Received: 22 February 2024 | Revised: 26 July 2024 | Accepted: 5 August 2024
DOI: 10.1111/ijpo.13166

ORIGINAL RESEARCH

Pediatric OBESITY WILEY

Association between bone age maturity and childhood adiposity

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Funding information
Mexcian Federal Foundus, Grant/Award Numbers: HIM 2015/055, HIM/2017/058; National Council for Humanities, Sciences and Technologies, Goverment of México (CONAHCYT)., Grant/Award Number: FOSISS2015-2261682

Summary

Background: Evidence shows that overweight and obesity are associated with advanced bone age (BA).

Objective: To analyse the effect of adiposity on BA among Mexican children.

Methods: This cross-sectional study included 902 children (5–18 years old). Anthropometric measurements, dual-energy X-ray absorptiometry (DXA) and automated hand X-ray-based BA measurements were obtained. BA curves of children stratified by sex and age were created based on nutritional status. We also calculated odds ratios for advanced BA associated with the body mass index (BMI), waist/height ratio and adiposity estimated using DXA (total and truncal fat mass).

Results: Participants with overweight/obesity by BMI (SDS ≥1) advanced earlier in BA than did normal weight participants (6.0 vs. 12.0 years in boys and 6.0 vs. 10.3 in girls, $p < 0.01$); similarly, participants with a greater body fat percentage (SDS ≥1) exhibited earlier advanced BA (7.5 vs. 10.0 years in boys and 6.0 vs. 9.6 in girls, $p < 0.01$). Differences were also observed according to the waist/height ratio and truncal fat. Children with a BMI or DXA SDS ≥1 had greater odds of presenting an advanced BA of more than 1 year (OR 1.79–3.55, $p < 0.05$).

Conclusions: Increased adiposity in children, mainly in boys, is associated with advanced BA at earlier ages.

KEYWORDS
adolescents, body fat, children, obesity, overweight, skeletal maturity

1 | INTRODUCTION

According to the World Health Organization (WHO), in 2022, more than 390 million children aged 5–19 years worldwide had overweight or obesity.[1] In Mexico, the combined prevalence of overweight and obesity in the 5- to 11-year-old group was 37.5%, and in the 12- to 19-year-old group, it was 42.9%, according to the 2021 National Health and Nutrition Survey (ENSANUT).[2]

The epidemic of childhood overweight and obesity is one of the most important public health problems. In addition to being associated with multiple comorbidities and having deleterious effects on health in the short and long term,[1] it can also affect children's growth and development.[3–6]

The evaluation of growth and development is crucial during the pediatric stage, as it is a dynamic process that continues until both skeletal and sexual maturity are complete. During childhood, the epiphyses begin to ossify until they are fully consolidated, at which point linear growth stops and adult height is reached.[7] This skeletal maturation process can be evaluated through the estimation of bone age (BA), which consists of comparing radiological images with reference patterns.[8] Ethnic differences in the rate of skeletal maturity have been reported.[9–11] In Mexican children, we have reported that BA is less than the chronological age (CA) up to 10 years of age, and an advance of approximately 1 year is observed at the end of puberty.[12] A similar situation has been reported in other ethnic groups.[9–11]

Multiple factors, such as genetics, hormones, the environment, health status, physical activity, nutrition and body composition, could explain the differences in growth and maturation between individuals.[3,13,14] Nutritional status plays an important role in regulating linear growth,[13,15] development[13,15–18] and skeletal maturation.[6,19–21] Children with overweight or obesity exhibit accelerated linear growth in the prepubertal stage[4,5,22–25] followed by a smaller increase in height during adolescence, resulting in a shorter pubertal growth spurt.[4,5,23–26]

Likewise, overweight and obesity can be associated with an earlier onset of puberty.[4,18,22,23,27–31] This association is stronger in girls,[28,29,31] and the evidence remains controversial in boys.[4,27,30–34] In turn, early-maturing individuals have also been reported to accumulate more subcutaneous adipose tissue on the lower trunk than later-maturing peers of the same age and sex.[35]

The association between adiposity and advanced skeletal maturity in both sexes has been described by various authors,[6,19–21,25,36–42] although information on the Hispanic population is scarce.[6,40] However, other authors have not identified differences in skeletal maturity according to nutritional status.[3,43] Therefore, our objective was to analyse the effect of adiposity on BA curves for Mexican children. The relevance of this study lies in the lack of previous studies on the Mexican population, which has a high prevalence of children and adolescents affected by obesity, the inclusion of a representative sample size stratified by sex with a wide range of ages, the use of automated BA readings with lower reading errors than the human eye and the consideration of both anthropometric variables and dual-energy X-ray absorptiometry (DXA) for assessing adiposity.

