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Original Article

The Association of Extreme Body Weight with Bone Mineral Density in Saudi Children

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Abstract

Objective: The objective to investigate the effect of extreme body weight; obesity and undernutrition, on bone mineral density (BMD). **Methodology:** This study is a descriptive cross-sectional study carried between January and June of 2019, and included 224 children and adolescents without any comorbidities or chronic disease. Important data collected included anthropometrics, past medical and surgical history, history of medication intake, level of physical activity and pubertal assessment. Data entry and analysis were conducted using Statistical Package for Social Sciences version 24. **Results:** Gender distribution showed 48.2% were male and 51.8% were female. The mean age was 9.98 ± 3.5 years. Mean weight was 34.89 ± 18.2 kg. Mean BMD z-score was − 1.64 ± 1.4. Weight was considered to significantly correlate with BMD stature at a $P = 0.014$. Subjects who were underweight showed a lower mean BMD z-score of <−2 than those who were overweight/obese (mean BMD z-score = −1.60). **Conclusion:** Both extremes of weight are considered a significant risk factor for the development of low BMD in children. We recommend the early recognition of weight aberrations and consequent aggressive intervention with strict lifestyle modifications to promote the development of maximum peak bone mass.

Keywords: Body mass index, bone mineral density, children, overweight, underweight

Résumé

Objectif: étudier l'effet du poids corporel extrême; l'obésité et la dénutrition, sur la densité minérale osseuse. **Méthodologie:** Cette étude est une étude transversale descriptive réalisée entre les mois de janvier et juin 2019, et a inclus 224 enfants et adolescents sans aucune comorbidité ni maladie chronique. Les données importantes recueillies comprenaient l'anthropométrie, les antécédents médicaux et chirurgicaux, les antécédents de prise de médicaments, le niveau d'activité physique et l'évaluation pubertaire. La saisie et l'analyse des données ont été effectuées à l'aide du progiciel statistique pour les sciences sociales (SPSS) version 24. **Résultats:** La répartition par sexe a montré que 48,2% étaient des hommes et 51,8% étaient des femmes. L'âge moyen était de 9,98 ± 3,5 ans. Le poids moyen était de 34,89 ± 18,2 kg. Le score z moyen de DMO était de -1,64 ± 1,4. On a considéré que le poids était significativement corrélé à la stature de la DMO à une valeur p de 0,014. Les sujets présentant une insuffisance pondérale ont présenté un score z de DMO moyen inférieur à <-2 que ceux qui étaient en surpoids/obèses (score z moyen de DMO = -1,60). **Conclusion:** Les deux extrêmes de poids sont considérés comme un facteur de risque important pour le développement d'une faible DMO chez les enfants. Nous recommandons la détection précoce des aberrations de poids et une intervention agressive conséquente avec des modifications strictes du mode de vie afin de favoriser le développement d'une masse osseuse maximale.

Mots-clés: insuffisance pondérale; en surpoids; indice de masse corporelle; densité minérale osseuse; les enfants

Introduction

Body weight is an important marker of overall health status, providing an insight into the general state of the metabolic, musculoskeletal, immune, and reproductive systems.[1] It is closely associated with bone density in both genders and even considered by some a stronger contributing factor to bone mass

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than age.[2-6] Obesity is now a global concern as it is reaching an epidemic level with an expected prevalence of over 1 billion people by the year of 2030. Obesity is the result of high caloric intake that is in excess of energy expenditure.[7-10] A higher body mass index (BMI) is generally believed to correlate positively with a higher bone mineral density (BMD)[11] due to the increased mechanical force applied to weight-bearing bones[12] and possible hormonal fluctuations. However, most of these studies have been conducted on the adult population, and obese children are found more likely to have deficiencies in nutrients necessary for the healthy development of bone and a higher incidence of fracture as a consequence.[13,14]

Low body weight, on the other hand, is often evidence of an underlying poor nutritional status. Malnutrition predisposes to essential mineral deficiencies, hypoalbuminaemia, osteomalacia, physical impairment, and a loss of muscle mass; all of which contribute to impaired bone mineralization and therefore a lower BMD.[15] In addition, a low BMI is also considered an important risk factor for the development of osteoporosis due to poor physical condition and absence of significant mechanical forces exerted on weight-bearing bones to promote its growth.[16]

As published research that focuses on the effect of extreme body weights on BMD in the pediatric population is scarce, we aimed to investigate the trends in BMD in response to different body mass indices throughout childhood and adolescence.

