



# An epidemiological evaluation of fractures and its determinants among Lebanese schoolchildren: a cross-sectional study

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## Abstract

**Summary** The purpose of this study is to establish the prevalence and determinants of fractures among 974 Lebanese schoolchildren aged 8–18. Fractures might be less common in the Lebanese pediatric population compared to western populations. Male gender and high SES are independent risk factors for fractures, while 25(OH)D and BMI have no impact.

**Purpose** To establish the prevalence of fractures among Lebanese schoolchildren and its relationship with age, gender, BMI, 25 hydroxyvitamin D (25(OH)D) levels, and socioeconomic status (SES).

**Methods** In this cross-sectional study, 974 Lebanese schoolchildren aged 8–18 years old, mean age  $13.37 \pm 2.92$  (508 boys and 466 girls), were recruited from 10 schools with different SES. For each participant, a questionnaire was used to collect data regarding history of fractures. Serum 25(OH)D was also measured.

**Results** The prevalence of Lebanese children sustaining  $\geq 1$  fracture was 16.9% and was higher in boys compared to girls (22.2% vs 11.1%,  $p < 0.0001$ ). A 71.3% of fractures were localized in the upper limbs and 20% of participants had at least one displaced fracture. Children who sustained a fracture had a non-significant higher BMI compared to those without ( $p = 0.096$ ). The percentage of children with fractures was higher in children from high SES compared to those from middle and low SES (respectively 23.3% vs. 16.3% and 13.8%,  $p < 0.0001$ ). Fractures occurred at a younger age in girls compared to boys, but this difference was non-significant ( $p = 0.13$ ). 25(OH)D levels were significantly higher in children with fractures compared to those without ( $p = 0.017$ ). Finally, female gender was protective against upper limb fractures ( $p = 0.009$ ). In a logistic regression analysis, male gender and high SES were independently associated with fractures, while BMI and 25(OH)D were not.

**Conclusion** Our study demonstrates that the prevalence of fractures in the Lebanese pediatric population might be lower than western populations. It also confirms that male gender and high SES are independent risk factors for fractures, while 25(OH)D and BMI were not independently associated with fracture risk.

**Keywords** Fractures · Lebanese · Schoolchildren

## Introduction

Fractures account for 10–25% of accidents and injuries in childhood [1, 2] and therefore represent a major public health issue. The lifetime risk of sustaining a fracture in childhood is high with great variation across countries. Approximately one third of British children sustained at least one fracture before reaching the adult age [2], whereas, in Swedish boys, this prevalence reaches 42% [3, 4], compared to 22.6% in the Turkish pediatric population (below the age of 16) [5]. In the United States (US), the annual occurrence rate was of 9.47 per 1000 children aged 0–19 years old [6].

While fractures occur more often in boys compared to girls [1–4, 7–10], girls sustain fractures at a younger age (peak

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incidence 11–12 years vs. 13–14 years for boys) [2–5, 7, 8]. In addition, the distal radius is the most common fracture site in children across all studies [1–7, 11, 12], accounting for 17.8% of all fractures presenting to the emergency room in the US [6] compared to 24.1% in New Zealand [7], 26.4% in Turkey [5], and 30% in Britain [2].

Fractures are mostly secondary to trauma, low energy trauma being responsible for more than two-thirds of fractures [1, 3, 4, 8, 13]. However, other contributing factors, such as endocrine and nutritional factors, were also involved. A significant positive relationship between obesity [1, 4, 14–20], a high carbohydrates diet [8, 13], and incidence of fractures was described. In addition, conflicting results were published regarding the relationship between 25 hydroxyvitamin D (25(OH)D) levels and incidence of fractures, with some studies showing an inverse association [15, 21–23], while others failed to observe any association [24, 25].

The prevalence and predictors of pediatric fractures have been poorly studied in Middle Eastern countries. The only report studying pediatric fractures in this part of the world came from Saudi Arabia where the prevalence of subjects aged 12–17 years (mean age 14) reporting a history of fractures was 18.6% [23]. The purpose of this study is to determine the epidemiology and clinical features of fractures in Lebanese schoolchildren.

