M. Costacurta*, L. Sicuro**, L. Di Renzo***, R. Condò*, A. De Lorenzo***, R. Docimo*

University of Rome "Tor Vergata", Rome, Italy
**Department of Dentistry, Paediatric Dentistry Unit*
***Researcher of the Italian National Institute of Statistics (ISTAT)*
****Department of Neuroscience, Division of Human Nutrition*

e-mail: *raffaella.docimo@ptvonline.it*

Childhood obesity and skeletal-dental maturity

ABSTRACT

Aim *The aim of this cross-sectional study was to evaluate the skeletal maturation assessed through cervical vertebral maturation (CVM) and dental age, in normal weight, pre-obese and obese patients, using the Body Mass Index (BMI) and the Dual energy X-ray Absorptiometry (DXA).*
Methods *A group of 107 healthy patients, aged between 6 and 12 years (mean age 8.77±1.79), underwent anthropometric measurements, BMI calculation, and DXA exam at the Department of Neuroscience, Human Nutrition Unit, University of Rome "Tor Vergata" and the assessment of skeletal and dental age at the Paediatric Dentistry Unit of PTV Hospital, University of Rome "Tor Vergata". The subjects were classified as underweight, normal weight, pre-obese and obese according to FM% McCarthy cut-offs classification and BMI classification. Statistics: The analyses were performed using the SPSS software (version 16; SPSS Inc., Chicago IL, USA). The assessment of differences through the means of continuous variables among the different groups were analysed using the One-Way-Anova test. The Student's t test was also applied for each group of children (using McCarthy and BMI classifications) between chronological and skeletal-dental age; the Fisher's exact test was performed between the gender categorical variable and McCarthy cut-offs classification, and between McCarthy and BMI classifications. Besides, to evaluate the association between skeletal and dental age, a Pearson correlation coefficient was calculated. In all the assessments a significant level of alpha = 0.05 was considered.*
Results *The comparison between BMI and DXA data shows statistically significant differences between BMI-FM% (McCarthy cut-offs) classifications (p≤0.001). According to FM% (McCarthy cut-offs) classification, from the Anova analysis among the groups a statistically significant difference between skeletal age (p=0.03) and dental age (p=0.02) was observed, while the difference related to the chronological age (p=0.22) among the groups, was not significant. The correlation between dental and skeletal age is almost the highest (Pearson correlation coefficient=0.994) and statistically significant (p=0.01). According to FM% McCarthy classification, it is observed that with an increase in the FM%, that is passing from normal weight to obese children, the skeletal-dental age always increases with respect to the chronological age. The difference between chronological and skeletal-dental age is statistically significant for pre-obese (p=0.01) and obese (p<0.001) children, while it is not significant for underweight (p=0.46) and normal weight (p=0.33) children. According to the BMI classification, from the Anova analysis no statistically significant differences were observed among the groups as for chronological, dental and skeletal age. Applying the same inferential analyses and taking into account the BMI classification, in the obese subjects were observed not statistically significant differences as for chronological and skeletal-dental age (p=0.09).*
Conclusion *The results highlighted a relation between skeletal-dental age acceleration and body fat percentage measured by DXA.*

Keywords *Body composition; Cervical vertebral maturation; Dental age; Obesity; Skeletal maturation.*

Introduction

The prevalence of overweight and obesity in children over the recent years is steadily increasing worldwide; the World Health Organization, in fact, has defined obesity as "a global epidemic disease" [WHO, 2003].
According to the American Academy of Pediatrics, Committee on Nutrition, overweight and obesity are now the most common medical conditions of childhood [Krebs and Jacobson, 2003]. In Italy, obesity levels in children aged 8-9 years ranged from 7.5% in the North to 16.6% in the South [Binkin et al., 2009], while the prevalence of obesity in 6-9 year-old children living in Central-Northern Italy was respectively 8.9% and 9.0% [Albertini et al., 2008].
Childhood overweight and obesity present both immediate and long-term health risks: cardiovascular effects (hypertension, hypercholesterolemia,

