) and sex was used for grading BMI-percentile. The unpaired t-test was used to compare mean chronological age of the various stages of MP3 according to sex. Multinomial logistic regression was used to determine the predictive effect of age, sex, and BMI percentile on pubertal growth spurt.*

Results*: The BMI-percentile did not show a significant correlation with the pubertal growth spurt (r=0.089, p=0.448). Sex (p=0.004) and chronological age had significant (p<0.001) predictive effect on the skeletal maturation, unlike the BMI-percentile. A one-percentile increase in the BMI-percentile decreases the likelihood of healthy children to be in the peak-pubertal by 1.504 when compared to obese children (p=0.305).*

Conclusion*: This study showed that BMI-percentile is a weak predictor of skeletal maturation. However, obese children had a tendency towards advanced skeletal maturation than healthy participants. It is therefore suggested that orthodontists should consider early implementation of jaw modification treatments among obese children.*

Keywords: *Body Mass Index-Percentile, skeletal maturation.*

Introduction

The periods of childhood and adolescence are important periods where critical decisions concerning orthodontic treatment modalities are taken, especially with improvement of dental and facial aesthetics.[1] The diagnosis and commencement of orthodontic treatment should therefore be based on individualized assessment of the maturation status of the patient.[2] Maturation status of an individual can be evaluated using body height, skeletal maturation, dental calcification, dental emergence, and chronological age.[3-6] Generally, skeletal maturation is closely related to the growth of the craniofacial growth, and is largely affected by nutrition, genetic make-up, and hormonal variation.[7,8]

The body mass index (BMI) was first described by Keys and his colleagues to be used among adults to classify the level of adiposity.[9] It has since become a popular screening tool among children and adolescents to determine those who are underweight, healthy, overweight, and obese.[10] The prevalence of body mass discrepancy especially with overweight and obesity is on the increase and appears to be more common among children attending private school.[11,12] Since BMI-for-age is used to grade body size (underweight, healthy, overweight, obesity), determination of its effect on skeletal maturation among the age-seeking orthodontic patients (childhood and adolescents) has received the attention of some researchers.[13-15] Evaluation of skeletal maturation is particularly important to the orthodontist when there is consideration for growth modification, when using functional and orthopaedic appliances. Therefore, factors like BMI-percentile that could affect it should be duly considered during orthodontic treatment planning.[16]

The effect of BMI-percentile on skeletal maturity has been researched by several authors among different population using different methods for the evaluation of skeletal maturation.[13,17,18] The literature have shown that there is a trend toward advanced skeletal maturation among overweight and obese children compared to those within the healthy category of BMI-percentile.[19] Some authors have reported that BMI-percentile is not a significant predictive factor, [13,14] while others observed a statistical significant finding.[20-22]

The various methods of evaluating skeletal maturation which include cervical vertebrae maturation, hand wrist radiograph, dental calcification stages, and middle phalanx of the third finger are reliable for the estimation of skeletal maturity.[23,24] The study conducted among a Turkish population showed that BMI percentile had significant predictive effect on skeletal maturation estimated with hand wrist radiograph but it was not significant with the skeletal maturation estimated with cervical vertebrae maturation stages.[18] The need for low exposure to radiation is therefore a major consideration for evaluating orthodontic patients. The use of developmental stages of the middle phalanx of the third finger allows for low exposure to radiation yet producing a reliable tool for evaluation of skeletal maturation.[25]

To the best of our knowledge, studies on the predictive effect of BMI-percentile on skeletal maturation among Nigeria children seem to be scarce. Thus, the aim of this present cross-sectional study is to estimate the predictive effect of BMI-index on the skeletal maturation of Northern Nigerian children using the developmental stages of the middle phalanx of the third finger.

Material and Methods

Study design and setting:

The study was a cross sectional descriptive study and was carried out at the Federal Medical Centre, Keffi, Nasarawa State, Nigeria. All consecutive patients who presented at the Child Dental Clinic (between December, 2020 and July 2021) and have met the criteria for the study were recruited.

Participants' recruitment:

Selection criteria

Participants recruited included patients between ages 5 to 17 with no history of any form of orthodontic treatment, no congenital or developmental defect, parents who gave informed consent, and participants who also gave assent to participate in the study. Individuals with serious childhood illnesses that could affect development and growth, congenital anomaly, and those who refused consent and assent were excluded from the study.