2 | METHODS

This analytical cross-sectional study of 902 healthy Mexican children (5–18 years old) was conducted from November 2016 to August 2019. We performed random, multistage and stratified sampling from Mexico City's primary and secondary schools registered with the Mexican Ministry of Public Education. Factors such as public/private sector, education level and administrative delegation were considered for stratification. Invitations were sent to parents, and we also included family members and friends who met the inclusion criteria. All participants underwent a medical evaluation with a physical examination by a pediatric physician to check their health status and classify sexual maturity according to the Tanner stages. Anteroposterior radiography of the non-dominant hand was performed to analyse BA automatically using BoneXpert® software, version 3.2.2. (Visiana, Fremtidsvej 1, DK-2970 Hørsholm, Denmark). BoneXpert is a cutting-edge software tool that utilizes artificial intelligence technology to provide accurate and standardized BA assessments. The accuracy of BoneXpert is clearly better than the accuracy of a single manual rating.[44] The BoneXpert BA determination method shows a significant positive correlation with CA and Greulich–Pyle in eutrophic children and adolescents. It also shows a correlation with overweight and obesity. The impact of being overweight or obese on BA could be identified using BoneXpert.[40] For the purpose of this study, advanced BA was defined as a BA greater than the CA and was considered clinically significant when it exceeded 1 year.

Certain exclusion criteria were applied in the selection of subjects for this study to ensure the accuracy and reliability of the anthropometric, DXA and BA measurements. Individuals with chronic degenerative diseases, except overweight and obesity, were excluded. These diseases encompassed a range of conditions, such as endocrinological, respiratory and neurological diseases; renal failure; genetic disorders; and dysmorphic syndromes. No intake of drugs known to modify bone mass (e.g., hormone therapy, corticosteroids, antiepileptics and methotrexate) was allowed. Additionally, females with a history of pregnancy and subjects with limb amputation or metal implants were also excluded.

Anthropometric measurements of the children were recorded by trained personnel with accreditation from the International Society for the Advancement of Kinanthropometry (ISAK). Weight was obtained using a digital scale accurate to 0.1 kg (Seca® 884, Hamburg, Germany), while height was obtained using a stadiometer accurate to 0.1 cm (Seca® 225, Hamburg, Germany).

Body mass index (BMI) was determined by dividing the weight in kilograms by the square of the height in metres. The *Z* score of the BMI was calculated, taking into account CA and sex, and referenced to the WHO data to assess the relative position of BMI within the population.[45]

Waist circumference was measured at a specific point between the lower costal border and the iliac crest during end-expiration. Non-elastic flexible tape with a precision of 0.1 cm (Seca® 200) was used for this purpose. The waist/height ratio (WHtR) was calculated by dividing the waist circumference by the height in centimetres.

The nutritional status of the participants was determined using both their BMI and WHtR. A BMI SDS <1 indicated a normal weight, whereas a BMI SDS ≥ 1 indicated overweight or obesity. Similarly, the absence of abdominal obesity was defined as a WHtR <0.5, while a WHtR ≥ 0.5 indicated the presence of abdominal obesity.[46]

Adiposity, or body fat content, was estimated using DXA (Lunar-iDXA by GE Healthcare®) according to the manufacturer's instructions and analysed with Encore® software version 15, obtaining body fat percentage (BF%) and truncal fat mass (TrFM) in kilogram. The standard deviation score (SDS) values were obtained for BF% and TrFM according to reference values for Mexican children and adolescents.[47] Participants with BF% SDS <1 were classified as having a normal weight, while those with BF% SDS ≥ 1 were considered to have overweight or obesity. The same criteria were applied to the TrFM.

Informed consent was obtained from all parents or guardians prior to the study, while subjects aged 7 years and older provided informed consent. Notably, this study was conducted in strict accordance with the ethical guidelines outlined in the Declaration of Helsinki. This study protocol was reviewed and approved by the

TABLE 1 General characteristics of the participants stratified according to sex and nutritional status measured using body mass index.

	Boys $n = 503$		Girls $n = 399$	
	Normal weight, $n = 337$ (66.9%)	Overweight/obesity, $n = 166$ (33.1%)	Normal weight, $n = 245$ (61.4%)	Overweight/obesity, $n = 154$ (38.6%)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
CA (years)	11.79 ± 4.22	11.44 ± 3.66	12.10 ± 4.00	12.48 ± 3.49
BA (years)	11.80 ± 4.71	12.28 ± 3.87	12.32 ± 4.23	13.41 ± 3.53*
Weight (kg)	39.06 ± 16.72	52.90 ± 20.55*	38.41 ± 13.80	56.05 ± 17.45*
Weight for age SDS	−0.43 ± 0.80	1.89 ± 1.11*	−0.34 ± 0.69	1.60 ± 1.08*
Height (cm)	144.85 ± 22.57	146.67 ± 18.85*	141.70 ± 18.31	148.16 ± 15.55*
Height for age SDS	−0.44 ± 0.86	0.12 ± 1.00*	−0.65 ± 0.87	−0.08 ± 1.09*
BMI (kg/m^2)	17.52 ± 2.65	23.50 ± 4.15*	18.30 ± 2.76	24.71 ± 4.13*
BMI SDS	−0.29 ± 0.73	2.06 ± 0.86*	−0.51 ± 0.61	1.80 ± 0.60*
WC (cm)	63.07 ± 9.39	78.61 ± 12.19*	63.08 ± 8.24	78.23 ± 10.32*
WHtR	0.43 ± 0.02	0.53 ± 0.05*	0.44 ± 0.04	0.52 ± 0.04*
BF%	22.69 ± 5.32	35.08 ± 6.67*	31.41 ± 4.86	40.04 ± 5.23*
BF% SDS	−0.36 ± 0.85	1.25 ± 0.70*	−0.22 ± 0.80	1.20 ± 0.82*
TrFM (kg)	3.59 ± 2.22	9.24 ± 4.66*	5.52 ± 2.97	11.3 ± 4.70*
TrFM SDS	−0.39 ± 0.76	1.39 ± 0.62*	−0.30 ± 0.70	1.39 ± 0.65*
	n (%)	*n* (%)	*n* (%)	*n* (%)
Prepubertal (Tanner 1)	176 (52.2)	92 (55.4)	95 (38.7)	47 (30.5)
WHtR ≥0.5	108 (32.0)	163 (98.1)*	102 (41.6)	151 (98.0)*
BF% SDS ≥1	24 (7.1)	113 (68.0)*	13 (5.3)	99 (64.2)*
TrFM SDS ≥1	11 (3.2)	122 (73.4)*	6 (2.4)	118 (76.6)*

