Original Research

Adolescent Body Mass Index and Skeletal Maturation Assessed with Hassel and Farman's Cervical Vertebrae Staging Method

Sushila Sah[1], Preeti Bhattacharya[2], Ravi Bhandari[3], Taufique Anwer[4], Sumit Joshi[5], Akash Prakash Singh[6], Ahmad Muzaffar[7]

[1]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [2]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [3]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [4]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [5]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [6]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India, [7]Department of Orthodontics, Institute of Dental Sciences, Bareilly, Uttar Pradesh, India

ABSTRACT

Introduction: Obesity and underweight are two growing paradox problems in today's world. The global disparity in terms of fat and hungry zones is the most visceral way, in which this inequality is lived, felt, and seen. Body mass index (BMI) is normally used to describe of the level of fatness. Orthodontists frequently deal with children and adolescents for growth modulation therapy. **Purpose:** The purpose of this study was to investigate whether the increase or decrease in BMI influences the skeletal maturation in adolescent orthodontic patients. **Material and Method:** Four BMI groups: Group I (underweight), Group II (normal-weight), Group III (overweight), and Group IV (obese) with 25 subjects each and of 14–17 years of age were studied. Each subject's lateral cephalogram was studied for cervical vertebrae (CV) as a skeletal maturation indicator using Hassel and Farman's CV maturation index (CVMI) staging. **Statistical Analysis:** Analysis was performed using the SPSS version 20.0. Pearson product correlation was run to determine the relationship between BMI and CVMI. Linear regression and ANOVA was performed for finding the regression correlation between the BMI and CVMI. **Results:** The Pearson correlation test showed statistically significant linear relationship between BMI and CVMI ($r = 0.423$). The correlation was between BMI and CVMI, which was with 95% confidence with $P < 0.001$ (two-tailed). ANOVA test was used to find the regression correlation between BMI and CVMI, in which the beta (standardized regression coefficient) was 0.423. **Conclusion:** There was a significant positive linear relationship between CVMI and BMI, where an increase in BMI is likely to affect the CVMI and thereby the skeletal maturation.

Key words: Cervical vertebral maturation, skeletal maturation, body mass index, obesity, underweight

INTRODUCTION

Obesity and underweight are two growing paradox problems in today's world. The global disparity in terms of fat and hungry zones is the most visceral way, in which this inequality is lived, felt, and seen. Many ramifications and negative medical consequences are associated with obesity and underweight. The body weight and the level of fat accumulation depend on health status, basal metabolism, hormonal balance, physical exercise, diet, race, and heredity.[1] Body mass index (BMI) is usually used to describe the level of fatness classifying into underweight, normal, overweight, and obese. Raw BMI scores are practically pointless in growing children as the adiposity varies with age and gender during childhood and adolescence. BMI is age and gender-specific. BMI percentiles are a fast, non-invasive, and handy method to measure a child's height-weight status.[2] According to the Center for Disease Control (CDC) growth charts, a BMI over the 95th percentile is obese, 85th–95th percentiles are considered overweight, and those below the 5th percentile are underweight.[3]

Orthodontists frequently deal with children and adolescents for growth modulation therapy. Growth is an active process that commences right after conception. Complex interactions of genes, hormones, and nutrients regulate the postnatal craniofacial skeletal growth.[4] It is known that the growth velocity in obese shows faster linear growth in the 1st years of life which maintained till the beginning of puberty and later a growth spurt equal with the lean subjects.[5] It is understandable that by an obese body mass, growth

Corresponding Author:
Sushila Sah, Department of Orthodontics,
Institute of Dental Sciences, Bareilly, Uttar Pradesh, India.
E-mail: sushilasah465@gmail.com

and development, will be affected but to what extent this occurs is presently unknown.[6] Thus, the objective of this study was to investigate whether the increase or decrease in BMI influences skeletal maturity in an adolescent orthodontic patient.

MATERIAL AND METHOD

Patients age 14–17 years, referred to the Department of Orthodontics and Dentofacial Orthopedics at the Institute of Dental Sciences, Bareilly, needing orthodontic treatment were considered to be a part of the study. As a part of the routine orthodontic investigation, each patient's height and weight were recorded and a lateral cephalogram was taken. Subjects with any previous history of craniofacial trauma or congenital anomalies or any significant medical history that would affect physical development and growth were excluded from the study.

