

Relationship between Body Mass Index Percentile and Skeletal Maturation and
Dental Development in Orthodontic Patients

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ABSTRACT

Kervin B. Mack: Relationship between Body Mass Index Percentile and Skeletal Maturation and Dental Development in Orthodontic Patients
(Under the direction of Dr. Lorne Koroluk)

Objective: To investigate the relationship between body mass index (BMI) percentile and skeletal and dental maturity.

Methods: Orthodontic patients between 8 and 17 years of age were assessed using a retrospective chart review. Skeletal maturation was assessed using the Cervical Vertebral Method (CVM), dental age using the Demirjian method, and weight status using BMI percentile. Linear regression and logistic regression models were used to assess the effect of BMI percentile on dental age and CVM stage respectively.

Results: 540 subjects were included. CVM stage and dental age were more advanced in subjects with increased BMI percentile. For dental age the coefficient for BMI percentile was 0.005 years per 1 unit increase ($p < 0.001$) and the odds ratio for BMI percentile's effect on CVM was 1.02 ($p < 0.001$).

Conclusion: Orthodontists should consider weight status when evaluating the timing of growth modification treatment in growing patients.

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SECTION I:

LITERATURE REVIEW

Prevalence and Etiology of Obesity

Childhood overweight and obesity rates have soared in recent years. In 1965 the percentage of 6-11 year olds in the United States classified as overweight was 4.2%. In 2002 that number had risen to 15.8%. In adults the prevalence of obesity has increased from 13.3% to 31.1 percent while overweight prevalence has increased from 45 to 65% during the same time period.(1) The 1988-1994 National Health and Nutrition Examination Survey found that 11% of children were above the 95th percentile while 25% of children were above the 85th percentile with respect to Body Mass Index for age.(2) In 2007-2008, 11.9 percent of children aged 2-19 years were at or above the 97th percentile, 16.9% were at or above the 95th percentile and 31.7% were at or above the 85th percentile on the BMI-for-age charts.(3) Perceptions have also changed with time; men and women who are both overweight and obese are less likely to perceive themselves as overweight, despite the evidence that more people are overweight. This change in self-perception could possibly be contributing to a decreased desire to lose weight in the United States. (4) The dramatic and widespread increase in the prevalence of overweight and obesity in the general

population could have an impact on the demographics of the average orthodontic practice.

The terminology and the measurement standards for overweight patients have undergone numerous changes in recent years. In 1994, patients with a BMI-for-age in the 85th to the 95th percentile were termed “at risk for overweight” and those above the 95th percentile were “overweight.” More recently, patients between the 85th to 95th percentile for BMI-for age have been defined as “overweight” while patients above the 95th percentile are defined as “obese”. In addition, the term “obesity” is a measure of adiposity, which is not something that a percentile based on BMI can actually describe.(5) BMI does not take into account the potential that an individual can be of high body mass due to a greater percentage of lean tissue.

Structured physical education days have been shown to result in 39-43% increase in moderate to vigorous physical activity for children versus non-physical education days.(6) Unfortunately, the lifestyle of US children appears to be becoming more sedentary as school exercise programs are cut and children exercise less at home. This lack of physical activity in children has negative implications in many aspects of health including: cardiovascular health, overweight/obesity prevalence, academic performance, and bone mass in adulthood. Naturally occurring physical activity has the tendency to wane over the course of childhood, thus necessitating prescriptive physical activity.(7) In addition, eating habits in the US have changed significantly over the years. The consumption of calorie rich foods and increase in total daily caloric intake

combined with the trend of decreasing physical activity is partially to blame for the rise in childhood overweight and obesity. (2)

Assessment of Obesity

The need for an accurate method of assessing a child or adolescent's weight status has been discussed for decades. Malina, et al demonstrated the changes that occur in body composition throughout childhood and the teenage years. In both males and females, body fat composition alters dramatically depending on age. Girls have a rapid increase in body fat percentage until age 12; then the rate of increase slows dramatically. Boys tend to have an increase of body fat percentage until it peaks around age 12, followed by a decrease in body fat percentage until age 17, when body fat percentage again begins to rise. (8) Any model of assessment that does not account for these changes in body composition experienced by the growing child is inadequate.

Multiple standards for indexing a child's height and weight compared to those of other children their age have been suggested. In the late 70's Cole, et al provided extensive discussion regarding the need for producing standardized methods of assessing a child's height and weight in relation to similar-aged peers.(9) He proposed the use of Body Mass Index (BMI) as an estimate of body fat content in children. There are other methods that are more accurate, however none are as quick, noninvasive or simple as the measurement of height and weight to calculate BMI. A BMI of 30 Kg/m² or higher has been widely accepted as the criteria for diagnosis of obesity in adults. However, since body mass index changes considerably with growth, the use of a cut-off point based

on age has been advocated.(10) Waist circumference is another easily obtained measure that has been commonly employed in the assessment of childhood weight status.(11)

Other methods of assessment for childhood weight status exist. Pecoraro et al compared the usefulness of Biomass Impedance Analysis (BIA) with BMI and Triceps Skinfold Thickness (TST). With biomass impedance, a low level electrical current is passed through the body to assess electrical conductance through fatty tissues and lean tissues. TST involves the measurement of the skinfold thickness using calipers. Findings indicated that BIA and possibly TST were more accurate than BMI in predicting fat mass in children.(12)

Sequelae of Obesity

Childhood obesity has been shown to strongly associate with adult obesity. A study by Eriksson found that high BMIs were as predictive of adult obesity at 6 months as they were at 11 years of age.(13) Childhood waist circumference has been shown to have a strong correlation to poorer health outcomes including elevated systolic and diastolic blood pressure and total cholesterol. (11)

Childhood waist circumference has been shown to be associated with adult hypertension, but it can be modified by lifestyle change.(14) BMI has also been correlated in 12-13 year olds with increased total cholesterol, triglycerides, LDL and HDL cholesterol levels, insulin levels and glucose levels.(15)

The altered physical health outcomes of obesity may be mediated through a litany of factors. Obesity has been shown to be correlated with reduced levels of free testosterone, total testosterone, and sex hormone binding globulin in men.