Abbreviations: BA, bone age; BF%, body fat percentage; BMI, body mass index; CA, chronological age; SDS, standard deviation score; TrFM, truncal fat mass; WC, waist circumference; WHtR, waist/height ratio.
*$p < 0.05$ for the comparison between the normal weight and overweight or obesity groups according to BMI.

Research, Ethics and Biosafety Committees of the Hospital Infantil de México Federico Gómez (HIM 2015/055 and HIM 2017/058).

2.1 | Statistical analysis

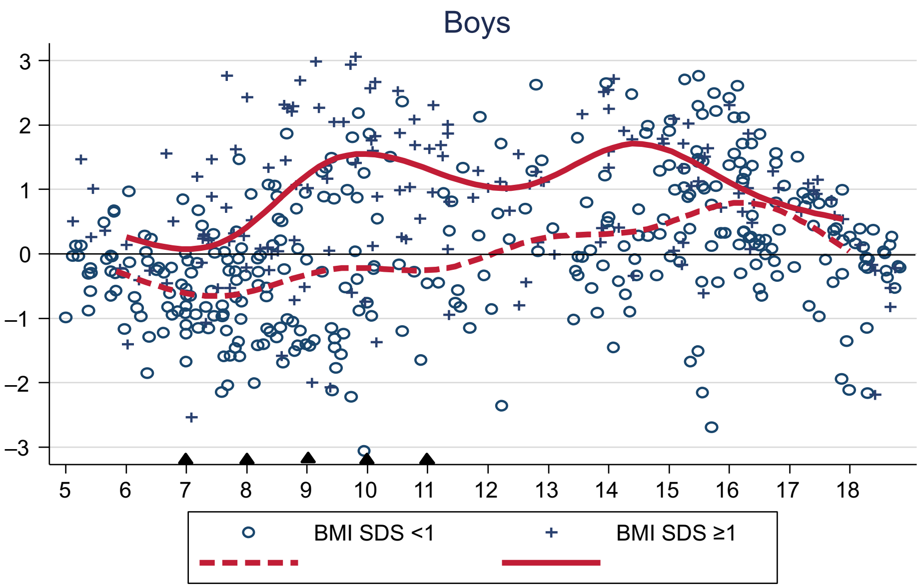
Means and standard deviations or frequencies were used, depending on the type of variable and the normality of the data. The WHO AnthroPlus® program was utilized to estimate the SDS of BMI for each participant, taking into account the CA and sex of the individuals.[48] The difference between the BA and CA was plotted against the CA, stratified by sex and nutritional status. The means were smoothed at 2-year intervals, and scatter plots were constructed for visual representation.

For comparison, nutritional status was categorized based on the BMI SDS (<1 vs. ≥1) and WHtR (<0.5 vs. ≥0.5). Additionally, the BF% *Z* score (BF% SDS) and truncal fat mass *Z* score (TrFM SDS) were compared (<1 vs. ≥1). Student's *t* test was used to compare the groups (normal weight vs. overweight or obesity) by sex, including participants at each CA. Additionally, we employed the chi-square test to statistically examine the association between categorical variables in the normal weight group and those characterized as overweight or obese. A *p* value < 0.05 was considered to indicate statistical significance. Logistic regression analysis was performed to determine odds ratios (ORs) and 95% confidence intervals (95% CIs) for an advanced BA by more than 1 year for children with overweight/obesity according to the BMI, WHtR, BF% and TrFM classifications.

3 | RESULTS

In Table 1, we provide a comprehensive overview of the participants' anthropometric characteristics and BA categorized by sex and nutritional status by BMI. Additionally, we present the pubertal status and body composition parameters assessed using DXA.

Figure 1 shows the BA-CA curves of participants stratified by sex as a function of CA and nutritional status according to the BMI SDS. Boys with overweight and obesity had an advanced BA beginning at 8.0 years of age, which was maintained until the end of the growth stage (BA 14–15 for girls and 16–17 for boys). However, boys with