Sample size calculation

The prevalence (p) of obese (≥95th percentile) in North Central Nigeria has been reported to be 3.1%.[12] Therefore, a minimum sample size of 44 was arrived at using the above formulae. Participants were thereafter recruited using convenience sampling method. Our study sample consisted of 74 participants comprising 44 males (mean age of 10.75 ± 2.73 years) and 30 females (10.00 ± 3.01 years).

Variables measured

The development stages of the middle phalanx of the third finger were used to evaluate the skeletal maturation status of the study participants. Also, the body mass index was calculated from the height (m) and weight (kg) measured using a stadiometer. BMI percentile for each participant was obtained using the growth charts specific for age and sex according to the standard WHO growth chart specific for age (2-20 years) and sex.

Data collection

A digital peri-apical x-ray sensor was used to obtain the radiographs of the middle phalanx of the third finger. Each participant was asked to stretch their middle phalanx on a flat surface with the proximal inter-phalangeal joint of the middle finger centered on the digital sensor and the x-ray tube perpendicular to it (figure 1). Hagg and Taranger method[26] (figure 2), was used to grade the developmental stages of the middle phalanx of the third finger.

Figure 1. Digital peri-apical radiographic view of the middle phalanx of the third finger of a study participant.

Description of equipment and machines

The Carestream peri-apical x-ray machine model CS2100 with a standard wall-mounted unit was used for this study. It has an exposure dose of 60KV-7mA at a distance of 20cm from the x ray tube focal spot to the skin. Carestream digital sensor, RVG 142 size 1 (24mm x 40mm), was used to obtain the radiographs of the study participants. The exposure time was 0.016 seconds and the dose emitted was 0.10mGy. The optimal dose deliver to patients was 1.21mGy.cm^2, as the exposure surface of the size 1 sensor is 12.1cm.

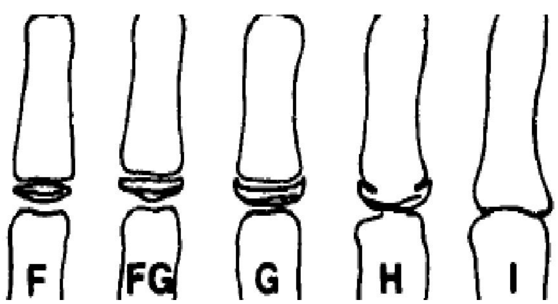

Figure 2: Developmental stages of the middle phalanx of the third finger (MP3) according to Hagg and Taranger.

Developmental stages of the middle phalanx of the third finger (figure 2)

Stage F: Epiphysis is as wide as the metaphysis. It occurs before the onset of peak height velocity with more than 80% of pubertal growth remaining.

Stage FG: Epiphysis is as wide as the metaphysis, with distinct medial and/or lateral border of the epiphysis forming a line of demarcation at right angles to the right angle to the distal border. It indicates the accelerating slope of pubertal growth spurt.

Stage G: The sides of the epiphysis have thickened and also caps its metaphysis, forming a sharp edge distally at one or both sides. This stage corresponds to the peak of pubertal growth.

Stage H: Fusion of the metaphysis and epiphysis have started (from the mid-point). It indicates the decelerating slope, but before the end of growth spurt.

Stage I: Complete fusion of the metaphysis and epiphysis. This stage indicates the attained end of growth spurt.

The developmental stages of MP3 were thereafter collapsed into 3 groups (stages MP3-F and MP3-FG as pre-peak pubertal, stage MP3-G as peak pubertal while stages MP3-H and MP3-I as post-peak pubertal).

Measurement of body mass index (BMI) and body mass index-percentile weight (in kilogram) and height (in meters) were measured using the stadiometer. The body mass index was calculated by dividing the weight in kilogram (kg) by the square of the height in meters (m^2). BMI percentile for each participant was obtained from BMI scores with reference to the standard WHO growth charts specific for age (2-20 years) and sex. A BMI-percentile less than 5%, between 5%-85%, between 85%-95%, and greater than 95% were considered underweight, healthy, overweight, and obese respectively.

Intra-investigator reliability:

Eight radiographs of the middle phalanx of the third finger were randomly selected and assessed at two different sections with two weeks interval, to determine intra-class reliability. Intra-class coefficient (ICC) showed excellent intra-investigator reliability to be 0.904 for the developmental stages of the middle phalanx of the third finger, p<0.001.