Methodology

This is a descriptive, cross-sectional study that was carried in King AbdulAziz University Hospital between January 2019 and June 2019. This study was conducted in compliance with the tenets of the Helsinki declaration, and ethical approval was obtained from the Research Ethical Committee at King AbdulAziz University alongside a written consent from legal guardians and verbal consent from the children. Literature search for similar research was through typing relative MeSH terminology in the PubMed search engine while filtering search results according to publication date, narrowing the results to articles that were published within the past 5–10 years to obtain recent references.

Subjects were recruited in the general paediatric clinic through inviting children/adolescents and their legal guardians/parents to participate in this research. Data were collected through interviewing legal guardians/parents and physically examining the children in a private room at the general paediatric clinic. Data collected from parents included family history of bone disease, past medical and surgical history of the child/adolescent, medication intake, previous fractures, and level of physical activity. The children underwent a general physical examination and pubertal assessment in addition to having their anthropometric measures, height, and weight, recorded.

Weight was recorded in kilograms using an electronic scale, and results were classified into three categories as follows according to BMI: Underweight, normal, and overweight/obese. Patients were categorized by weight standard deviation (SD) into underweight if the weight SD was <−1, overweight/obese if the weight SD was >+1, and normal weight if the weight SD was between −1 and +1.

BMD was obtained through quantitative ultrasound (QUS) measurement at either right or left distal radii for each subject using the Sunlight Omnisense 7000S device (Sunlight Technologies, Rehovot, Israel). The QUS constitutes a hand-held ultrasound probe emitting sound at a pulse of a particular frequency that is refracted through a certain angle from soft tissue to bone. A proportion of this returns from the bone at the same angle that is then received by the device. Therefore, the duration through which the ultrasound waves propagate through the bone tissue from signal emission to its detection at the transducer is measured as a value termed speed of sound (SOS) and consequently was attributed the unit of meters/second (m/sec). BMD was considered low if the Z score was <−1. Activity level was assessed through evaluating both duration and frequency of activities that prompted cardiovascular effort; this included swimming, cycling, dancing, martial arts, and running sports such as football, baseball, and basketball. In line with the WHO guidelines for adequate physical activity in children, 60 min of moderate to vigorous intensity per day was considered sufficient to classify the child as physically active.

Inclusion and exclusion criteria

A total of 714 children were examined. Children/Adolescents were included in the study if they were within an age range of 2 and 18 years and were visiting the general paediatric clinic for a wellness check-up or regular follow-up. Children/adolescents were excluded if they had short stature, were taking steroid-containing medications, had any comorbidities or chronic health disease, had Vitamin D deficiency, no consistent SOS values were attainable using the QUS, pertained to a low socioeconomic status, and/or due to incomplete data.

Statistical analysis

Data entry and analysis were conducted using Statistical Package for Social Sciences (SPSS) version 24 (IBM SPSS Statistics for Windows, version XX (IBM Corp., Armonk, NY, USA). Categorical variables were expressed either in frequency or in proportion with Chi-square tests utilized to study the relationship between them. Continuous variables were expressed in range, mean, and SD. One-way ANOVA testing was carried out to study the relationship between categorical variables and continuous variables and was used to determine the presence or absence of a significant association, with calculated $P < 0.05$ interpreted to be significant. Significant results were further illustrated in simple linear graphs to represent the difference in mean z-scores between different categories with an estimated 95% confidence interval.

Results

The sample size included 224 children who qualified for this study. Gender distribution revealed that 48.2% were male

and 51.8% were female. Age ranged between 2 and 19 years, with a mean age of 9.98 ± 3.5 years. Height ranged between 68 and 182 cm, with a mean height of 133.18 ± 18.7 cm, and in SD ranging from 2.69 to −1.97. BMI values ranged between 12.42 and 29.11 and BMI z-scores ranged from the lowest value of −2.57 and the highest value of 4.03. BMD in the form of z-score was between −5 and +1.80 with the mean BMD at −1.64 ± 1.4. Half of the total sample sizes (52.7%) were considered to be of normal weight, 35.7% were considered underweight, and 11.6% were considered either overweight or obese [Table 1]. Statistical analysis showed a significant correlation between normal weight and higher Z-scores of bone density when compared to both overweight/obese and underweight, both of which showed significantly lower Z-scores for BMD ($P = 0.14$) [Figure 1]. Underweight subjects demonstrated a mean BMD z-score of <−2, whereas overweight/obese subjects demonstrated a mean BMD z-score of −1.60. Furthermore, correlation studies between BMI z-scores and BMD z-scores showed a significant negative correlation of $P = 0.045$. Pearson's coefficient for the strength of this correlation was 0.12.