The relationship appears to be bidirectional, however. Weight loss in the setting of massive ($\text{BMI} > 40 \text{ kg/m}^2$) obesity has been shown to increase testosterone levels.(16) Obese boys and girls have been shown to have increased estrogen levels through several mechanisms. Adipose tissue contains aromatase which can produce estrogen from adrenal androgen precursors. Additionally, there is a decrease in hepatic metabolism of estrogens due to obesity's effects on the liver.(17) Obesity has been shown to reduce both stimulated and spontaneous release of Human Growth Hormone (HGH). Normalization of body weight appears to return HGH secretion to normal levels. There does not appear to be a similar relationship between obesity and circulating Insulin like Growth Factor - 1 (IGF-I) which is the primary mediator for the actions of HGH. Leptin levels are also increased in obesity, and have been associated with decreases in bone mass by decreasing bone formation; also leptin has been shown to slowly rise before puberty and may have a permissive role in the onset of puberty.(18) Advanced bone age as determined by hand-wrist radiographs has also been reported to be associated with obesity in the literature.(19) Obesity and increased leptin levels may thus be associated with early onset of puberty and advanced skeletal maturation.

In addition to the physical sequelae of obesity, there are also psychological sequelae. Wang and colleagues found that children who were obese were twice as likely to have low self-esteem than children who were normal weight. (20) Meriaux described increased feelings of loneliness, sadness and peer victimization in the everyday experiences of overweight

children.(21) Ali and colleagues have suggested that the causative agent for poorer mental health outcomes was not actual weight status. Self-perceived weight status in the context of body dissatisfaction and weight stigmatization appears to be a confounder associated with depressive symptoms and poor self-esteem.(22)

Methods of assessing Physical Maturity

Beyond skeletal and dental maturity there are a multitude of methods for assessing physical maturity. Tanner staging which assesses sexual maturity consists of five stages, with stage 1 being the least mature (preadolescent) and stage 5 being the most mature (adult). In boys, Tanner Sexual Maturity Ratings (SMR) assess pubic hair (amount, coarseness, color and location), penile length and breadth, scrotal development and testicular size. In girls, Tanner SMR assess breast development (size and morphology) and pubic hair (location, color, morphology, quantity).(23) Although much of the Tanner SMR cannot be observed during a typical orthodontic interaction, there is some useful aspect for the orthodontic practitioner. In girls, breast buds usually appear one year prior to the peak velocity for physical growth, while during peak growth, most girls have noticeable breast development and axillary hair. Once menstruation begins, the growth spurt is usually near completion. In boys, pubertal growth spurts tend to extend over longer periods of time and occurs later in puberty; the peak height velocity tends to coincide with the appearance of axillary hair and facial hair on the upper lip.(24)

Dental Maturation

Dental maturation can be assessed using a method developed by Demirjian which utilizes a single panoramic radiograph. This method involves an assessment of root and crown development of ipsilateral mandibular teeth (except third molars) for their stage of root and crown development. Each tooth is graded on stage of development from A (least developed) to H (development complete). Each letter grade is associated with an experimentally determined maturity score based on the specific tooth and the gender of the subject. The maturity scores can then be summed to produce an overall maturity score correlated with a specific dental age based on the 50th percentile of children at that age in 1973.(25) It has been suggested that this method should be updated to correspond with the current secular trend in childhood development.(26)

Celikoglu, et al evaluated the applicability of the Demirjian method in assessing the dental age of eastern Turkish children and found mean dental age advancement in respect to chronological age that varied according to age group between 0.2-1.9 years in girls and 0.4-1.3 years in boys.(27) Nik-Hussein and colleagues evaluated the validity of the Demrijian method in Malyasian children versus a modification of the methodology by Willems. Their findings suggested that the Demirjian method did consistently overestimate dental age in relation to chronological age in comparison to the Willems method. However, accuracy was improved in situations in which the first premolar was more advanced in developmental stage than the 2nd premolar and 2nd molar.(28) Other methods of evaluating dental age have been presented including the Star method, a volumetric evaluation of the ratio of pulp-to-tooth volume in fully developed

monoradicular teeth using cone beam computed tomography (CBCT) (29), the Kohler method, a method using the degree of third molar development(30), and modifications of the original Demirjian method with new maturity scores(31). The Star method requires the additional radiation of a CBCT while the Kohler method requires the presence third molars, and is more reliable for ages 16-22, not younger patients. An additional method suggests a 14 stage classification system for each tooth that can be used to calculate the dental age.(32) The Demirjian method has been widely used in numerous investigations, is relatively simple, and requires no special interventions other than a panoramic radiograph.