## Methods

### Population

In this cross-sectional study, ten private and public schools were targeted for recruitment using a randomized stratified sampling. The schools were selected from the areas of Great Beirut and Mount Lebanon, both areas concentrating the majority of the Lebanese population. Recruitment was done between May 2013 and October 2014. Schools were then classified, on the basis of socioeconomic status (SES) determined by the yearly school fees, into three groups: high SES (between 5000 and 7000 \$/year), moderate SES (between 3000 and 5000 \$/year), and low SES (between 1000 and 3000\$/year or free), the last group corresponding to public or semi-public schools. Only healthy children aged between 8 and 18 years were included in the study. Children with any acute or chronic medical conditions were excluded from the study, as well as those with previous or taking medications that may affect fracture risk such as oral corticosteroids or antiepileptic drugs.

### Anthropometric measurements

All children underwent weight and height measurement using the same device, shoes off, and wearing light clothes. A digital

calibrated scale was used to measure weight. The calculation of body mass index (BMI) was performed according to the standard formula:  $BMI = \text{weight (kg)} / (\text{height})^2 \text{ (m)}$ . To account for variability by age and sex, all BMI measurements were compared with age- and sex-specific reference values from the 2000 CDC growth charts to define weight status [26]. This comparison was chosen because of the lack of reference values in Lebanon. Normal weight is defined as a BMI between the 5th and 85th percentile, overweight as a BMI  $\geq$  85th and  $<$  95th percentile, whereas obesity is identified at a BMI  $\geq$  95th percentile and underweight at  $<$  5th percentile.

### Collection of data

Informed consent was signed by the children's parents, and the study was approved by the Ethics Committee of our hospital (CEHDF449). Participants' parents completed a questionnaire in the presence of an interviewer about their children's medical and surgical history as well as any reported use of chronic medication. Specific information was also obtained regarding history of fractures, and if present, additional information about the age at which fracture occurred, the fracture site (upper vs. lower limb) and the type of fracture (displaced vs. non-displaced), was collected.

### Laboratory analysis

Non-fasting sampling was performed on all subjects between 8 and 10 a.m. Blood specimens were then centrifuged the day of sampling, and the serum subsequently frozen at  $-20^\circ\text{C}$  for a period of less than 2 months. 25(OH) D levels were measured using the Diasorin Liaison chemiluminescent assay. The lowest reported value was 4 ng/ml, and the intra-assay coefficient of variation was less than 20%.

### Statistical analysis

Data were analyzed using the statistical package for social science (SPSS) Version 21 (SPSS Inc., Chicago, IL). Results of categorical and quantitative continuous variables were respectively expressed as frequencies and mean  $\pm$  standard deviation. Normality was tested using the Shapiro-Wilk test. When comparing quantitative data between two groups, either a Student's *t* test or a Mann-Whitney *U* test was used depending on the normality of the distribution. When comparing more than two groups, either a Kruskal-Wallis test with a Conover-Iman pairwise comparison and Bonferroni correction or an Anova test with Tukey pairwise comparisons was used depending on the normality of the distribution. A chi-square test was used to compare the distribution of a sample between groups. Logistic regression analysis was used to assess the independent variables that affect the occurrence of

overall fractures and upper limb fractures. A  $p$  value  $< 0.05$  was considered as significant.

## Results

### Demographic characteristics

The study population includes 974 children aged 8 to 18 years old: 466 girls and 508 boys (respectively 47.8% and 52.2% of the population) with a mean age of  $13.37 \pm 2.92$  years.

Baseline anthropometric and biological characteristics of the population according to gender, socio-economic status (SES), and BMI categories are shown in Table 1. There is no difference in age between boys and girls (respectively  $13.39 \pm 2.80$  versus  $13.34 \pm 3.04$  years,  $p = 0.63$ ). The mean BMI expressed in percentiles is  $61.5 \pm 29.7$ . Of the total population, 12.9% are defined as obese, 17.7% as overweight, 66.3% as normal, and 3.1% as underweight. BMI is higher in boys compared to girls; this difference is at the limit of significance ( $63.22 \pm 30.36$  vs.  $59.63 \pm 28.89$ ,  $p = 0.06$ ). However, the prevalence of obesity is significantly higher in boys compared to girls (16.3% vs. 9.2% respectively,  $p = 0.001$ ).