In terms of pubertal status, 55.7% of were prepubertal at a tanner stage of 1, with 29.2% at a tanner stage of 3–4, and 15.1% reaching full puberty at a tanner stage of 4–5. Although not found to be statistically significant ($P > 0.05$), the mean of BMD z-score was found to be higher (z-score = −1.25) in those with a tanner stage of 4–5 than in those with a tanner stage of 1–3 (z-score <−1.70) [Figure 2]. In terms of physical activity, 94.6% of the samples were found to be physically active, whereas 5.4% were considered inactive. The mean of BMD z-score was found to be lower (z-score <−2) in those who were not physically active when compared to their physically active counterparts (z-score = −1.61), but the difference was not statistically significant [Figure 3] ($P > 0.05$).

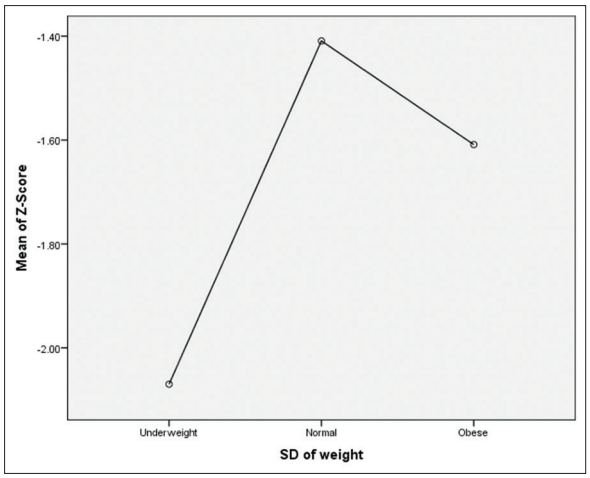

Figure 1: Relationship between the mean of bone mineral density in z-score and the categories of weight in standard deviation

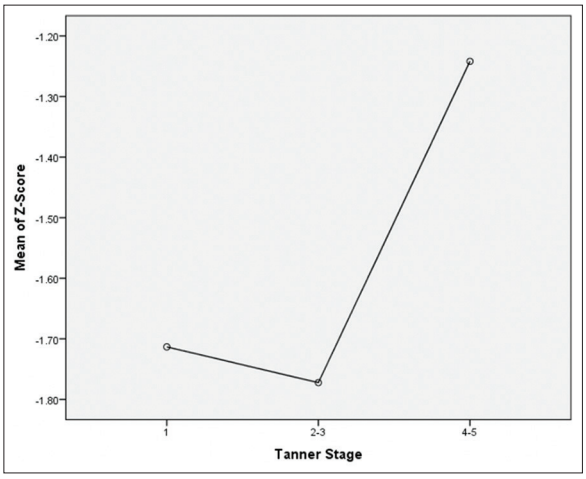

Figure 2: Relationship between mean bone mineral density in z-score and tanner stage

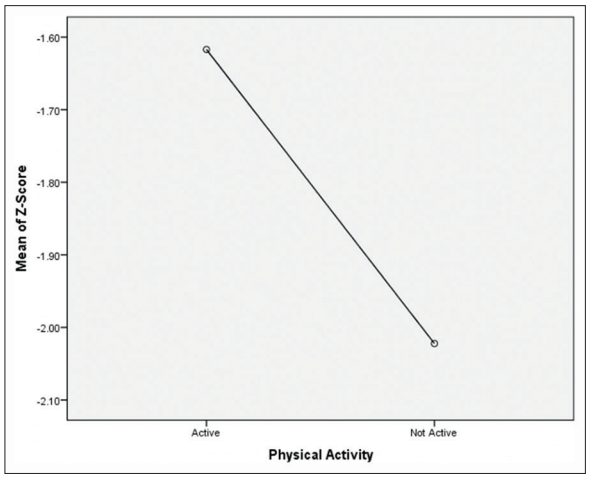

Figure 3: Relationship between mean bone mineral density and physical activity

Discussion

The effect of mechanical loading on the development of skeletal strength and resilience is widely recognized. With the increase in incidence of both underweight and overweight children, it is anticipated that the fracture risk as well as incidence of pediatric osteoporosis will also rise in parallel.[17] Majority of the studies investigating the relationship between BMI and BMD were carried out on a population of adults, particularly those investigating hormonal influences, which almost exclusively focused on postmenopausal women. Fewer studies have managed to include healthy children and young adolescents in their population sample.