After the calculating, the BMI percentile for each patient, the records of 100 patients (25 subjects in each group) fulfilling the above-mentioned criteria were selected for the study and divided into four groups:

- Group I – Underweight (<5th percentile)
- Group II – Normal (5th–85th percentile)
- Group III – Overweight (85th–95th percentile)
- Group IV – Obese (>95th percentile).

For evaluating the cervical vertebrae (CV) stages, Hassel and Farman's CV maturation index (CVMI) staging[7] was used [Table 1 and Figure 1]. CV C2, C3, and C4 were traced on each cephalometric film by one tracer on an acetate paper using a 0.3 mm 3H pencil. By identifying changes at the inferior border and body morphology of the cervical vertebrae: C2, C3, and C4, staging was done from CVMI 1 to CVMI 6.

Table 1: Hassel and Farman's cervical vertebrae maturation indicators[7]

CVMI stages	Characteristic changes on cervical vertebrae
1 Initiation	• Growth expected – Substantial • The lower border of C2, C3, and C4 are flat • Upper borders are tapered posterior to anterior
2 Acceleration	• Growth expected – Significant • The lower border of C2 and C3 starts developing concavities • The C4 lower border is flat • Rectangular C3 and C4
3 Transition	• Growth expected – Moderate • C2 and C3 lower borders with distinct concavities • The lower border of C4 starts to develop concavity • Rectangular C3 and C4
4 Deceleration	• Growth expected – Little • The lower borders of C2, C3, and C4 with distinct concavities • Nearly squarish C3 and C4
5 Maturation	• Growth expected – Very little • The lower borders of C2, C3, and C4 with accentuated concavities • Squarish C3 and C4
6 Completion	• Growth expected – nil • The lower border of C2, C3, and C4 with deep concavities • Height of C3 and C4 greater than the width

Statistical analysis

The analysis was performed using the SPSS 20.0 version. A descriptive analysis of the qualitative variable is shown as a number and percentages. A Pearson product correlation was run to determine the relationship between BMI and CVMI. Linear regression was performed to predict the value of BMI on CVMI (if there is a relationship, is it dependent on each other). ANOVA was performed for finding the regression correlation between BMI and CVMI. $P < 0.005$ was considered statistically significant. All the data were reported with exact *P*-values and 95% confidence intervals. The present study was approved by the Ethical Committee of Bareilly International University, Bareilly.

RESULT

A total of 100 films were studied consisting of 25 subjects in each group. The Group I (underweight) comprised 14 (56.0%) males and 11 (44.0%) females, Group II (Normal), 14(56.0%) males and 11 (44.0%) females, Group III (overweight), 17 (68.0%) males and 8 (32.0%) females, and Group IV 18 (72.0%) males and 7(28.0%) females. Upon comparing the sex proportions (M/F) of four groups, revealed that these groups had statistically similar sex proportions (P=0.450).

The age of Group I (underweight), II (normal-weight), III (overweight), and IV (obese) groups ranged from 14 to 17 years with a mean (±SD) 15.04 ± 1.21 years, 15.08 ± 1.12 years, 14.80 ± 1.04 years, and 14.60 ± 1.04 years, respectively. When the mean age of four groups was compared using ANOVA, similar age among the four groups was found, that is, it did not differ statistically ($P = 0.236$).

The distribution of different CVMI stages among all 4 BMI groups are shown in Table 2. About 60% of underweights subjects were found to be in Stages 2 and 3, 80% of