dyslipidemia), endocrine effects (hyperinsulinism, insulin resistance, impaired glucose tolerance and type II diabetes), adulthood overweight and obesity, pulmonary problems (asthma, obstructive sleep apnoea, Pickwickian syndrome), orthopaedic problems [Lloyd et al., 2011; Saha et al., 2011; WHO, 2003]. In girls, obesity can develop in the early stages of puberty [Slyper, 2006; Ahmed et al., 2009] and can considerably accelerate the linear growth [Slyper, 2006]; in boys, there can be a considerable variations in the timing of puberty (accelerated or delayed) [Slyper, 2006, Kleber et al., 2011]. Obesity can lead to an increase in the average stature during childhood [Kleber et al., 2011] and to an early craniofacial growth (increased mandibular length, prognathic jaws, reduced upper anterior face height) [Ohrm et al., 2002].

The aim of this cross-sectional study was to assess the skeletal maturation through the cervical vertebral maturation (CVM) and dental age, in normal weight, pre-obese and obese patients, using the Body Mass Index (BMI) and Dual energy X-ray Absorptiometry (DXA).

Materials and methods

A group of 107 healthy patients, aged between 6 and 12 years (mean age 8.77±1.79), underwent anthropometric measurements, BMI calculation, and DXA exam at the Department of Neuroscience, Human Nutrition Unit, University of Rome “Tor Vergata” and the assessment of skeletal-dental age at the Paediatric Dentistry Unit of PTV Hospital, University of Rome “Tor Vergata”, after obtaining a written informed consent from parents or guardians. The exclusion criteria for group recruitment were the presence of systemic and endometabolic diseases.

1) Anthropometric measurements: body weight (kg) was measured to the nearest 0.1 kg, using a scale (Invernizzi, Rome, Italy), height (cm) was measured using a stadiometer to the nearest 0.1 cm (Invernizzi, Rome, Italy).
2) The BMI was calculated using the standard formula: BMI = body weight (kg)/height (m^2).
3) DXA exam: the body composition analysis was determined by means of DXA (Lunar model DPX-IQ Lunar Corp., Madison, WI) fan beam scanner. The DXA exam assesses body fat mass (FM), body fat free mass (FFM), bone mineral density (BMD) and bone mineral content (BMC). The coefficient of variation (CV%=100x SD/mean) intra- and inter-subjects ranged from 1% to 5%. The coefficient of variation for bone measurements is less than 1%. The effective radiation dose from this procedure is about 0.01 mSv.
4) Skeletal age. The determination of the skeletal age was performed through the assessment of the cervical vertebral maturation (CVM), using the lateral cephalometric radiographs and the formulas developed by Caldas et al. [2010] providing the measurements of the third (C3) and fourth (C4) cervical vertebra.
   Female cervical vertebral bone age = 1.3523 + 6.7691 x AH3/AP3 + 8.6408 x AH4/AP4
   Male cervical vertebral bone age = 1.4892 + 11.3736 x AH3/AP3 + 4.8726 x AH4/AP4
   AH=anterior vertebral body height; AP=anteroposterior vertebral body length; 3=C3; 4=C4
5) The dental age was determined using the method codified by Demirjiyan [Demirjiyan and Goldstein, 1976] and panoramic radiographs.