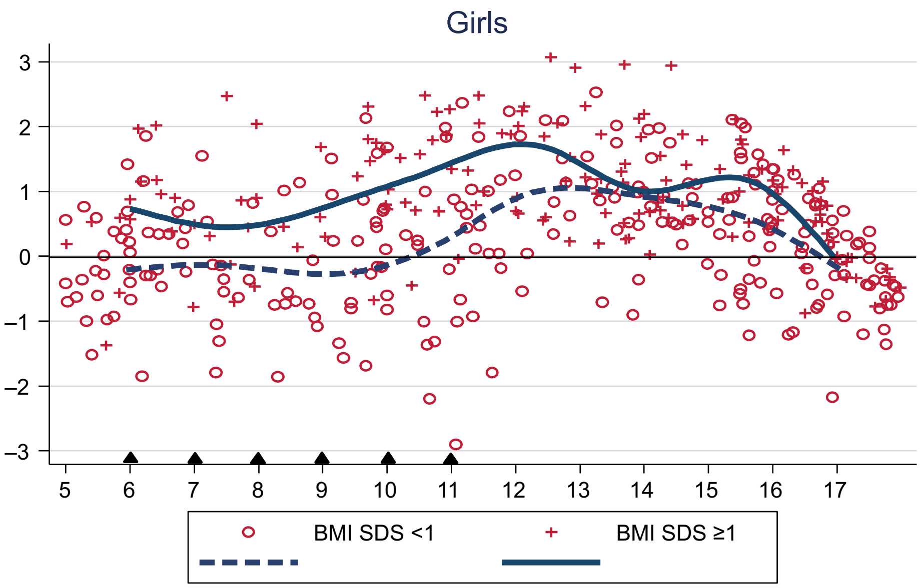


FIGURE 1 Bone age–chronological age curves of participants stratified by sex as a function of CA and nutritional status according to the body mass index standard deviation score. The mean difference between the BA and CA (BA–CA) is presented by CA and sex. The light dashed line represents children with a normal weight who had a BMI SDS <1. The solid line represents children with overweight or obesity who had a BMI SDS ≥1. The arrowhead indicates a statistically significant difference ($p < 0.05$) between the two groups at each CA, as determined using Student's *t* test.

normal weight maintained a BA lower than their CA until 12.0 years of age. These findings indicate that boys with overweight or obesity exhibit advanced BA 4.0 years earlier than do boys with normal weight and present a significantly greater BA of 7–11 years ($p < 0.05$).

Girls with overweight or obesity according to the BMI SDS had an advanced BA beginning at 6.0 years of age, which was maintained until the end of the growth stage. However, the girls with normal weight maintained a BA lower than their CA by up to 10.3 years. Taken together, these findings indicate that girls with overweight or obesity exhibit advanced BA 4.3 years earlier than do girls with normal weight and present a significantly greater BA of 6–11 years ($p < 0.05$).

A similar situation was observed for participants with abdominal obesity. Figure 2 shows the BA–CA curves of participants stratified by sex as a function of CA and nutritional status according to the WHtR. On average, boys with a WHtR ≥0.5 presented an increase in BA 4.6 years earlier than did participants with a WHtR <0.5 (7.5 vs. 12.1 years, $p < 0.01$), and they maintained a greater BA between 7 and 11 years ($p < 0.05$). Girls with a WHtR ≥0.5 presented an increase in BA, an average of 2.3 years earlier than girls with a WHtR <0.5 (6.3 vs. 8.8 years); however, significant differences between the curves were not observed.

Figure 3 shows the BA-CA curves of participants stratified by sex as a function of CA and nutritional status according to the BF%. Boys with a BF% SDS ≥1 presented an advanced BA from 7.5 years of age, which was maintained until the end of the growth stage. However, boys with a BF% SDS <1 maintained a BA lower than their CA for up to 10.0 years. This finding indicates that boys with a BF% SDS ≥1 exhibit advanced BA 2.5 years earlier than boys with a BF% SDS <1 and present a significantly greater BA between 7 and 11 years of age ($p < 0.05$).