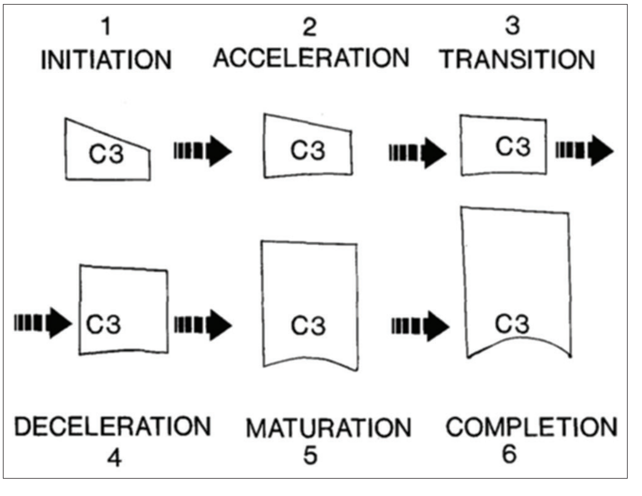

Figure 1: C3 as a guide for cervical vertebrae maturation indicators[7]

normal-weight subjects were found to be in Stages 4 and 5, and 64% of overweight subjects were found to be in Stages 5 and 6 and 60% of obese subjects were found to be in Stages 4 and 5.

The correlation between BMI and CVMI is represented in Table 3. The Pearson correlation test showed a statistically significant linear relationship between BMI and CVMI (r = 0.423). The correlation was between BMI and CVMI, which was with 95% confidence with $P < 0.001$ (2 tailed). The direction of the relationship was found to be positive and the magnitude of the association was strong with r = 0.423 with $R^2 = 0.179$, thus, a total variation of 0.179 in <18% of the sample [Table 4]. ANOVA test was used to find the regression correlation between BMI and CVMI, in which the beta (standardized regression coefficient) was 0.423. Implying that with a change in the 1-unit change in BMI, an increase of 0.423 in CVMI will be noticed [Table 5].

Table 2: Frequencies of each maturation stage in BMI groups

CVMI stages	Underweight	Normal	Overweight	Obese.
1	8%	0%	0%	0%
2	16%	0%	0%	0%
3	24%	12%	24%	16%
4	36%	40%	12%	28%
5	12%	40%	40%	32%
6	4%	8%	24%	24%

Table 3: Table showing the correlation between BMI and CVMI

	CVMI	BMI
CVMI		
Pearson correlation	1	0.423**
Sig. (two-tailed)		0.000
N	100	100
BMI		
Pearson correlation	0.423**	1
Sig. (two-tailed)	0.000	
N	100	100

**. Correlation is significant at the 0.01 level (two-tailed).

Table 4: Regression analysis for BMI and CVMI

Model	R	R square	Adjusted R square	Standard error of the estimate
1	0.423[a]	0.179	0.171	1.06,788

a. Predictors: (Constant), BMI

b. Dependent variable: CVMI

Table 5: Regression coefficient table

Model	Unstandardized coefficients		Standardized coefficients	*t*	Sig.
	B	Standard Error	Beta		
(Constant)	2.442	0.411		5.936	0.000
BMI	0.081	0.018	0.423	4.626	0.000

a. Dependent variable: CVMI

DISCUSSION

Obesity is one of the significant public health problems in developed countries and results from multiple interactions between genes and the environment. The body weight and the level of fat accumulation depend on health status, basal metabolism, hormonal balance, physical exercise, diet, race, and heredity.[1] The prevalence of overweight and obese adolescents has increased rapidly in developed as well as developing countries. Meanwhile, the prevalence of underweight is also increasing in many regions of the world, leading to a "bidirectional crisis."[8]

Various factors such as genes, nutrients, hormones, and epigenetic factors regulate craniofacial growth.[9] Perverted growth may result if there is an issue in any of these mechanisms. The general health of a child influences skeletal maturation and any prior knowledge of a certain type of skeletal predisposition can help in early diagnosis and treatment planning.

CDC growth charts were used to categorize underweight, normal weight, overweight, and obese constructed on the percentile-based data. CVMI was used as a skeletal maturation indicator for the participants. The orthodontists usually depend on the skeletal age more than the chronologic age as a gauge of growth modulation therapy. Although there has been criticism regarding the sensitivity of CVMI, there is no gold standard method. According to Wong *et al.*[10] in 2009, the CVMI method was considered sensitive for detecting growth maturity in too young or too old age ranges of subjects, but is quite helpful for precise detection of the growth maturity during the growth spurt period, that is, adolescence which comprises the test sample group of our study with age 14–17 years. Many studies Mack *et al.*, Akridge *et al.*, and Costacurta *et al.*[2,11,12] have reported accelerated skeletal growth in obese individuals. In our study too increased, BMI was associated with early skeletal maturation.