Subjects classification criteria

a) The subjects were classified as pre-obese/obese according to Mc Carthy’s age-sex specific centile curves. The 2nd centile was selected to define the upper limit of underweight, 85th and 95th centiles to define the lower limits of pre-obese and obese [McCarthy et al., 2006]. According to FM% McCarthy classification the subjects were subdivided in four groups: Group A underweight (FM%<2nd centile), Group B normal weight (2nd centile<FM%<85th centile), Group C pre-obese (85th centile<FM%<95th centile), Group D obese (FM%>95th centile).
b) The subjects were considered as pre-obese/obese according to the age and sex specific BMI (BMI classification), by using Italian population specific growth charts [Cacciari et al., 2006]. The 3rd, the 75th, the 95th centiles were considered the cut-off to evaluate underweight, overweight and obese subjects. According to BMI classification the subjects were subdivided in four groups: Group E underweight (BMI<3rd centile), Group F normal weight (3rd centile<BMI<75th centile), Group G preobese (75th centile<BMI<95th centile), Group H obese (BMI>95th centile).

Statistical analysis

The analyses were performed using the SPSS software (version 16; SPSS Inc., Chicago IL, USA). The assessment of differences through the means of continuous variables among the different groups were analysed using the One-Way-Anova test. The Student’s t test was also applied for each group of children (using McCarthy and BMI classifications) between chronological and skeletal-dental age, except for Groups A-E. To assess the differences between the mean of chronological and skeletal-dental age for the Groups A-E, the Nonparametric Mann-Whitney test was applied.

The Fisher’s exact test was performed between the gender categorical variable and McCarthy cut-offs classification, and between McCarthy and BMI classifications. Besides, to evaluate the association between skeletal and dental age, a Pearson correlation coefficient was calculated. In all the assessments a significant level of alpha = 0.05 was considered.

Results

The sample of 107 children, aged between 6 and 12 years (mean age 8.77±1.79) consists of 57 females (53%) and 50 males (47%).

The Fisher's exact test pointed out that there were not statistically significant differences in the distribution of males/females among the Groups A, B, C, D (p=0.41).

The Anova analyses showed a statistically significant difference among the Groups A, B, C, D and between the skeletal (p=0.03) and dental age (p=0.02), while for the chronological age the difference among the Groups is not significant (p=0.22) (Table 1).

The correlation between dental and skeletal age is almost the highest (Pearson correlation coefficient=0.994) and it is statistically significant (p=0.01).

According to the FM% McCarthy classification, together with the increase of the FM%, which is passing from normal weight to obese children, the skeletal-dental age always increases with respect to the chronological age. Such increase in skeletal-dental age corresponds to 6 months for normal weight children (Group B), 16 months for pre-obese children (Group C) and 17 months for obese children (Group D). Regarding the delay, a difference between chronological age and skeletal-dental age, is present in 60% of underweight children, in 4.2 % of normal weight children and it is not present at all in pre-obese-obese children; on average, it is possible to observe that in Group A the skeletal-dental age is lower than chronological age by 12 months. Such differences are statistically significant if we consider the Groups A, B, C, D (p<0.001), while within each group the difference between chronological and skeletal-dental age is statistically significant for pre-obese (p=0.01) and obese (p<0.001) children, while it is not significant for underweight (p=0.46) and normal weight children (p=0.33).

The Fisher's exact test, used to compare the Groups A, B, C, D according to the FM% McCarthy classification and the Groups E, F, G, H according to BMI classification, has pointed out statistically significant differences between the two classifications (p<0.001).

The Anova test did not highlight any statistically significant differences among the Groups E, F, G, H for chronological, skeletal and dental age (Table 2).

By applying the same inferential analysis and by taking into account the BMI classification, it is possible to observe that within the group of normal weight children (Group F) there are statistically significant differences between chronological age and skeletal-dental age (p=0.01); the skeletal-dental age, in fact, is greater that the chronological age by a value of 11 months. In addition, for what concerns the group of obese children (Group H) the skeletal-dental age is greater than 17 months, but such datum is not statistically significant

		MEAN	SD	P-VALUE (ONE-WAY ANOVA TEST)
Chronological Age	Group A	9.30	1.72	0.22
	Group B	9.52	1.66	
	Group C	8.58	1.63	
	Group D	9.35	1.66	
Skeletal Age	Group A	8.50	1.83	0.03
	Group B	9.97	1.83	
	Group C	9.93	1.85	
	Group D	10.74	1.85	
Dental Age	Group A	8.34	1.77	0.02
	Group B	10.01	1.83	
	Group C	9.93	1.88	
	Group D	10.74	1.78	

TABLE 1 Mean and Standard Deviation (SD) of chronological, skeletal and dental age in McCarthy classification.