Respectively 26%, 26.5%, and 47.5% of children were recruited from high, middle, and low SES schools, without any significant difference in this repartition according to gender ( $p = 0.51$ ).

### Prevalence of fractures and their characteristics

As shown in Tables 2, 165 children (16.9% of the total population) had a history of one or more fractures: 144 (87.3%) sustained a single fracture and 21 (12.7%) multiple fractures ( $\geq 2$  fractures) with a total number of recorded fractures of 195. Furthermore, 139 fractures (71.3%) were located in the

upper limbs vs. 51 (26.1%) in the lower limbs. One hundred thirty-two children (80%) had non-displaced fractures compared with 33 (20%) with displaced ones.

### Fracture characteristics according to gender

Out of the 508 boys included in the study, 113 (22.2%) had a history of fractures, of which 16 (14.2%) reported a history of two or more fractures. Out of the 466 girls, 52 (11.1%) had a history of fractures; of which 5 (9.6%) had two or more fractures. The prevalence of fractures is higher in boys compared to girls ( $p < 0.0001$ ) (Table 2). Fractures occurred at a younger age in girls compared to boys ( $9.53 \pm 4.33$  vs.  $10.53 \pm 3.30$  years old) even if this difference is non-significant ( $p = 0.13$ ) (Table 2).

In addition, in boys, 95 (69.3%) fractures were located in the upper limb compared to 39 (28.5%) in the lower limb, while, in girls, 44 fractures (75.9%) occurred in the upper limb vs. 12 (20.7%) in the lower limb, with no significant difference according to gender ( $p = 0.8$ ). Finally, 30 (26.5%) fractures were displaced in boys compared to 3 (5.8%) in girls (Fig. 1). This gender difference is statistically significant ( $p = 0.002$ ).

### Relationship between fractures and BMI, 25(OH)D, and SES

The mean BMI was higher in children with a history of fracture compared to those without, although this difference did not reach the limit of significance ( $p = 0.096$ ), whereas 25(OH)D levels were significantly higher in children with a history of fractures compared to those without ( $p = 0.017$ ) (Table 3).

In addition, the percentage of children with fractures was higher in children from high SES compared to those from

**Table 1** Demographic characteristics of the study population according to age, gender, socio-economic status, and BMI category

	Total ( $n = 974$ )	Boys ( $n = 508$ )	Girls ( $n = 466$ )	$p$ value
Age	$13.37 \pm 2.92$	$13.39 \pm 2.80$	$13.34 \pm 3.04$	0.63
BMI (percentiles)	$61.5 \pm 29.7$	$63.22 \pm 30.36$	$59.63 \pm 28.89$	0.06
$\geq 95$	126 (12.9%)	83 (16.3%)	43 (9.2%)	0.001
$\geq 85$ and $< 95$	172 (17.7%)	100 (19.7%)	72 (15.5%)	
$\geq 5$ and $< 85$	646 (66.3%)	312 (61.4%)	334 (71.7%)	
$< 5$	30 (3.1%)	13 (2.6%)	17 (3.6%)	
Socio-economic status				0.51
High	253 (26%)	137 (27%)	116 (24.9%)	
Middle	258 (26.5%)	127 (25%)	131 (28.1%)	
Low	463 (47.5%)	244 (48%)	219 (47%)	

Age and BMI (percentiles) are reported as mean values and standard deviations. For BMI percentiles, 2000 CDC growth charts data (26) are used as reference