Skeletal Maturation

Orthodontists previously assessed skeletal maturation by evaluating the development of various bones in a hand-wrist radiograph. The most common use of hand-wrist radiographs is the assessment for ossification of the ulnar sesamoid bone of the thumb.(33) Another method of evaluating skeletal maturity originated in 1972 from a thesis by Lamparski, referred to as the Cervical Vertebral Maturation method (CVM). (34) The CVM method utilizes developmental changes in the appearance of cervical vertebrae on a lateral cephalometric radiograph to assess skeletal maturity. While this simple method is comparable to the hand-wrist radiograph method, it reduces radiation exposure by eliminating the need for an extra radiograph in orthodontic records patients.(35) Variations of this technique have been developed and promoted.(36) (37) The CVM method not only provides a convenient method for staging skeletal maturation, it also provides a method for estimating when peak mandibular growth will occur. This estimation of peak mandibular growth is of

critical importance in the treatment of orthodontic patients who require growth modification. Soegiharto, et al performed a study evaluating the discriminatory ability of the Fishman Skeletal Maturation Index (SMI), which is a method involving the evaluation of 11 anatomical sites on the hand-wrist radiograph, and the CVM on over 2000 patients. The findings indicated that the differences in discriminatory ability were insignificant, and suggested that the use of hand-wrist films in patients with lateral cephalometric films may not be justified in the context of increased radiation exposure and limited improvements in diagnostic capabilities.(38) Other studies have reached similar conclusions.(39)

In another study, Soegiharto, et al evaluated the CVM and SMI in relation to chronological age and found that although there was a correlation between increased skeletal maturity and increased chronological age, the timing of skeletal maturity milestones varied between sexes and ethnic groups.(40)

Franchi, et al, analyzed the validity of using the 6 stage CVM method proposed by Lamparski with modifications as a biological indicator of skeletal maturity. They utilized a retrospective review of patients whose heights, weights, dental casts and lateral cephalograms were collected annually from 3 to 18 years of age and found that the greatest increment in mandibular, craniofacial and statural growth occurred between stages 3 and 4 of the CVM. They concluded that the CVM was an accurate method of detecting the onset of the pubertal spurt of mandibular growth thus determining optimal treatment timing.(41) A subsequent study by Gu and colleagues substantiated these observations using Tantalum implants placed in the cranium during childhood which served as stable landmarks on which

superimposition of radiographs could be performed and similarly found that peak mandibular growth was occurred between stages 3 and 4 of the CVM. (42)

Uysal, et al also investigated the correlation between chronological age and skeletal maturation using the cervical vertebrae (utilizing the Hassel and Farman method (37)) as well as the hand-wrist radiograph using the Brown system.(43)

The findings showed a correlation between chronological age and skeletal maturation using both methods as well as a direct correlation between the methods.(44)

Dental Maturation and Obesity

Previous investigators have demonstrated a positive correlation between age-adjusted BMI and dental developmental age. A retrospective study of 104 children used the Demirjian method with panoramic radiographs and categorical classifications of obese, overweight and normal weight based on age and sex-specific BMI to assess the relationship between weight status and dental development. Dental development was found to be more advanced in children with increased BMIs after adjusting for age and gender, which suggested that patients who are overweight may require an earlier orthodontic consultation than their peers.(26) Flores-Mir and colleagues found that there was no relationship between nutritional status and dental maturity using the Demirjian method. However, they only scored the lower left mandibular canine in patients with known growth stunting (height for age < 95% of the median) versus normal controls.(45) An extensive search of the literature returns no other studies that have evaluated dental maturation and weight status.

Skeletal Maturation and Obesity

Previous studies investigating skeletal maturation and obesity have focused on the hand wrist film.(46, 47) Russell, et al investigated the relation between skeletal maturation and adiposity in African American and Caucasian children. Hand-wrist radiographs were used to assess skeletal maturity while BMI Standard Deviation Score was the measure of adiposity. The findings suggested that there was a significant correlation between skeletal age and BMI. (46) Akridge, et al, however, performed a study involving 107 children to assess the relationship between childhood obesity and skeletal maturation using Fishman's hand-wrist analysis and found that although there was a trend for obese subjects to have accelerated skeletal maturation compared with normal or overweight subjects, it did not reach statistical significance.(48)

A controlled study of age and sex matched Swedish teenagers between the ages of 14 and 16 assessed differences in craniofacial morphology between obese and non-obese children. Obese children were more likely to have increased mandibular length, prognathic jaws and reduced anterior face height compared to children of normal weight.(49)

Obesity and Growth

A study of over 150,000 school children measured height and weight at age 7 and determined the age of Peak Height Velocity (PHV) and the onset of the pubertal growth spurt. BMI Z-score at age 7 was then calculated and used as a predictive variable. The results demonstrated that the heaviest children entered puberty significantly earlier than the lightest children.(50)

In 1970 Frisch and Revelle, hypothesized that critical body masses promoted pubertal events in adolescents.(51) Studies have since explored the relationship between sexual maturity and increased body mass index. The preponderance of evidence suggests that there is a positive correlation between increased body mass index and early sexual maturity in females,(52)(53)(54) but the directionality of that relationship has also been questioned.(54)(52) In boys, it has been suggested that those with higher childhood BMI tend to have earlier onset of puberty.(55) while others investigators have indicated a reverse relationship exists between BMI and pubertal onset in boys.(54)

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SECTION II:

MANUSCRIPT

A. INTRODUCTION

Recently, the rates of obesity in the U.S. population have been increasing among both children and adults.(1) Children are living more sedentary lifestyles and are less likely to participate in structured physical activity at school.(2) Individuals are also less likely to perceive themselves as overweight or obese, regardless of their actual weight status, thus reducing their motivation for increased physical activity.(3)

Multiple methods for assessing weight status have been described including: waist circumference, skin fold thickness, biomass impedance, body mass index, and age and weight specific body mass index percentile. Age and weight specific body mass index (BMI) percentile offers a quick, non-invasive and readily accessible method of assessing a growing child's weight status. Children who are above the 95th percentile are described as obese, those from the 85th to 95th percentile are described as overweight, 5th to 85th percentile is normal weight and those below the 5th percentile are described as underweight.(4-7)

Long-term sequelae of childhood obesity have been well documented in the medical literature. Elevated blood pressure, lipid levels, insulin levels, and growth hormone levels, as well as decreased bone mass and testosterone levels,

and psychological effects such as feelings of loneliness and self-esteem have all been shown to be associated with childhood obesity.(7-14). Suggested dental sequelae of obesity include a tendency for prognathic jaws and an increased dental caries rate.(15, 16)

In growing patients, dental development and skeletal maturation are widely used to determine the timing of orthodontic treatment and the selection of treatment modalities. No previous study has evaluated the relationship between Body Mass Index (BMI) percentile and both dental age and CVM (skeletal maturation) and only one study has comprehensively evaluated the relationship between dental age and any measure of obesity. (17)

The objective of this study was to assess the relationship between weight status using BMI percentile and skeletal and dental development in a large group of actively growing orthodontic patients.