		MEAN	SD	P-VALUE (ONE-WAY ANOVA TEST)
Chronological Age	Group E	9.8	1.8	0.16
	Group F	9.0	1.6	
	Group G	9.2	1.4	
	Group H	9.9	2.1	
Skeletal Age	Group E	10.0	2.1	0.12
	Group F	10.0	1.8	
	Group G	10.6	1.6	
	Group H	11.3	2.3	
Dental Age	Group E	10.0	2.1	0.08
	Group F	10.0	1.8	
	Group G	10.6	1.6	
	Group H	11.3	2.1	

TABLE 2 Mean and Standard Deviation (SD) of chronological, skeletal and dental age in BMI classification.

	BMI (kg/m^2)	FM (%)	FFM (kg)	FM (kg)
Skeletal age	0.503[1]	0.409[1]	0.757[1]	0.580[1]
Dental age	0.516[1]	0.415[1]	0.762[1]	0.558[1]
BMD trunk (g/m2)	0.691[1]	0.514[1]	0.824[1]	0.690[1]
BMD ribs (g/m2)	0.752[1]	0.633[1]	0.770[1]	0.747[1]
BMD pelvis (g/m2)	0.567[1]	0.354[1]	0.786[1]	0.561[1]
BMD vertebral column (g/m2)	0.596[1]	0.479[1]	0.676[1]	0.604[1]
BMD whole-body (g/m2)	0.619[1]	0.406[1]	0.782[1]	0.603[1]
BMC trunk (g)	0.786[1]	0.643[1]	0.889[1]	0.801[1]
BMC ribs (g)	0.847[1]	0.757[1]	0.800[1]	0.853[1]
BMC pelvis (g)	0.626[1]	0.455[1]	0.888[1]	0.653[1]
BMC vertebral column (g)	0.643[1]	0.515[1]	0.766[1]	0.651[1]
BMC whole-body (g)	0.714[1]	0.521[1]	0.937[1]	0.722[1]

TABLE 3 Spearman's correlation coefficients ([1]p≤0.001), between skeletal-dental age, BMI, FFM, FM and bone mass (BMD, BMC).

(p=0.09).

In order to understand the relationship between the body composition and the bone mineralisation, an analysis to assess the correlation among the parameters was carried out.

Table 3 reports the Spearman's correlation coefficients, concerning skeletal-dental age, BMI, FFM, FM and bone mass in terms of BMD and BMC. The FFM is positively correlated with the whole-body BMD (R= 0.782) and BMC (R=0.937), with vertebral column BMD (R= 0.676) and BMC (R=0.766), with skeletal age (R=0.757) and dental age (R=0.762), with a greater degree of concordance with respect to the FM (Kg, %) and to BMI.

Discussion

The studies present in the literature, that assessed skeletal maturation and dental age in childhood obesity, used the BMI index and often reported contrasting results [Akridge et al., 2007; Basaran et al., 2007; Chen et al., 2010; Eid et al., 2002; Hilgers et al., 2006].

BMI index is the most commonly used index to classify overweight-obesity [Mei et al., 2002]; it is mainly used in the aepidemiological studies as it is easy to calculate, non invasive, with a low cost and it also favours a rapid data comparison. The only limit is related to the fact that it is not capable of distinguishing between FM and FFM, thus being impossible to assess the body composition.

Instead, DXA is a method for assessing body composition, to measure the FM and the FFM; but this method is limited to research settings because of their complexity and cost [Mei et al., 2002].

The comparison between BMI and DXA data shows statistically significant differences between BMI and FM% (p<0.001).