**Table 2** Fracture characteristics in the overall population and in boys and girls separately

	Global population (974)	Boys (508)	Girls (466)
Number of children with a history of one or more fractures*	165	113	52
Total number of fractures	195	137	58
Prevalence of children with fracture history	16.9%	22.2%	11.1%
Mean age when fracture occurred	10.22 ± 3.67	10.53 ± 3.30	9.53 ± 4.33
Number of fractures			
Children with a single fracture	144 (87.3%)	97 (85.8%)	47 (90.4%)
Children with multiple (two or more) fractures	21 (12.7%)	16 (14.2%)	5 (9.6%)
Location of fracture (relative to total number of fractures $n = 195$ )			
Upper limb	139 (71.3%)	95 (69.3%)	44 (75.9%)
Lower limb	51 (26.1%)	39 (28.5%)	12 (20.7%)
Other	5 (2.6%)	3 (2.2%)	2 (3.4%)
Nature of fracture			
Children with non-displaced fractures	132 (80%)	83 (73.5%)	49 (94.2%)
Children with displaced fractures**	33 (20%)	30 (26.5%)	3 (5.8%)

Age is reported as mean values and standard deviations

\* $p$  value < 0.0001; \*\* $p$  value = 0.002

middle and low SES (respectively 23.3% vs. 16.3% and 13.8%,  $p < 0.0001$ ) (Table 3).

### Logistic regression analysis looking at the independent variables predicting the overall fracture occurrence (Table 4) and the upper limb fracture occurrence (Table 4)

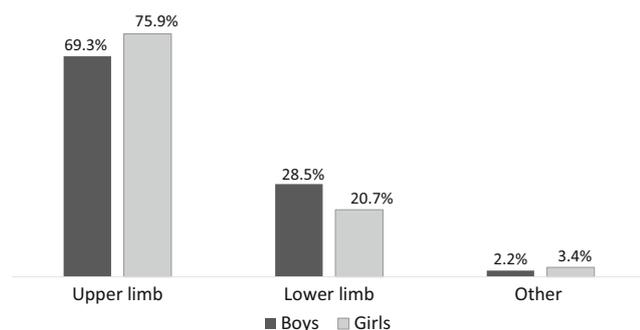
A logistic regression analysis was performed looking at the independent variables that affect the occurrence of overall fractures. Male gender and high SES were the only independent variables that increased the risk of sustaining any fracture (respectively,  $p < 0.0001$  and  $p = 0.003$ ). BMI was at the limit of significance ( $p = 0.071$ ), while 25(OH) D had no influence ( $p = 0.805$ ).

A separate logistic regression analysis was performed to look at the independent variables that affect the occurrence of upper limb fractures. Female gender was found to play a

protective role against these fractures ( $p = 0.009$ ), while no association was found with BMI ( $p = 0.554$ ).

## Discussion

Our study aimed to determine the prevalence of children with a history of fractures in a sample of 974 healthy Lebanese schoolchildren aged 8–18 years old, and to identify the characteristics and determinants of fractures in our population. We found that 16.9% of our children had sustained at least one fracture at the time of questioning and that upper limb fractures were the most common site of fracture (71.3% vs. 28.7% for other locations). The prevalence of fractures observed in our study is comparable to the one reported in the Al-Daghri Saudi study [23] where 18.6% of children with a mean age of 14 had a history of fractures. It is also close to the one observed in the Turkish pediatric population aged below 16 which is of 22.6% [5]. However, it is significantly lower than the one observed in Britain (where approximately one third of children sustained at least one fracture before reaching the adult age [2]), Sweden [4] (where it reaches 34%), and New Zealand [7] (where it is approximately 50%). However, in US, just under one in every five children had a fracture throughout childhood and adolescence [6]. The fracture prevalence observed in our population as well as in the Saudi one will be underestimated due to the fact that the mean age of the recruited children are respectively 13.4 and 14 years. This early age may miss fractures that might occur later in life before 18. Further explanatory factors for the lower prevalence of fractures in our population could be different ethnic and cultural



**Fig. 1** Localization of fractures according to sex (in percentages)

**Table 3** Difference in BMI, 25(OH)D levels, and SES between children with and without a history of fracture

	No history of fracture	History of fracture	<i>p</i> value
BMI (percentiles)	60.8 ± 29.87	64.96 ± 28.74	0.096
25(OH)D levels (ng/ml)	19.08 ± 7.30	20.37 ± 6.72	0.017
Socioeconomic status (SES)			<0.0001
Low <sup>a</sup>	399 (86.2%)	64 (13.8%)	
Middle	216 (83.7%)	42 (16.3%)	
High <sup>a</sup>	194 (76.7%)	59 (23.3%)	