Ethical consideration:

Prior to commencement of this research, ethical approval was obtained from the institution's Health Research Ethical Committee (FMC/KF/HREC/2571/21). Informed consent was obtained from the parents and guardians of the study participants, while verbal assent was gotten from the children.

Statistical method and data analysis:

Data collected were coded and entered in to the computer system and analysed using Statistical Package for Social Sciences (SPSS) version 22. Unpaired t-test was used to compare the means of the chronological age, height, weight and Body Mass Index (BMI) according to sex.

Unpaired t-test was used to compare mean chronological age of the various developmental stages of MP3 according to sex.

Kendaul tau-b, rank-biserial, and Spearman's correlation were used to determine the association of age, gender, and BMI-percentile with overall pubertal growth spurt. The developmental stages of MP3 were thereafter collapsed into 3 groups (stages MP3-F and MP3-FG as pre-peak pubertal, stage MP3-G as peak pubertal, while stages MP3-H and MP3-I as post-peak pubertal). A multivariate analysis was conducted using the multinomial logistic regression to determine the effect of some predicting independent variables (age, sex and BMI percentile) on the dependent variable (groups of pubertal growth spurt) with pre-peak pubertal growth spurt as the reference category.

Results

Table 1 shows the comparison of the mean values of chronological age, height, weight and body mass index (BMI) according to sex using unpaired t-test. Although males marginally had higher height (1.40 ± 0.13), females presented with greater weight (34.22 ± 10.48) which resulted in females having higher BMI. No statistical significant difference was recorded in these variables in relation to sex.

Table 1: Mean chronological age, height, weight and body mass index (BMI) using unpaired t-test

					95% CI		P value
Variables	Sex	N(%)	Mean ± SD	MD	Lower	Upper	
Chronological age (years)	Male	44 (59.5)	10.75 ± 2.73	0.750	-0.592	2.092	0.269
	Female	30 (40.5)	10.00 ± 3.01				
	Total	74 (100.0)	10.45 ± 2.85				
Height (m)	Male	44 (59.5)	1.40 ± 0.13	0.037	-0.053	0.078	0.706
	Female	30 (40.5)	1.39 ± 0.14				
	Total	74 (100.0)	1.40 ± 0.14				
Weight (kg)	Male	44 (59.5)	34.08 ± 12.97	-0.137	-5.813	5.519	0.920
	Female	30 (40.5)	34.22 ± 10.48				
	Total	74 (100.0)	34.14 ± 11/.94				
BMI (kg/m^2)	Male	44 (59.5)	17.01 ± 4.14	-0.344	-2.035	1.348	0.687
	Female	30 (40.5)	17.36 ± 2.55				
	Total	74 (100.0)	17.15 ± 3.56				

MD, Mean difference; CI- Confidence interval

The mean chronological age of the various BMI-percentile (underweight, healthy, overweight, and obese) and the mean BMI of underweight, healthy, overweight, and the obese participants against the sex were also determined using the unpaired t-test. Majority of the participants (70.3%) in this study were in the healthy percentile category. Healthy female participants were noted to have a statistically significant higher mean BMI (p=0.045) than males as shown in table 2.

Table 2: Comparison of the mean chronological age of the BMI-percentile and the mean BMI of the BMI-percentile according to sex using unpaired t-test.

					95% CI		P value
BMI-Percentile groups	Sex	N(%)	MEAN (SD)	MD	Lower	Upper	
Mean chronological age of the BMI-percentile							
Underweight (<5% percentile)	Male Female Total	8 (66.7%) 4 (33.3%) 12 (100%)	12.13 (4.12) 10.00 (2.71) 11.42 (3.73)	2.125	-2.2996	7.246	0.377
Healthy (5%-85% percentile)	Male Female Total	30 (57.7%) 22 (42.3%) 52 (100%)	10.47 (2.37) 10.32 (3.15) 10.40 (2.70)	0.149	-1.389	1.687	0.847
Overweight (85%-95% percentile)	Male Female Total	5 (62.5%) 3 (37.5) 8 (100%)	9.80 (1.64) 9.33 (1.15) 9.63 (1.41)	0.467	-2.211	3.144	0.684
Obese (>95% percentile)	Male Female Total	1 (50%) 1 (50%) 2 (100%)	13.00 (0.00) 5.00 (0.00) 9.00 (5.66)	8.000	-	-	-
Mean BMI of the BMI-percentile							
Underweight (<5% percentile)	Male Female Total	8 (66.7%) 4 (33.3%) 12 (100%)	14.12 (1.39) 13.86 (0.77) 14.04 (1.18)	0.259	-1.425	1.943	0.739
Healthy (5%-85% percentile)	Male Female Total	30 (57.7%) 22 (42.3%) 52 (100%)	16.43 (1.68) 17.54 (2.23) 16.90 (1.99)	-1.112	-2.200	-0.024	*0.045
Overweight (85%-95% percentile)	Male Female Total	5 (62.5%) 3 (37.5) 8 (100%)	20.72 (1.55) 19.74 (2.01) 20.35 (1.68)	1.000	-2.069	4.077	0.455
Obese (>95% percentile)	Male Female Total	1 (50%) 1(50%) 2 (100%)	39.04 (0.00) 20.14 (0.00) 29.59 (0.00)	18.900	-	-	-