B. MATERIALS AND METHODS:

The protocol for this retrospective research project was reviewed and approved by the Biomedical Institutional Review Board at the University of North Carolina – Chapel Hill.

Subjects:

Potential subjects consisted of consecutive patients who received initial pretreatment orthodontic records in the graduate orthodontic clinic at the University of North Carolina. Patient records were reviewed in reverse chronological order starting from July 31, 2009 using the following criteria:

Inclusion Criteria:

1. Pretreatment panoramic and lateral cephalometric radiographs of adequate diagnostic quality taken within one month of each other.
2. Height and weight recorded within 1 month of the panoramic and lateral cephalometric radiographs.
3. Age greater than or equal to 8 years but less than 17 years at the time of their pretreatment records.
4. A full complement of permanent mandibular teeth excluding third molars.

Exclusion criteria:

1. Second, 3rd and 4th cervical vertebrae not completely or clearly visible on the lateral cephalometric radiograph.
2. Presence of congenital anomalies of the 2nd, 3rd and 4th cervical vertebrae.
3. Any congenital tooth anomalies.
4. Any significant medical history that would affect physical development and growth.

The goal for the sample size was set at 500 eligible subjects. This sample size was selected to assure sufficient numbers of subjects in each CVM stage and to provide a reasonable distribution across the BMI percentile range.

Data Collection:

A computer search of the permanent patient database at the Department of Orthodontics identified all subjects seen for initial records between July 1, 2005 and July 31, 2009 along with their height, weight, date of birth, sex and race. For analysis purposes, race was categorized as African American, Latino, Caucasian or Other.

At the initial records appointment, height and weight were assessed after removing any over garments using a wall-mounted stadiometer and a standard mechanical scale (Continental Scale Works of Chicago™) and recorded in the subject's treatment record by the treating resident. Digital panoramic and cephalometric radiographs were also obtained at the initial records appointment.

Digital radiographs were retrieved independently of the demographic data to eliminate as much as possible any examiner bias resulting from contemporaneous viewing of the demographic data. Panoramic and cephalometric radiographs were evaluated using inclusion and exclusion criteria. Subjects who met the radiographic criteria in addition to other inclusion criteria were included until a sample of 540 eligible subjects had been identified. These subjects had been seen between September 14, 2006 and July 20 2009.

Panoramic radiographs for each subject were reviewed by a single investigator (KM), to determine the dental maturity score and dental age using a protocol developed by Demirjian (18). Dental maturity scores not explicitly identified in the Demirjian chart were either extrapolated or interpolated as necessary. A dental maturity score of "0" would denote no tooth calcification, and a score of "100" denoted complete tooth development.

The development of the second, third and fourth cervical vertebrae in the lateral cephalometric radiograph for each subject was reviewed by the same investigator (KM) to determine the cervical vertebrae maturation (CVM) stage according to a recent modification to the Lamparski method.(19) . BMI and BMI percentiles were calculated using age and gender specific Centers for Disease

Control growth charts.(20, 21) BMI categories were designated as follows: BMI percentile<5th percentile = underweight, 5th-85th percentile = normal weight, >85th-95th percentile = overweight, >95th percentile = obese. All data were recorded in a single electronic spreadsheet.

Reliability:

Fifty subjects were randomly selected and the dental maturity and skeletal maturity measures were repeated two weeks after the initial assessment. Weighted Kappa was used to assess examiner reliability. Weighted kappa values ranged from 0.66 for the first molar to 0.94 for the second premolar. All other weighted kappa values, including CVM staging, were greater than 0.80 (Table 1) The central and lateral incisors had 100 percent intra-examiner agreement among the fifty repeated measures and very little variability throughout the entire sample due to the natural course of near complete development of lower incisors prior to age 8.

Table 1: Intraexaminer Reliability

Weighted Kappa Statistics			
	Value	95% Confidence interval	
CVM Stage	0.83	0.74	0.92
Canine	0.82	0.68	0.97
1st premolar	0.83	0.71	0.94
2nd premolar	0.94	0.87	1
1st molar	0.66	0.03	1
2nd Molar	0.87	0.78	0.97

Statistical Analysis:

Bivariate analyses were performed using analysis of variance (race vs BMI percentile, dental age), unpaired t-test (sex vs BMI, dental age), chi-square (sex and race vs CVM). Linear regression analysis was used to determine whether the demographic variables (age, sex, race) or BMI percentile were associated with dental age while logistic regression was used to examine the associations with CVM. After collapsing CVM stages 1-3 into “prespurt” and stages 4-6 into “postspurt”, lack of fit testing was used for the linear regression and Wald test was used for the logistic regression analysis. Sex and age, centered at the sample mean of 13.07 years, were forced in the models and BMI percentile and race were assessed to determine whether inclusion would add significantly to the explanation of dental age or CVM.