BMI (percentiles) and 25(OH)D are reported as mean values and standard deviations. For BMI percentiles, 2000 CDC growth charts data (26) are used as reference

<sup>a</sup> The difference in distribution between the two groups is statistically significant

backgrounds, less risky type of sport activities in Lebanese children keeping them away from mechanical trauma, or the impact of the Mediterranean diet and sun exposure. Parallel to this, it should also be noted that in Lebanese individuals over 50, hip fracture rates are lower than in Northern countries [27] possibly due to ethnic differences. In addition, the higher prevalence of upper limb fractures in our population is in agreement with several pediatric studies across the world, in which the distal forearm represents the most common fracture site, with a frequency varying from 24 to 30% [1–8, 10–12, 28].

We then looked at the gender difference in the frequency and characteristics of fractures. We found that fractures occur more commonly in boys than in girls (22.2% versus 11.1%); a finding also supported by other studies [1–4, 7–11]. Boys were also more prone to multiple fractures, similarly to what has been previously reported; this may be due to the fact that sustaining one fracture increased the risk of sustaining another one [3, 7, 29]. These gender differences may partially be explained by more time dedicated to sports activities in adolescent males [8]. We also observed that fractures occurred at a younger age in girls compared to boys, with a non-significant difference. In several studies, fractures were found to occur earlier in girls (between 9 and 14 years, with a peak at 11 years), whereas in boys, a later and narrower interval of age was observed (13–14 years) [2–4, 7, 8]. This finding is most probably due to the later onset of puberty and growth spurt in boys. In addition, the peak incidence of fractures during the pubertal years has been explained by a discrepancy between height gain and the accrual of bone mineralization [2–5, 28]. During this phase, physiological changes occur in bone mass in response to increased calcium demand, for maximal skeletal growth and mineralization [30, 31]. This leads to a relative decrease in bone mineral density and therefore an increase in fracture occurrence, in particular the distal forearm ones [4, 30]. Finally, we did not find a gender difference in the repartition of fractures (upper vs. lower limb fractures). Contrary to our study, fracture distributions varied with sex in a Turkish study: Girls had more elbow, ankle, and shoulder fractures, whereas boys had more wrist and forearm fractures

[5]. Boys engaging in high-risk contact and competitive sports are probably more prone to upper limb and displaced fractures compared to girls [2–4, 7–9, 12, 17, 32].

We also found that the BMI of children with a positive history of fracture was higher compared to those without any history of fracture, although this difference was at the limit of significance. Previous studies had shown that a higher BMI is associated with an increased risk of sustaining a long bone fracture [1, 15, 17, 19, 33]. There are several reasons for this finding: a reduced bone mass relative to increased BMI, a greater mechanical load when obese/overweight children fall [1, 15], and poorer balance, motor skills and manual dexterity tasks in overweight/obese children [15, 16, 18, 20]. In addition, fat has a detrimental effect on skeletal health particularly during skeletal growth in adolescence; this by inducing hormonal imbalances and disruption of bone growth process [1, 14, 34]. Sedentary lifestyle, often associated with more time spent on television and computer watching, increase risk of wrist and forearm fracture. This is possibly related to reduced muscle strength and altered balance [8, 9, 17] or to an increased consumption of caffeine, sugar and phosphoric acid, compared to calcium rich food [13]. The lack of consistency between our results and other studies might be due either to the limited number of children with fractures in our population or to the fact that BMI was not measured at the time of fracture. Even if vigorous physical activity increases bone mass, it does not offer protection from the high risk of injuries accompanying contact sports [8]. Children, mainly boys, who engage frequently in high risk activities are more prone to fractures [3, 7]. At the opposite, it is often assumed that a sedentary lifestyle would reduce exposure to high level physical activities and therefore reduce fracture rates [8]. This assumption is negated by a case control study published in 2013 [9] which reported a higher rate of wrist fractures associated with more time spent watching television or playing video games.