Our findings suggested that there is a positive linear relationship between BMI and CVMI. Furthermore, with every 1unit change in BMI for age and sex, there was an 0.432 increase in CVMI. This means that for a 14-year-old adolescent at a given time, with almost every 3 unit increase or decrease in the normal BMI, we could expect an increase/decrease 1 CVMI stage, respectively. The results of the study were consistent with the studies done by Akridge *et al.*,[11] Costacurta *et al.*,[12] Mack *et al.*,[2] and Kumar *et al.*[13]

Orthodontic treatment impacts the general health of children and adults. A recent study found that 55% of the orthodontists never collected any weight data, and only 4% weighed patients on a scale or recorded heights using a stadiometer.[2] Obesity was not assessed in any way by 73% of the orthodontists or dentists, and most of those who did not consider it to be significant.[14]

The craniofacial structures play an important role in facial esthetics; therefore, an orthodontist needs to know the possible changes in the craniofacial structures due to BMI in their growth period. Recording height and weight and considering, its likely effect on the treatment plan is recommended for the orthodontists.

Both obesity and underweight possesses a risk for many health-related issues and orthodontist being a health-care professional need to counsel the patients and the guardian regarding the ill-effects and should refer them to a nutritionist/diet counselor for weight management.

CONCLUSION

There was a significant linear relationship between CVMI and BMI, where an increase in BMI is likely to affect the CVMI, thereby the skeletal maturation. Thus, during adolescence when the growth changes take place, patients with lower BMI will have delayed skeletal maturation whereas, patients with higher BMI will have early skeletal maturation. A significant number of patients seeking orthodontic treatment are adolescents; so, it might be beneficial for the patient as well as the orthodontist to consider the BMI while making the treatment plan.

REFERENCES

1. Simopoulos AP. Obesity and carcinogenesis: Historical perspective. Am J Clin Nutr 1987;45:271-6.
2. Mack KB, Phillips C, Jain N, Koroluk LD. Relationship between body mass index percentile and skeletal maturation and dental development in orthodontic patients. Am J Orthod Dentofac Orthop 2013;143:228-34.
3. Kuczmarski RJ. CDC Growth Charts. United States: National Center for Health Statistics; 2000.
4. Salas-Flores R, González-Pérez B, Barajas-Campos RL, Gonzalez-Cruz B. Changes on craniofacial structures in children with growth-hormone-deficiency. Rev Méd Inst Mex Seguro Soc 2010;48:591-5.
5. De Simone M, Farello G, Palumbo M, Gentile T, Ciuffreda M, Olioso P, *et al.* Growth charts, growth velocity and bone development in childhood obesity. Int J Obes Relat Metab Disord 1995;19:851-7.
6. Neeley WW 2nd, Gonzales DA. Obesity in adolescence: Implications in orthodontic treatment. Am J Orthod Dentofac Orthop 2007;131:581-8.
7. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofac Orthop 1995;107:58-66.
8. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet 2017;390:2627-42.
9. Van Limborgh J. Factors controlling skeletal morphogenesis. Prog Clin Biol Res 1982;101:1.
10. Wong RW, Alkhal HA, Rabie AB. Use of cervical vertebral maturation to determine skeletal age. Am J Orthod Dentofac Orthop 2009;136:484.
11. Akridge M, Hilgers KK, Silveira AM, Scarfe W, Scheetz JP, Kinane DF. Childhood obesity and skeletal maturation assessed with Fishman's hand-wrist analysis. Am J Orthod Dentofac Orthop 2007;132:185-90.
12. Costacurta M, Sicuro L, Di Renzo L, Condò R, De Lorenzo A, Docimo R. Childhood obesity and skeletal-dental maturity. Eur J Paediatr Dent 2012;13:128-32.
13. Kumar V, Venkataraghavan K, Krishnan R, Patil K, Munoli K, Karthik S. The relationship between dental age, bone age and chronological age in underweight children. J Pharm Bioallied Sci 2013;5:S73.
14. Huang JS, Becerra K, Walker E, Hovell MF. Childhood overweight and orthodontists: Results of a survey. J Public Health Dent 2006;66:292-4.