According to FM% (McCarthy cut-offs) classification it is observed that with an increase in FM%, in other words passing from normal weight children to obese children, the skeletal-dental age is greater than the chronological age. The difference between chronological age and skeletal-dental age, in fact, is statistically significant for pre-obese (p=0.01) and obese (p<0.001) subjects.

This trend is not observed in the BMI classification; in the group of obese subjects the skeletal-dental age is greater than the chronological age but this is not statistically significant (p=0.09); the same datum seems to be significant analysing Group F (p=0.01).

The explanation for these contrasting results could be explained considering the BMI misclassified adiposity status of a paediatric population compared to DXA.

According to Akridge at al. [2007] in obese subjects there are no statistically significant differences as for skeletal-dental maturation, but it is pointed out a trend of skeletal age acceleration when comparing normal weight and overweight subjects with the obese ones.

Several authors [Eid et al., 2002; Hilgers et al., 2006] agree stating that overweigh-obese subjects present an accelerated and statistically significant dental development if compared to healthy subjects.

The results of this study highlight a correlation between dental maturity and cervical vertebral maturity, as observed in other studies [Akridge et al., 2007; Chen et al., 2010; Basaran et al., 2007]. Other authors [Demirijan et al., 1985], instead, state that skeletal and dental development is subject to different control mechanisms.

For the first time, our results highlighted the relation between skeletal-dental age acceleration and body fat percentage measured by DXA. In addition, the data point out a strong association between bone mineralisation with the FFM%, rather than with BMI or FM%.

Some authors [Wang et al., 2005] report that the FFM is an important predictive factor for the BMD; the adipose tissue, instead, produces metabolically active molecules, such as the adipokines (leptin, adiponectin, proinflammatory cytokines) playing a role in the bone metabolism regulation [Rhie et al., 2010].

If obesity is associated with accelerated skeletal-dental maturation, for these patients paediatric dental and orthodontic treatment timing might vary. In fact, as for the paediatric dental planning, the early eruption of permanent teeth when the children might not be able to carry out a proper oral hygiene could result in an increased incidence of dental caries [Akridge et al., 2007; Costacurta et al., 2011; Hilgers et al., 2006]. Furthermore, an acceleration of skeletal-dental maturation in obese patients can influence orthodontic diagnosis, treatment planning and treatment outcome. The amount of potential remaining facial growth is vitally important in orthodontic growth modification and orthognathic surgical treatment planning [Akridge et al., 2007].

Neeley [Neeley and Gonzales, 2007] states that "the orthodontic therapy can be affected by obesity", given the probability for obese patients to show an irregular pubertal development, due to the hormonal changes associated with obesity, a different bone metabolism (leading to changes in growth and development or tooth movement), and specific craniofacial features (increased mandibular length, shorter upper face height, flatter or more concave profiles).

Conclusion

The results highlighted a relation between skeletal-dental age acceleration and body fat percentage measured by DXA.