Additionally, we observed an independent association between high SES and increased fracture risk during childhood

**Table 4** Logistic regression with the presence of fracture as a dependent variable

	Odds ratio	95% CI	<i>p</i> value
Gender			
Male	1	–	–
Female	0.416	[0.312–0.651]	< 0.0001
BMI (percentiles)	1.006	[1.000–1.012]	0.071
Socioeconomic status (SES)			
High	1	–	–
Middle	0.641	[0.409–1.004]	0.052
Low	0.511	[0.328–0.799]	0.003
25(OH) D levels	1.004	[0.976–1.032]	0.805

$R^2$  (McFadden) = 0.04

and adolescence. The relationship between SES and fracture risk has been poorly studied. In fact, Williams et al. found that SES plays a clear role in influencing the nature and extent of risky behaviors of adolescents, and subsequently affects fracture circumstances [35]. Contrary to our study results, in New Zealand, children with lower SES have slightly higher rates of fractures compared with children from a high SES [7]. However, in an Italian study, there was no significant relationship between SES and the risk of fracture [8]. The higher risk of fractures that we observe in high SES children could be due to different risk behaviors or to more time spent in activities carrying higher risks.

We also looked at the independent factors that may explain the occurrence of upper limb fractures. We found that female gender was protective against upper limb fractures whereas BMI played no particular role. In fact, the role of BMI as a determinant of the fracture site (upper vs. lower limb fractures) was not consistently proven. In some studies [1, 9], BMI was not found to affect the anatomic site of fractures while in others [15–17, 19], lower extremity fractures (especially lower leg, ankle and foot) occurred more frequently in overweight/obese children. Differences in body composition were reported in boys according to fracture sites: children with forearm fractures had significantly higher BMI, skinfold thickness and fat percentage z-scores compared to those with upper arm or hand fractures [15].

Finally, 25(OH)D was not found to be independently associated with a history of fracture in our population. In the literature, conflicting results were found regarding the relationship between 25(OH)D and fracture risk. This could be due to different ethnicities or to the relation between vitamin D and time spent outdoors doing sports. In some studies [21–23], a higher number of fractured children were vitamin D insufficient, while in others [24, 25], no association between vitamin D deficiency and increased fracture risk in childhood was seen. The lower vitamin D levels in obese and overweight

children could explain how vitamin D status has an impact on fracture risk [15].

## Limitations

Our study has several limitations. First, the prevalence in our population will be underestimated due to the fact that mean age of the recruited children was 13 years missing 3 to 5 years remaining time to have fractures, depending on whether 16 or 18 years of age is used as the upper limit in the definition of childhood. Second, recall bias may contribute to lower accuracy of collected data. Third, BMI assessment and blood sampling for 25(OH)D measurements were not done at the time when fracture occurred; this finding may impact the relationship between these parameters and the prevalence of fractures. Finally, the effects of diet and physical activity on fracture risks were not studied in our population.

## Conclusion

The present study is the second one to look at the prevalence and characteristics of pediatric fractures in a Middle-Eastern country. The prevalence of fractures recorded in a pediatric Lebanese cohort is 16.9% at a mean age of 13 years [2, 5–7]. The study also found that the predominant site of fractures in both genders is the upper limb and that male gender and higher SES were independently associated with fracture risk.

Further research is needed to evaluate the different mechanisms of injury and type of activities responsible for fractures in our population. In addition, the impact of endocrine and nutritional factors on the prevalence of fractures should be further studied. This may help to implement preventive measures such as child educational programs to promote safe playing strategies.

**Authors' contributions** NY and MA performed the data collection and participate to the writing of the manuscript. AJB performed the statistical analysis and interpreted the results. MHG designed the study, got the funding, and participate to the writing the manuscript. All authors read and approved the final manuscript.

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## Compliance with ethical standards

**Conflict of interest** None.

**Ethics approval and consent to participate** The study was approved by the Ethics Committee of our hospital (Reference number CEHDF449) and Informed consent was signed by the children's parents.

**Abbreviations** BMI, Body Mass Index (BMI); 25(OH)D, 25 hydroxyvitamin D; SES, socioeconomic status.

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