P<0.05

The developmental stages of MP3 were grouped into 3 stages (MP3-F and MP3-FG as pre-peak pubertal, MP3-G as peak pubertal, and MP3-H and MP3-I as post-peak pubertal) and the mean

BMI also plotted against sex, as shown in table 3. It was observed that females had lesser mean BMI at the pre-peak and at the peak of pubertal growth spurt, with no statistical, significant difference. The mean BMI at the post-peak pubertal stage for females was significantly higher (p=0.046) than males.

Table 3: Comparison of the mean BMI of the pubertal growth spurt according to sex using unpaired t-test.

PrPPS = Pre-Peak Pubertal Spurt (stages MP3-F and MP3-FG); PPS = Peak Pubertal Spurt (stage

					95% CI		P value
Mean BMI	Sex	N	Mean (SD)	MD	Lower	Upper	
PrPPS	Male	34 (68.0)	16.28 (2.37)	0..425	-0.964	1.814	0.541
	Female	16 (32.0)	15.85 (2.05)				
	Total	50 (100%)	16.14 (2.26)				
PPS	Male	6 (42.9)	20.93 (9.32)	2.386	-4.914	9.686	0.490
	Female	8 (57.1)	18.54 (1.99)				
	Total	14 (100%)	19.57 (6.09)				
PoPPS	Male	4 (40.0)	17.37 (1.34)	-2.410	-4.769	-0.051	0.046
	Female	6 (60.0)	19.78 (1.72)				
	Total	10 (100%)	18.81 (1.94)				

MP3-G); PoPPS = Post-Peak Pubertal Spurt (stages MP3-H and MP3-I), MD – mean difference, CI=Confidence interval

Table 4 shows a moderate, positive, statistically significant correlation (r=0.542, p<0.001) between chronological age and the pubertal growth spurt. There was, however, a weak level of association between sex and pubertal growth spurt (r=0.238). The BMI-percentile had very weak (r=0.089) and no statistically significant correlation with the pubertal growth spurt.

Table 4: Measure of association with pubertal growth spurt

	Pubertal growth spurt	
	Correlation coefficient	P value
Age	*0.542	<0.001
Sex	**0.238	0.042
BMI percentile	***0.089	0.448

*-Kendaul tau-b correlation; **-rank-biserial correlation; ***-Spearman's correlation

The multivariate analysis was conducted using the multinomial logistic regression to determine the effect of some variables (age, sex, and BMI percentile) on the dependent variable (groups of pubertal growth spurt), with pre-peak pubertal growth spurt as the reference category. This is shown in table 5. Males were 4.721 less likely to be in the post-peak pubertal than females (p=0.004). This indicates that females are more advanced than males. A one-year increase in the chronological age increases the likelihood of being in the post-peak pubertal growth spurt by 1.632 (p<0.001) than in the pre-peak pubertal growth spurt. However, a one-percentile increase in the BMI-percentile decreases the likelihood of healthy children to be in the peak-pubertal by 1.504 when compared to obese children (p=0.305). In summary, obese children are more likely to attain the peak pubertal stage than healthy children.

Table 5: Results of multinomial logistic model of pubertal growth spurt (pre-peak as reference category) using MP3 stages

				95% CI		
Predictive variables	B	Df	OR	Lower	Upper	P value
Sex (male)	-4.721	1	0.009	0.000	0.217	**0.004**
Chronological Age	1.632	1	5.116	2.318	11.291	**<0.001**
BMI percentile (Healthy 5%-85%)	-1.504	1	0.222	0.013	3.942	0.305

.OR-Odd ratio; CI- Confidence interval.