Multiple studies have shown that the prevalence of low BMI (underweight) is higher than that of high BMI (overweight/obese) among young children.[18-21] This is in keeping with our finding, as the percentage of underweight children was approximately 3 times the amount of those who were either overweight or obese. More so, many studies outlined the significant effect of BMI on BMD. Boot *et al.* revealed that a sample of 500 healthy children and adolescents between the ages of 4 and 20 years had demonstrated a significantly positive

Table 1: Frequency of children and adolescents who were underweight, overweight, obese, and of normal weight

Weight standard deviation (SD)	Frequency (n)	Percent (%)	Valid percent (%)	Cumulative percent (%)
Underweight	80	35.7	35.7	35.7
Normal weight	118	52.7	52.7	88.4
Overweight	21	9.4	9.4	97.8
Obese	5	2.2	2.2	100
Total	224	100	100	100

relationship between BMI and BMD.[22] On one end of the spectrum, adolescents with anorexia nervosa demonstrated a low BMD, suppression of bone formation, and an elevation in resorption markers.[23,24] In this study, the mean BMD z-score in the underweight category (weight SD <−1) was below −2. This illustrated that children in the underweight category had a lower BMD when compared to their normal or even overweight/obese counterparts, both of whom had mean BMD z-scores of −1.42 and −1.62. This is similar to the findings of a study by Akhlaque *et al.*, which stated that in both genders, underweight subjects are at a significantly higher risk of suffering from osteoporosis than those who were overweight/obese or had a normal BMI.[25] The effect of a low BMI on BMD is thought to be mediated by the reduced mechanical loading on the weight-bearing bones in children.[26]

On the other end of the spectrum, the discussion surrounding the effect of obesity on BMD is much more controversial. Leonard *et al.* demonstrated that overweight and obese children are more likely to have a higher BMD due to the protective effect of a high BMI on bones.[12,27] However, most of these studies were carried out in the adult population. A meta-analysis published in 2017 had studied the sample after adjusting for age and had concluded that adiposity had a stronger negative effect on BMD accrual in children and adolescents than in those above the age of 25 years. This was explained by the vulnerability of bone metabolism during the growth period in children.[28] More recent studies that are carried in the paediatric population now support this.

Rocher *et al.* describes a lower BMD in children who are overweight/obese particularly when compared to their healthy-weight controls, explaining this through a witnessed decrease in bone mineral content with increasing fat mass.[29] Although the metabolic function of bone marrow fat remains unclear, it is understood that marrow adipocytes may secrete either cytokines or adipokines that are capable of influencing adjacent osteoblastic activity.[17] Furthermore, some studies reinforce this concept by outlining an increase in circulating inflammatory cytokines experienced with obesity that are likely to significantly contribute to the process of bone loss.[30] Goulding *et al.* studied a sample of 90 children and adolescents who were subjected to repeated fracturing and had reported that 30% of the total sample were overweight, indicating that a high BMI is likely to play a considerable role in the increase of fracture risk amongst overweight and obese children.[31] This is supported by the higher propensity of overweight subjects for having poorer musculoskeletal control, less postural instability, and falling more heavily on their bones.[32,33] Moreover, Fawzy *et al.* reported a low BMD in 78.1% of overweight and 44.2% of obese subjects, with an overall statistically significant association between BMI and BMD.[16]

Intermittent weight-loading has a positive effect on bone homeostasis and BMD accrual. Children who are more physically active tend to have a statistically higher BMD than their less-active counterparts.[22] This is mirrored by the findings of our study where physically active children had a higher mean BMD z-score when compared to those who lead a sedentary lifestyle. However, the values were not statistically significant ($P > 0.05$). In addition, the hormonal changes during puberty are known to accelerate bone metabolism, homeostasis and growth due to the spike seen in the circulating serum concentration of both sex steroids and growth hormone levels.[22] Similarly, our finding supports this by showing a higher BMD in those with an advanced tanner stage of 4–5 when compared to those with tanner stages between 1 and 3, although the *P* value was also non-significant ($P > 0.05$).

Study limitations

The study sample was sample. Unfortunately, no local BMI charts are available for Arab/Saudi children and so the WHO normative data were used for BMI categorized. The QUS relied on a Caucasian ethnicity reference population as there is no Arab reference population yet.

Conclusion

Both underweight and overweight children have a higher likelihood of low BMD, leaving them more at risk for the development of fractures and paediatric osteoporosis. This poses a great concern as the future integrity of bone health throughout adulthood is dependent on peak bone mass, which is largely determined by the accrual of BMD throughout childhood and adolescence. We recommend increasing awareness of the inclination to a compromised BMD in this particular age group, the recognition of modifiable factors such as low or high BMI, and early intervention by controlling weight through diet and exercise with the goal of achieving optimum peak bone mass.

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Conflicts of interest

There are no conflicts of interest.

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