References

- Ahmed ML, Ong KK, Dunger DB. Childhood obesity and the timing of puberty. Trends Endocrinol Metab. 2009 Jul;20(5):237-42.
- 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 Dentofacial Orthop. 2007 Aug;132(2):185-90.
- Albertini A, Tripodi A, Fabbri A, Mattioli M, Cavrini G, Cecchetti R, Dalle Donne E, Cortesi C, De Giorgi S, Contarini V, Andreotti L, Veronesi B, Stefanelli I, Di Martino E. Prevalence of obesity in 6- and 9-year-old children living in Central-North Italy. Analysis of determinants and indicators of risk of overweight. Obes Rev. 2008 Jan;9(1):4-10.
- Başaran G, Ozer T, Hamamci N. Cervical vertebral and dental maturity in Turkish subjects. Am J Orthod Dentofacial Orthop. 2007 Apr;131(4):447.e13-20.
- Binkin N, Fontana G, Lamberti A, Cattaneo C, Baglio G, Perra A, Spinelli A. A national survey of the prevalence of childhood overweight and obesity in Italy. Obes Rev 2009;17:1-9.
- Cacciari E, Milani S, Balsamo A, Spada E, Bona G, Cavallo L, Cerutti F, Gargantini L, Greggio N, Tonini G, Cicognani A. Italian cross-sectional growth charts for height, weight and BMI (2 to 20 yr). J Endocrinol Invest 2006;29:581-593.
- Caldas Mde P, Ambrosano GM, Haiter Neto F. Computer-assisted analysis of cervical vertebral bone age using cephalometric radiographs in Brazilian subjects. Braz Oral Res. 2010 Jan-Mar;24(1):120-6.
- Chen J, Hu H, Guo J, Liu Z, Liu R, Li F, Zou S.Correlation between dental maturity and cervical vertebral maturity. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Dec;110(6):777-83.
- Costacurta M, Di Renzo L, Bianchi A, Fabiocchi F, De Lorenzo A, Docimo R. Obesity and dental caries in paediatric patients. A cross-sectional study. Eur J Paediatr Dent. 2011 Jun;12(2):112-6
- Demirjian A, Buschang PH, Tanguay R, Patterson DK. "Interrelationships among measures of somatic, skeletal, dental, and sexual maturity". Am J Orthod. 1985 Nov;88(5):433-8.
- Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol. 1976 Sep;3(5):411-21
- Eid RM, Simi R, Friggi MN, Fisberg M. Assessment of dental maturity of Brazilian children aged 6 to 14 years using Demirjian's method. Int J Paediatr Dent. 2002 Nov;12(6):423-8.
- Hilgers KK, Akridge M, Scheetz JP, Kinane DE. Childhood obesity and dental development. Pediatr Dent. 2006 Jan-Feb;28(1):18-22.
- Kleber M, Schwarz A, Reinehr T. Obesity in children and adolescents: relationship to growth, pubarche, menarche, and voice break. J Pediatr Endocrinol Metab. 2011;24(3-4):125-30.
- Krebs NF, Jacobson MS; American Academy of Pediatrics Committee on Nutrition. Prevention of pediatric overweight and obesity. Pediatrics. 2003 Aug;112(2):424-30
- Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and adult cardiovascular disease risk: a systematic review. Int J Obes (Lond). 2010 Jan;34(1):18-28.
- McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. Body fat reference curves for children.Int J Obes (Lond). 2006;30(4):598-602.
- Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH.Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. Am J Clin Nutr 2002 Jun;75(6):978-985
- Neeley WW 2nd, Gonzales DA. Obesity in adolescence: implications in orthodontic treatment. Am J Orthod Dentofacial Orthop. 2007 May;131(5):581-8.
- Ohrn K, Al-Kahlili B, Huggare J, Forsberg CM, Marcus C, Dahllöf G. Craniofacial morphology in obese adolescents. Acta Odontol Scand. 2002 Aug;60(4):193-7.
- Rhie YJ, Lee KH, Chung SC, Kim HS, Kim DH. Effects of body composition, leptin, and adiponectin on bone mineral density in prepubertal girls. J Korean Med Sci. 2010 Aug;25(8):1187-90.
- Saha AK, Sarkar N, Chatterjee T. Health Consequences of Childhood Obesity. Indian J Pediatr. 2011 Jun 10.
- Slyper AH. The pubertal timing controversy in the USA, and a review of possible causative factors for the advance in timing of onset of puberty. Clin Endocrinol (Oxf). 2006 Jul;65(1):1-8.
- Wang MC, Bachrach LK, Van Loan M, Hudes M, Flegal KM, Crawford PB. The relative contributions of lean tissue mass and fat mass to bone density in young women. Bone. 2005 Oct;37(4):474-81.
- World Health Organization. Diet, nutrition and the prevention of chronic diseases. Word Health Organ Tech Rep Ser 2003;916:1–149.