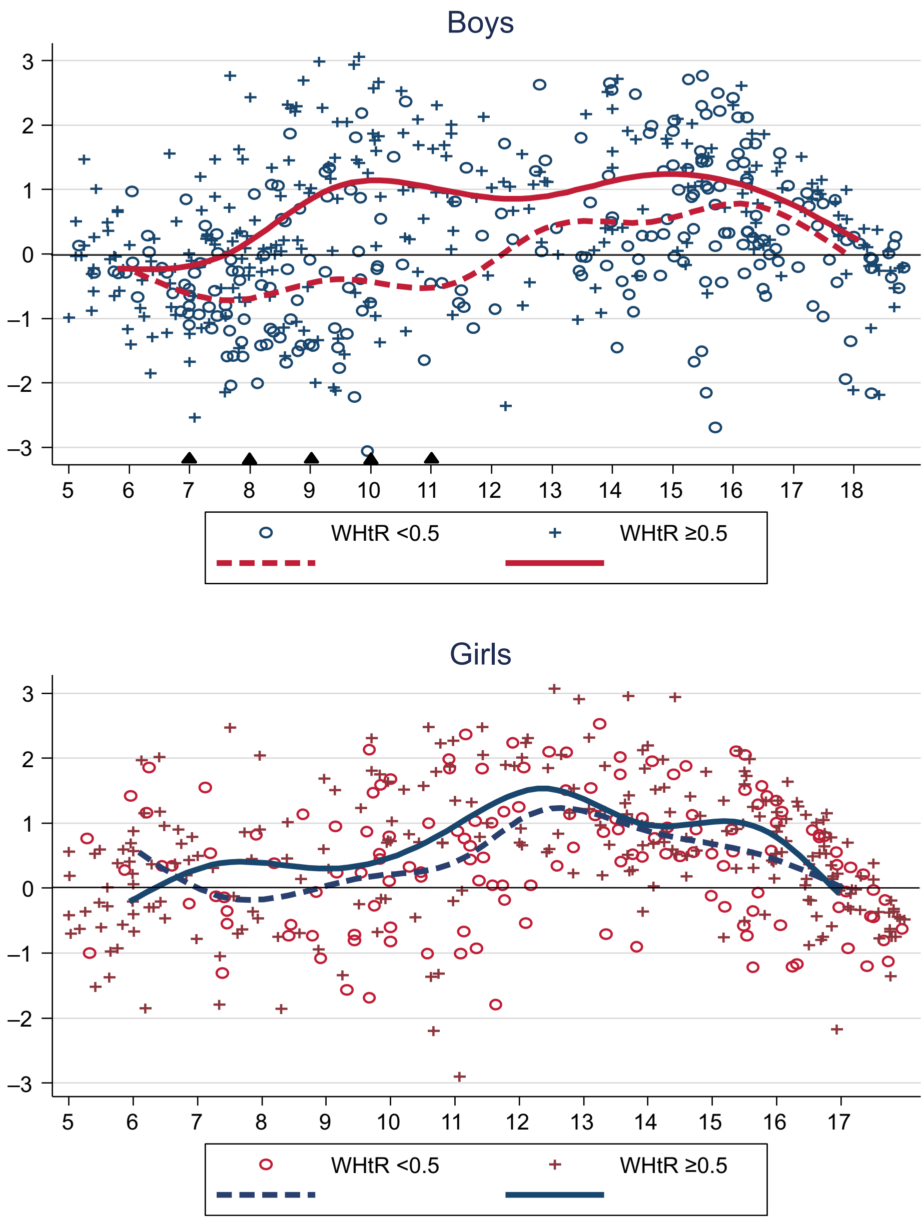


FIGURE 2 Bone age–chronological age curves of participants stratified by sex as a function of CA and nutritional status according to the waist/height ratio. The mean difference between the BA and CA (BA–CA) is presented by CA and sex. The light dashed line represents children with a WHtR <0.5. The solid line represents children with a WHtR ≥0.5. The arrowhead indicates a statistically significant difference ($p < 0.05$) between the two groups at each CA, as determined using Student's *t* test.

Girls with a BF% SDS ≥1 exhibited advanced BA starting at 6.0 years of age, and this advancement persisted until the completion of the growth stage. Conversely, girls with a BF% SDS <1 maintained a BA lower than their CA until the age of 9.6 years. However, significant differences between the curves were not observed.

A similar situation was observed for participants with a higher TrFM. Figure 4 shows that boys with a TrFM SDS ≥1 present, on average, an advanced BA 3.8 years earlier than participants with a TrFM SDS <1 (6.2 vs. 10 years, $p < 0.01$) and maintain a greater BA between 7 and 11 years of age ($p < 0.05$). Girls with a TrFM SDS ≥1 presented an increase in BA on average 3.8 years earlier than girls with a TrFM SDS <1 (6.1 vs. 9.9 years, $p < 0.01$) and maintained a greater BA between 7 and 10 years of age ($p < 0.05$).

In our study, 56.9% of participants with a BMI greater than 2 SDS experienced more than 1 year of advanced BA and the 43% more than 2 years (data not shown). Table 2 presents the ORs and 95% CIs for advanced BA of more than 1 year based on anthropometric and DXA parameters. Children of both sexes with higher BMIs, BF% and TrFMs had greater odds of experiencing advanced BA (WHtR only in boys).

4 | DISCUSSION

This study aimed to investigate the association between adiposity and skeletal maturity in Mexican children, providing further evidence for the effects of excess body fat. Our findings suggest that adiposity may play a significant role in influencing growth potential by increasing the BA at a faster rate than the CA. These results hold particular significance in countries characterized by a high incidence of overweight and obesity, such as Mexico, which ranks among the countries with the highest rates of childhood overweight and obesity