C. RESULTS:

813 patient records were reviewed to obtain 540 subjects who met all inclusion criteria. Of the two hundred seventy three potential subjects who were excluded: 176 did not meet age requirements, 52 had incomplete or non-diagnostic radiographs, 22 did not have all of their radiographs taken within the allotted time period, 20 had missing or supernumerary teeth, 1 subject had a cervical vertebrae anomaly, and 2 subjects had recording errors or omissions in the chart.

Approximately 70 percent of the sample was Caucasian, 12 percent African-American, 12 percent Hispanic and 6 percent other races. Slightly more than half of the sample was female (56.3%). Thirty percent (30%) of the sample was

categorized as overweight or obese while only 3.8 percent was underweight. All CVM stages were represented, although the vast majority of subjects were in stage 3, 4 or 5. (Table 2)

Table 2: Univariate Descriptive Statistics of the Demographic Variables

Demographics of the study sample n=540			
		Frequency	Pct (%)
Race	African American	63	11.7
	Caucasian	378	70.1
	Latino	63	11.7
	Other	35	6.4
Sex	Male	236	43.7
	Female	304	56.3
BMI Category	Underweight (<5 th percentile)	15	3.8
	Normal (5 th -85 th percentile)	361	66.9
	Overweight (85 th -95 th percentile)	94	17.4
	Obese (>95 th percentile)	70	13
CVM Stage	1	39	7.2
	2	55	10.2
	3	95	17.6
	4	160	29.6
	5	125	23.2
	6	66	12.2

The mean chronological age (13.07 ± 1.63 years) was statistically different from the mean dental age (14.24 ± 1.84 years) (Paired T-test $p < 0.01$). The difference between dental age and chronological age was calculated as a proxy for degree of dental advancement in an individual. The mean dental advancement overall was $1.17 \text{ years} \pm 1.29$. On average, males were more

dentally advanced than females, 1.33 years versus 1.05 years respectively (Unpaired t-test; $p=0.01$).

The bivariate relationships among measures are provided in Table 3. There were no statistically significant mean differences among racial groups for chronological age (ANOVA: $p=0.16$), dental age ($p=0.34$) or BMI percentile ($p=0.18$). The distribution across the BMI categories was also fairly even, except for a smaller percentage of the “other” race group who were classified as obese. (Table 3)

Table 3: Weight Status by Race

Weight status by race				
	Underweight	Normal Weight	Overweight	Obese
Caucasian	2.9%	67.0%	17.2%	12.9%
Black	3.2%	61.9%	20.6%	14.3%
Latino	1.6%	68.3%	14.3%	15.9%
Other	2.9%	71.4%	20.0%	5.7%

Males and females were not statistically significantly different in chronological age (Unpaired T-test: $P=0.19$) but were significantly different, on average, with respect to dental age and BMI percentile (Unpaired T-test: $P = 0.01$ and <0.01 respectively). Males were more advanced in dental age (t-test $p=0.01$) and had lower BMI percentiles (t-test $p<0.01$) than females. (Table 4)

Figure 1 and figure 2 illustrate the distribution of weight status for males and females respectively. In general, slightly more females were overweight (4% greater) and obese (1% greater) as compared to males (Figures 1 and 2).