Discussion

Orthodontists tend to rely more on skeletal maturation as an indicator to commence growth modification treatment. Therefore, factors that would influence the pattern of skeletal maturation of orthodontic patients should be evaluated prior to commencement of treatment.

This present study showed a statistically significant level of moderate association between age and skeletal maturation (pubertal growth spurt). The level of association between sex and pubertal growth spurt was, however, weak but statistically significant. It was also observed in this present study that the body mass index-percentile (BMI-percentile) had a weak, positive correlation with the pubertal growth spurt. The positive correlation between BMI-percentile and pubertal growth spurt as observed in this study corroborates earlier findings.[27,28] DuPlessis et al observed that the positive correlation between BMI-percentile and skeletal maturation was weak[27], which is supported by the result of this current study. However, the same authors[27,28,] observed the correlation to be statistically significant which is at variance with the findings of this current study. Ethnic variation and genetic influence of the study populations may account for the differences observed. **S**imilar studies conducted among Iranian and Turkish populations by Hedayati & Khalafinejad[14] and Erhamza et al[18] respectively did not show significant correlation between BMI-percentile and skeletal maturation using the cervical vertebrae maturations stages, which agrees with the observation made in this present study.

The final model developed in this study showed that age and sex had significant predicting effect on skeletal maturation, which agrees with previous studies.[14,18,22] A one year increase in age accelerates the skeletal maturation by 1.632 times. Males were more likely to be skeletally delayed than females; that is, males were 4.721 times as likely to hit the pre-pubertal growth spurt than females. These findings show that females tend to be more advanced in skeletal maturation than males. These findings are also consistent with results earlier reported by previous researchers.[18,22]

The predicting effect of BMI-percentile on skeletal maturation appears contentious. In our study, a one-percentile increase in the BMI-percentile decreases the likelihood of healthy children to be in the peak-pubertal by 1.504 times when compared to obese children. In other words, obese children have a tendency towards advanced skeletal maturation. This is consistent with previous studies[18,22,28] but at variance with the observation made by Bodapati et al,[17] who reported that an increase in body mass does not relate to early skeletal maturation. Erhamza et al[18] evaluate the effect of BMI-percentile on skeletal maturation using the cervical vertebrae and the hand wrist bones. The authors[18] observed that the predicting effect of BMI-percentile was not significant with the cervical vertebrae bones (odd ratio, 0.204; P=0.204), which is corroborated by findings from our study. The same authors[18] however observed a significant predictive effect of BMI-percentile with the hand wrist bones (odd ratio, 1.016; P=0.015), which is at variance with this present study.

Lack of compatibility between the two methods used for the evaluation of the skeletal maturation was cited as a reason for the differences observed in the predictive influence of BMI-percentile.[18] In our study, the middle phalanx of the third finger was used to evaluate the skeletal maturation of study participants and our findings agree with the observations made by Akridge et al[13] who used the Fishman hand wrist analysis for evaluation of skeletal maturation, and also with reports made by Hedayati & Khalafinejad[14] who used the cervical vertebrae for the evaluation of skeletal maturation. Findings from our study are however at variance with observations made by other researchers who reported significant predicting effect of BMI-percentile on skeletal maturation.[20-22]

BMI-percentile is now a screening tool for categorising children and adolescents as either underweight, healthy, overweight, or obese.[10,29] It is important to note that the prevalence of obesity is gradually on the increase globally.[12,30] Children and adolescents are the major age groups who seek orthodontic care for the purpose of improving their aesthetics and better oral functions. Since findings from our present study reveal that an increase in BMI-percentile has a tendency towards accelerated skeletal maturation, orthodontists should make it a routine practice to determine the BMI-percentile of their patients. Advanced skeletal maturation among those who are obese means that the implementation of growth modification treatment should be done earlier than healthy group individuals.[31] This is important so that the active period of growth needed for skeletal modification will not be missed.

Conclusion

The following conclusions were arrived at from our study:

1. BMI-Percentile did not show a statistically significant correlation with skeletal maturation.
2. Age and sex were significant predictive factors of skeletal maturation.
3. Individuals with higher BMI-Percentile have a tendency towards advanced skeletal maturation but it was not statistically significant.

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