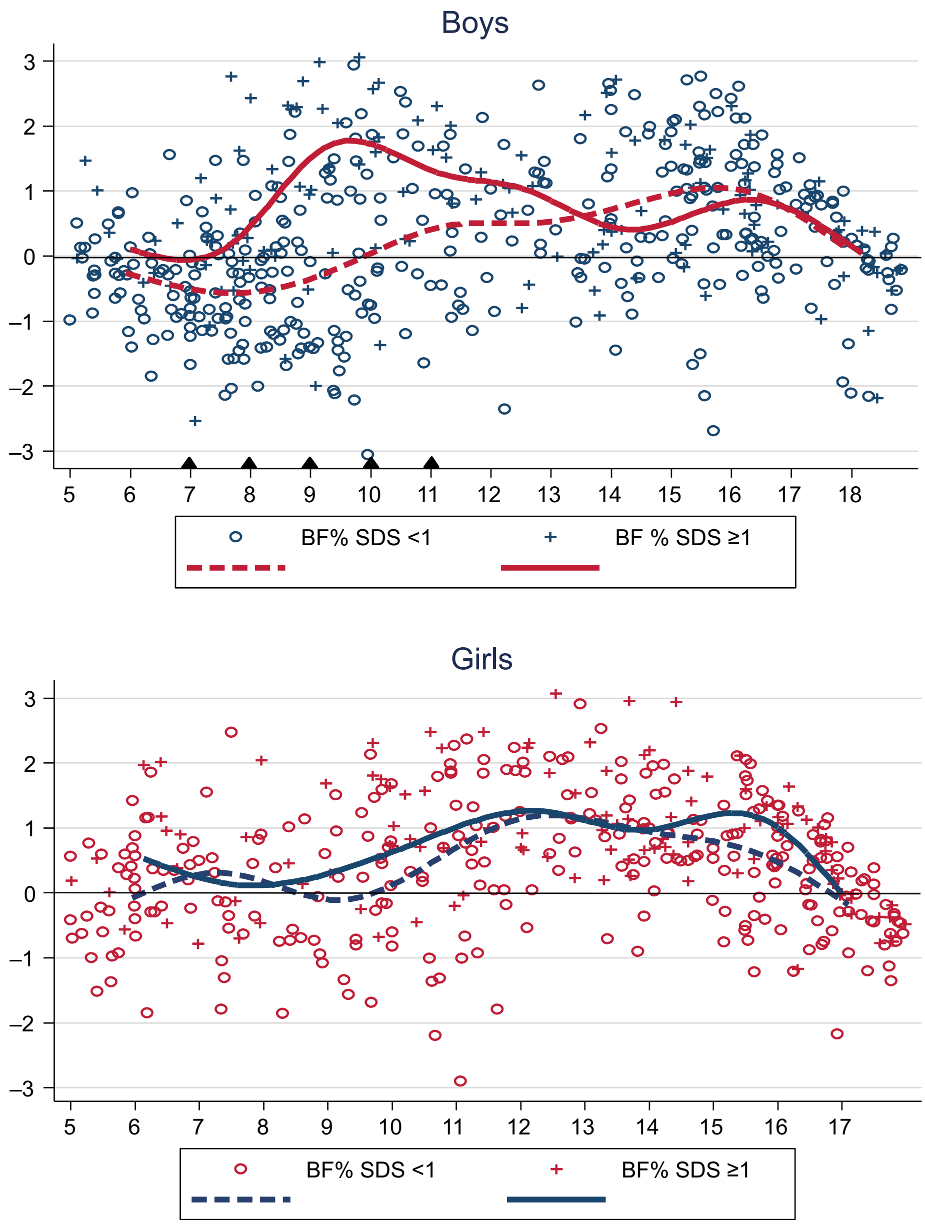


FIGURE 3 Bone age–chronological age curves of participants stratified by sex as a function of CA and nutritional status according to the BF% standard deviation score. The mean difference between the BA and CA (BA–CA) is presented by CA and sex. The light dashed line represents children with a BF % SDS <1. The solid line represents children with a BF% SDS ≥1. The arrowhead indicates a statistically significant difference ($p < 0.05$) between the two groups at each CA, as determined using Student's t test.

worldwide.[49] Notably, our results indicate that the observed advanced BA in Mexican children[12] may be partly attributed to the presence of excessive adiposity.

The strengths of our study lie in the use of robust measurement techniques to investigate the association between adiposity and skeletal maturity in Mexican children. We employed artificial intelligence to accurately assess BA, eliminating the subjectivity associated with traditional methods.[44,50] Furthermore, we employed DXA, which is considered a reliable method for assessing body composition. Additionally, we incorporated anthropometric indices such as BMI and the WHtR, which are readily available and more commonly used in clinical practice. We added a body composition comparison with specific reference values for Mexican children and adolescents.[47]

Growth and development are strongly influenced by an individual's nutritional status, making it crucial to investigate this relationship. Previous research has indicated that children with overweight or obesity tend to experience advanced skeletal maturity.[6,19–21,25,36–39] Notably, De Groot and colleagues reported a significant correlation between the BMI SDS and BA SDS in children with obesity ($r = 0.55$, $p < 0.001$).[37] The relationship between adiposity and skeletal maturity has been corroborated in different populations, such as those in the United States,[6,21,36,38] Korea,[19,41] the Netherlands,[37] Belgium,[42] Israel,[39] Brazil[40] and China.[20] Moreover, studies have examined a wide range of age groups, including pre-schoolers, schoolchildren and adolescents, as well as prepubertal and pubertal children. Several investigations have focused on participants with conditions such as premature adrenarche,[6] hyperinsulinemia,[19,39] insulin resistance[19] and monogenic obesity,[37] further highlighting the association between adiposity measures and BA.

Our findings suggest that boys and girls with overweight or obesity exhibit signs of advanced BA as early as the age of 6 years when their nutritional status is assessed using anthropometric parameters.