Figure 1: Weight status in males

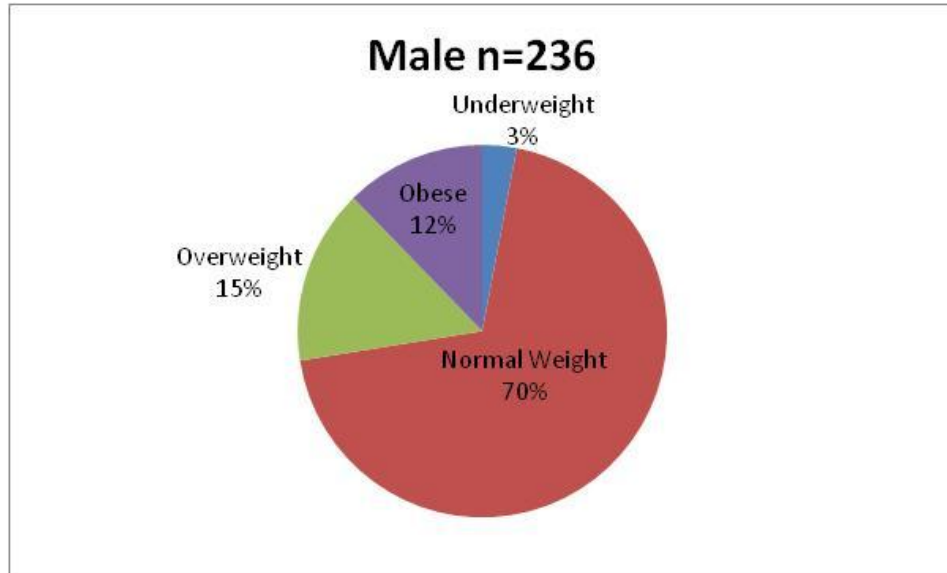


Figure 2: Weight status in females

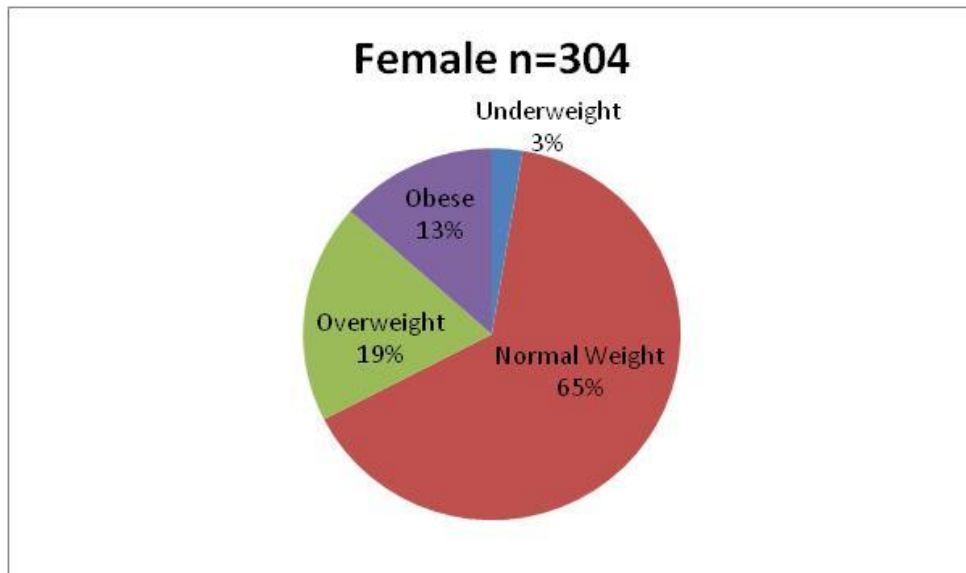


Table 4: Race and gender in relation to age, dental age and BMI percentile

Race and Gender in relation to age, dental age and BMI percentile									
	Chronological Age			Dental Age			BMI percentile		
	Mean	SD	P value	Mean	SD	P value	Mean	SD	P
African American	13.26	1.75	0.16	14.45	1.84	0.34	67.05	27.94	0.18
Caucasian	13.02	1.58		14.17	1.80		63.29	28.56	
Latino	13.36	1.78		14.54	1.85		70.48	24.74	
Other	12.68	1.66		14.08	2.26		60.32	26.95	
Male	13.17	1.59	0.19	14.50	2.10	0.004	61.60	28.55	0.05
Female	12.99	1.66		14.04	1.59		66.45	27.57	

Although there was no difference among the racial groups in age or BMI percentile, there was a statistically significant difference in the prevalence of a pre-spurt (CVM 1-3) versus post-spurt (CVM 4-6) stage among the groups (chi-square test $p < 0.05$) and between males and females (chi-square test $p < 0.001$). (Table 5)

Table 5: Race and gender in relation to CVM stage

Race and gender in relation to CVM stage									
	CVM Stage								Sig.
	1	2	3	4	5	6	Pre spurt (CVM 1-3)	Post spurt (CVM 4-6)	
African American no.(%)	6	7	12	19	11	8	25 (39.68%)	38 (60.32%)	
Caucasian	30	38	71	109	85	45	139 (36.77%)	239 (63.22%)	$p=0.04$
Latino	0	6	6	22	21	8	12 (19.05%)	51 (80.95%)	
Other	3	4	6	9	8	5	13 (37.14%)	22 (62.86%)	
Male	29	33	58	71	27	18	120 (50.84%)	116 (49.15%)	
Female	10	22	37	89	98	48	69 (22.70%)	235 (77.30%)	$p < 0.001$

Chronological age and dental age both increased incrementally with increases in CVM stage. Table 5 illustrates the mean dental and chronological age for each of the CVM stages. (Table 6)

Table 6: Dental and Chronological Age in relation to CVM

Dental and Chronological Age in relation to CVM		
CVM Stage	Mean Chronological Age	Mean Dental Age
1	11.27	12.30
2	11.76	12.94
3	12.40	13.65
4	13.02	14.29
5	13.97	15.02
6	14.59	15.71

In the initial model for dental age, race did not contribute significantly to the explanation beyond that of age and gender ($p = 0.34$) and was removed from the model. Sex, chronological age, and BMI percentile were statistically significant explanatory variables for dental age (Table 7). Sex and chronological age had the largest estimated parameter values. The expected change in dental age for a unit change in BMI percentile is 0.005 years after adjusting for gender and age Figure 4 displays the dental age and BMI percentile relationships for males and females when age is centered at the sample mean (13.07 years). (Table 7) (Figure 4)

Race was not a statistically significant explanatory factor for CVM ($p=0.12$) and was not included in the final model. Sex had the largest odds ratio (OR=7.96), with girls being more likely to be skeletally advanced (CVM stage 4, 5 or 6) than males. The odds ratio for age was 3.09 and the odds ratio for BMI percentile was 1.02. (Table 8)

Table 7: Final model for dental age and its parameter estimation:

The final model for dental age and its parameter estimation						
Parameter	DF	Estimate	95% C.I.		T	P-value
Intercept	1	14.092	13.808	14.375	97.77	<.0001
Gender (Female)	1	-0.333	-0.548	-0.120	-3.07	0.0022
Age	1	0.820	0.755	0.885	24.8	<.0001
BMI percentile	1	0.005	0.001	0.009	2.74	0.0063

Table 8: Final model for CVM (Pre vs Post spurt) and its odds ratio:

The final model for CVM and its odds ratio					
Parameter	DF	Estimate	95% C.I.		P-value
Gender (Female)	1	7.96	4.78	13.25	<.0001
Age	1	3.09	2.50	3.81	<.0001
BMI percentile	1	1.02	1.01	1.03	<.0001

Figure 5 displays the estimated probability of subjects being more advanced (CVM stage 4, 5 or 6) versus less advanced (CVM stage 1, 2 or 3) for males and females, with age centered at the sample mean.