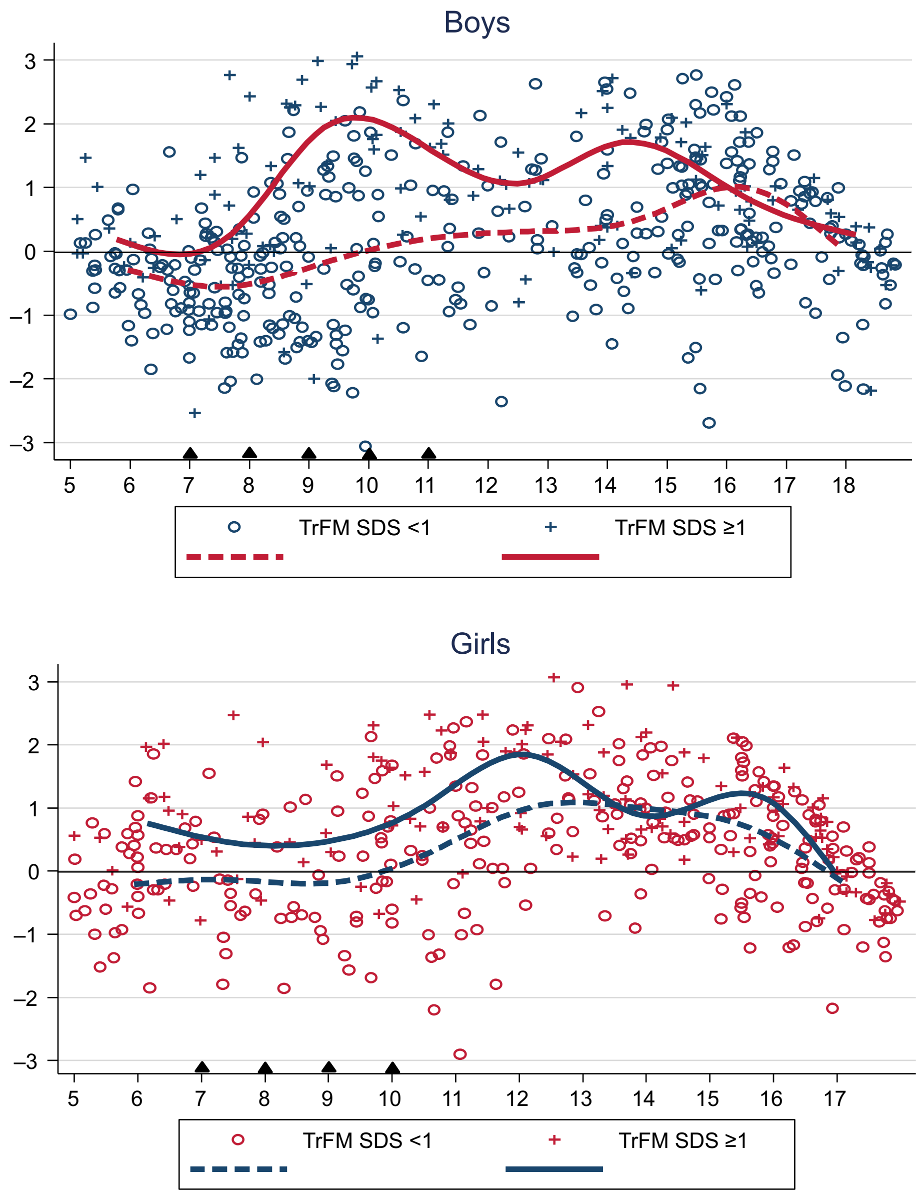


FIGURE 4 Bone age–chronological age curves of participants stratified by sex as a function of CA and nutritional status according to the truncal fat mass standard deviation score. The mean difference between the BA and CA (BA–CA) is presented by CA and sex. The light dashed line represents children with a TrFM SDS <1. The solid line represents children with a TrFM SDS ≥1. The arrowhead indicates a statistically significant difference ($p < 0.05$) between the two groups at each CA, as determined using Student's *t* test.

TABLE 2 Logistic regression analysis of the associations of anthropometric and dual-energy X-ray absorptiometry parameters with advanced BA >1 year.

	Boys *n* = 503			Girls *n* = 399		
	OR	95% CI	*p* Value	OR	95% CI	*p* Value
BMI SDS ≥1	3.55	2.36–5.33	<0.001	2.87	1.85–4.45	<0.001
WHtR ≥0.5	1.67	1.12–2.49	0.011	1.05	0.67–1.63	0.821
BF% SDS ≥1	1.84	1.21–2.80	0.004	1.79	1.13–2.84	0.012
TrFM SDS ≥1	2.70	1.77–4.11	<0.001	2.07	1.32–3.24	0.001

Abbreviations: BF%, body fat percentage; BMI, body mass index; TrFM, truncal fat mass; WHtR, waist/height ratio.

Previous research has also documented early-onset advanced BA in children with obesity utilizing anthropometric measures.[6,19–21,36–39,51]

Likewise, our study revealed that among participants with obesity (BMI SDS ≥2), 56.9% experienced an advanced BA of more than 1 year and 43% experienced an advancement of more than 2 years (data not shown). These results indicate higher percentages than those previously reported by Klein et al. in the United States, who found that 33% of the children with obesity showed an advancement of more than 2 years.[38] We believe that these differences could potentially be attributed to ethnic origin. Research has shown that Hispanic and Mexican populations tend to exhibit a higher BA compared to their CA, particularly after the age of 10. It is important to note that the study conducted by Klein primarily focused on Caucasian children.[11,12]

Furthermore, our analysis indicated that boys with a BMI SDS ≥1 had an OR of 3.55 for advanced BA of more than 1 year, while girls had an OR of 2.87 (Table 2). These findings are consistent with those of a study by Ke et al., which revealed that pre-school-aged children with overweight, as determined by BMI, have a greater likelihood of having an advanced BA of at least 1 year (OR 3.27, 95% CI 2.20–4.87), and these odds are further amplified in children with obesity (OR 4.73, 95% CI 2.99–7.48).[20]

In our research, we also observed a noteworthy progression in skeletal maturity associated with adiposity when using DXA as a tool to assess nutritional status. These findings align with previous research conducted by Russell et al., who also reported positive correlations of DXA-measured fat mass with BA/CA and BA-CA ($r > 0.46$, $p < 0.001$).[21] Similarly, Costacurta et al. reported a significant association between skeletal–dental age advancement and body fat percentage measured using DXA.[52]

Furthermore, our investigation revealed that boys who have greater WHtR and boys and girls with higher TrFM experience greater advanced BA (Table 2). This finding aligns with the previous results of Koziel et al., who reported that children with early maturation, as determined by the age of peak growth velocity, tend to accumulate more subcutaneous fat in the lower trunk.[35] However, these findings differ from those of a previous study conducted by van Lenthe et al., in which they utilized skinfold ratios to evaluate the truncal fat distribution and reported no association with skeletal maturity in boys or girls.[53]

The advancement in skeletal maturity, which was observed after the age of 6 years in boys and girls with obesity, gradually diminished towards the end of the puberty stage. This result indicates a transient effect of advanced skeletal maturity during the growth phase, which subsequently decreases as complete bone maturity is achieved and children approach their near-adult height.

Numerous researchers have made significant efforts to understand the link between obesity and BA by exploring the underlying hormonal mechanisms involved in this phenomenon. It has been reported that insulin and insulin resistance may play a crucial role in the advanced BA observed in children and adolescents with obesity.[19,39,41] The role of insulin in this process encompasses several pathways. Firstly, insulin is known to reduce the levels of insulin-like growth factor-binding protein 1, resulting in increased levels of both total and free insulin-like growth factor-1 (IGF1). This rise in IGF1 levels has been associated with enhanced proliferation and differentiation of chondrocytes, the cells responsible for bone growth. Additionally, insulin stimulates the secretion of gonadotropin-releasing hormone and luteinizing hormone, which play crucial roles in regulating puberty onset. Insulin also promotes the production of steroids in the ovaries and adrenal glands, further contributing to the acceleration of pubertal development. Moreover, insulin reduces the levels of sex hormone-binding globulin, subsequently increasing the bioavailability of sex steroids. Collectively, these processes lead to accelerated linear growth, skeletal maturity and premature closure of the epiphyseal growth plate.[54] Other studies have highlighted the role of increased dehydroepiandrosterone sulphate levels and leptin as factors associated with the progression of BA in children with obesity.[37,38,41] The role of aromatase should also be acknowledged as a significant factor contributing to the association between obesity and advanced BA. Aromatase, found in adipose tissue, plays a critical role in catalysing the peripheral conversion of low-potency androgens to higher-potency estrogens. These estrogens affect the progression of puberty and subsequent skeletal maturity.[42–55]

A BA greater than the CA indicates a lower growth potential at a given age. Since adiposity is related to an advanced BA, its inclusion should be considered in future height prediction models along with the variables of age, sex, mean parental height and BA. Thodberg et al. proposed adjusting adult height prediction models as a function of BMI by showing that a positive BMI SDS requires negative correction for the prediction of adult height. Specifically, they observed a correction magnitude of approximately 1.5 cm per BMI SDS up to age 13 years in boys, while girls exhibited an effect of <0.5 cm per BMI SDS.[56] Our findings may have important implications for therapeutic decision-making in patients with growth and development disorders. However, we recognize the limitations of the cross-sectional design of this study. Hence, further longitudinal studies are needed to comprehensively understand the complex interplay between adiposity and childhood growth patterns, leading to the attainment of final height. While the overall prevalence of overweight and obesity in our sample was 35.4%, the limitation of a relatively low prevalence of obesity alone, which was <15%, must be noted. This low prevalence presented challenges in conducting a stratified analysis based on overweight and obesity due to the limited sample size. However, the combined prevalence of overweight and obesity in our study is similar to the nationally reported rates.[2]

We conclude that excess adiposity in Mexican children, mainly in boys, is associated with an advanced BA at earlier ages and of greater magnitude, which may impact growth potential.

AUTHOR CONTRIBUTIONS

CVAG conducted the literature search, collected and analysed the data, interpreted the findings, generated the figures and contributed to the writing of the manuscript. KKM conducted the data analysis and interpretation and contributed to the generation of the figures. LGD designed the data collection instruments, collected the data, coordinated and supervised the data collection and participated in the data interpretation. VGJ conducted the literature search and contributed to the data interpretation. MLAL conceived and designed the study, conducted the literature search, coordinated and supervised the data collection, interpreted the findings and drafted the manuscript. All the authors critically reviewed the manuscript for important intellectual content, approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

ACKNOWLEDGEMENTS

We thank Dr. Thodberg for support with the use of the BoneXpert software. We thank all the participating children and their parents for their participation and the Consejo Nacional de Humanidades Ciencias y Tecnologías (CONAHCYT) for the scholarship awarded to the master's student Ana Gabriela Chávez Vázquez and to the Universidad Nacional Autónoma de México master's and doctorate programs in Health Sciences.

FUNDING INFORMATION

The study was supported by Mexican Federal Funds (HIM 2015/055 and HIM/2017/058) and by Consejo Nacional de Humanidades Ciencias y Tecnologías (CONAHCYT). The funding source was not involved in the research or preparation of the article.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

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How to cite this article: Chávez-Vázquez AG, Klünder-Klünder M, Lopez-Gonzalez D, Vilchis-Gil J, Miranda-Lora AL. Association between bone age maturity and childhood adiposity. *Pediatric Obesity*. 2024;19(12):e13166. doi:10.1111/ijpo.13166