Figure 3: Regression representation of Dental age in relation to BMI percentile

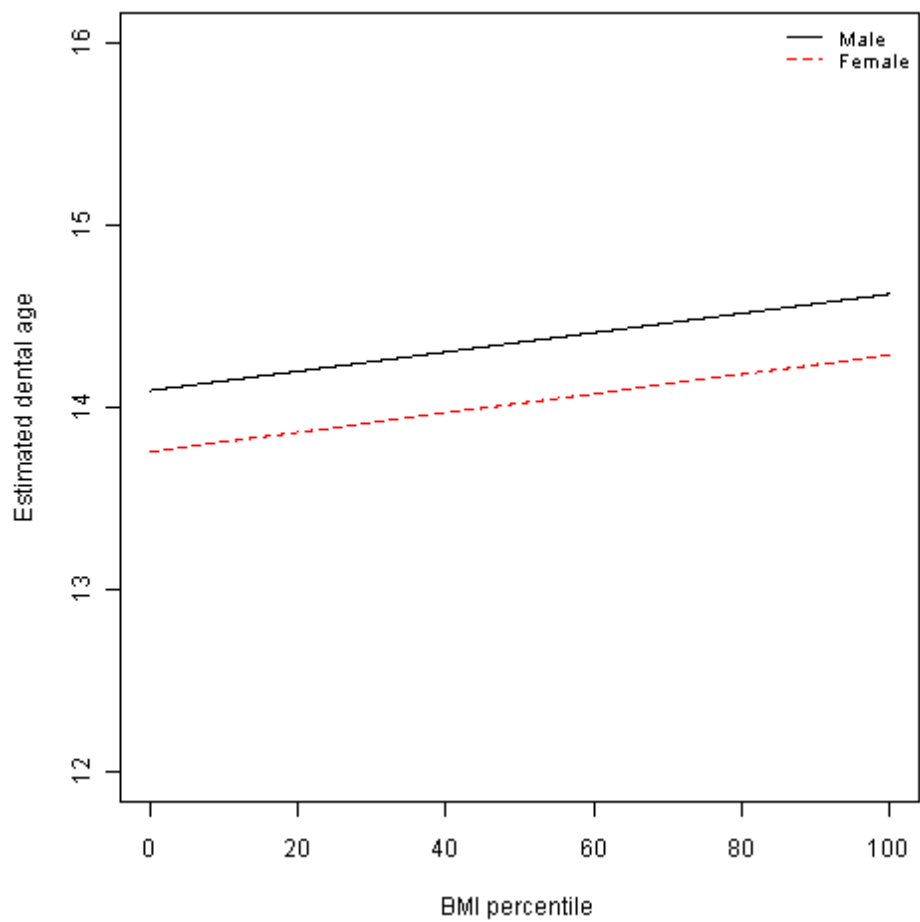
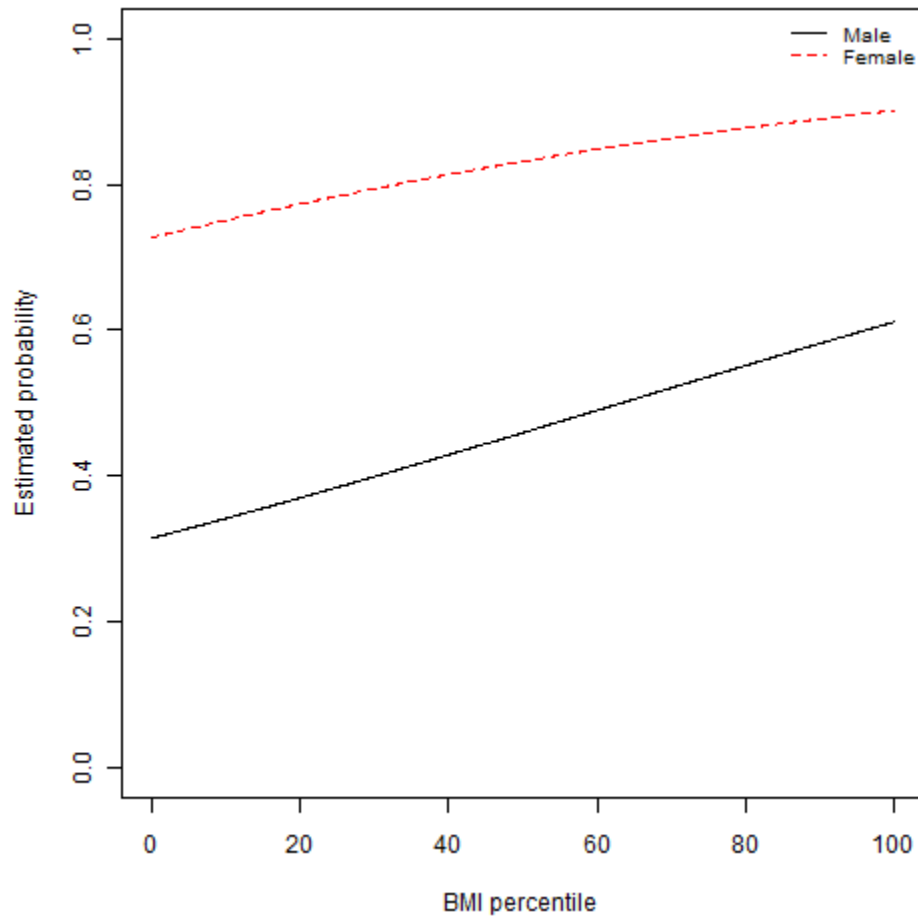


Figure 4: Estimated probability of advanced CVM (stage 4-6) in relation to BMI percentile



D. DISCUSSION

Intra-examiner reliability was excellent in this study with only the mandibular first molar having only a “good” weighted Kappa statistic (0.66). In the age group sampled in the study, almost all first molars would be expected to have complete or near-complete root development. In the repeated measures sample, 49 of 50 (98%) measurements were in agreement and almost all of

those were “complete root development”. The Kappa statistic has been shown to be unreliable in cases with high trait prevalence within a sample.(22)(23)

Multiple studies have attempted to validate the Demirjian methodology for different ethnic and racial groups.(24-26) Our study found no mean differences in dental age among races, which could be due to inadequate sample sizes in the non-Caucasian groups. The mean difference between dental and chronological age of 1.17 years was consistent with previous studies using the Demirjian methodology. A mean dental age advancement of 0.7 years in males and 0.5 years in females was reported by Nik-Hussein.(24) Hilgers reported that girls had a significantly larger dental age difference than did boys: the mean dental age advancement ranged from -0.09 years to 2.38 years in boys depending on age and International BMI index, while girls ranged from 0.72 to 3.33 years of dental age advancement. .(17) In this study, greater average advancement occurred in males than females. This could have arisen due to methodology. Male dental maturity scores were extrapolated to age 18 in order to “age” individuals with complete mandibular dental development (dental maturity score of 100). It was not necessary to extrapolate dental maturity scores for girls, since a score of “100” was already correlated with a dental age of 16.(18) This adjustment may have resulted in an artificial elevation of the dental age of males, especially since 40 of the males in the sample had dental ages greater than 16, while there were no girls with a dental age greater than 16. Weight status was defined in this study using established parameters for underweight, normal weight, overweight and obesity based on percentile data.

The widely used 2000 CDC growth charts are based on data from 5 cross sectional studies performed from 1963 to 1994. A sample that is consistent with the data used to establish the standards should have 15 percent of children overweight or obese (20). Our observed prevalence of overweight and obesity (30%) exemplify how BMI in the population has changed in recent years and is consistent with other recent publications. (27) We elected to use the continuous measure of BMI percentile rather than the categorical classifications in the statistical modeling because of the large range of BMI percentiles included within the “normal weight” category and the relatively small number of patients who fell into the “underweight” category. Recently, the prevalence of high BMI percentiles has been slightly higher in boys than girls.(27) In this sample, the BMI percentile, on average was slightly higher in females and the proportion of girls in the overweight/obese categories was slightly larger than in boys (32% vs 27%)

The findings for CVM in relation to chronological age are consistent with Baccetti, but varied slightly from Basaran.(19) (28) The Basaran study was limited only to Turkish subjects. In addition, Basaran used the Hassel and Farman(29) methodology, which would tend to make CVM 5 and 6 patients older than the Baccetti methodology. Other studies have reported a low correlation between chronological age and CVM.(30)

Dental age has been shown to be related to the CVM stage and gender. Chen demonstrated that for a given CVM stage, females tended to be more dentally advanced than males.(31) However, given that males tend to be older

when they reach the same CVM stages (28), this effect seems to be even more pronounced. In our study, girls demonstrated a statistically significant increased prevalence of advanced CVM stages. This is consistent with other studies that have shown girls attain certain cervical vertebrae landmarks at a younger age. (32) Basaran demonstrated that girls were younger than their male counterparts when they reached CVM stages 1-5, but older than their male counterparts when they reached CVM stage 6.(28) Uysal also demonstrated that girls reached skeletal maturity milestones earlier than boys using hand-wrist radiographs.(25) Our findings from the final model for dental age indicated that for every 1 percentile increase in BMI percentile for age, there was a 0.005 year increase in dental age. This means that for children at the extremes of BMI percentile, ie: 5th percentile versus 95th percentile, and centered on the mean age of our sample, we could expect to see a mean dental age difference as great as 5.4 months. There is no standard definition for clinical significance, however, a reasonable follow up period for a patient in growth observation is approximately 6 months, meaning an obese child may require one less observation appointment than an underweight child prior to starting treatment. Chronological age and male gender also had large impacts on dental age. .

The final model for CVM stage also demonstrated a strong impact of age and gender. The odds ratio for BMI percentile was 1.02 for each BMI percentile unit when holding other variables constant. For children at the extremes of BMI percentile, this equates to an odds ratio of 2.8, meaning that for 2 children of the same age, a child in the 95th percentile is nearly 3 times more likely to be in CVM

stage 4, 5 or 6 versus CVM stage 1-3 than a child in the 5th percentile would be. This is a significant finding as there is an increased likelihood that obese children around 13 years of age are past the point of peak growth, and underweight children are more likely to have significant growth remaining. Baccetti reported that class II malocclusions are best treated during CVM stage 3, right around the peak velocity of mandibular growth.(19) This leads one to postulate that perhaps class II patients who are obese should be evaluated for treatment earlier than non-obese class II patients if growth modification is a potential treatment option.

During the course of treatment, orthodontists have a unique opportunity to impact the general well-being and health of children and adolescents. A recent study of orthodontists found that 55 percent never collect any weight information, and that only 4 percent weighed patients on a scale or measured heights using a stadiometer. Seventy-three percent did not assess for obesity in any way, and the majority of those that did make an assessment did so in a subjective fashion.(33) In addition, there is some evidence to suggest that obesity and overweight have a negative impact on the dental caries rate.(16)

Considering the known health-related concerns associated with overweight and obesity, it is an orthodontist's responsibility as a healthcare provider to counsel and discuss weight concerns with patients and possibly actively refer or counsel obese patients. Historically orthodontists have focused on the alignment and occlusion of the teeth, more recently the focus has shifted to the craniofacial structures, soft tissues and smile esthetics. As health care providers, orthodontists have great potential to extend this focus further to impact

the current and future health of children and adolescents by being more actively involved in weight assessment and counseling.

E. CONCLUSIONS

The following conclusions were identified:

1. The Demirjian methodology overestimates dental age in both males and females.
2. Dental age and CVM stage increase in relation to BMI percentile. There may be significant clinical implications in patients at the extremes of BMI percentile values.
3. A significant percentage of orthodontic patients are either overweight or obese. As health care professionals, it may be beneficial for orthodontists to collect objective weight information for treatment purposes as well as health counseling.

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