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Abstract

Objective: To assess the strength of the association between suggested risk factors and fracture prevalence in children.

Materials and Method: A cross sectional observational study. Children aged 6 to 15 years and their guardians presenting to the Emergency Department of a single tertiary paediatric hospital were recruited. Self-reported data on vitamin D intake, calcium intake, and physical activity were collected. All participants had a radiograph of their injured limb reported by a consultant radiologist, on the basis of which they were classified into fracture or no fracture groups. Statistical analysis included descriptive statistics and binary logistic regression.

Results: Of the 130 patients recruited, 53 (41%) had sustained a fracture. The overwhelming majority of children (98%) did not consume the recommended daily dietary amount of vitamin D (400 IU/day). Low calcium intake and low levels of physical activity were also ascertained. However, there were no significant differences between fracture and no fracture groups for vitamin D intake, calcium intake or physical activity. Both site of injury (wrist) and sex (males) were associated with increased fracture risk (p=0.001 and p=0.05, respectively). Logistic regression showed a statistically significant relationship between calcium intake and fracture risk (every additional unit of calcium consumption (mg/day) decreased the likelihood of fracture by 0.002, 95% CI, 0.001 - 0.003).

Conclusion: Low dietary intake of calcium and vitamin D and low levels of physical activity were evident. Fracture risk was significantly associated with reduced calcium intake but showed no association with vitamin D intake or physical activity.

Keywords: Children, Fracture, Radiology, Calcium Intake, Vitamin D Intake, Physical Activity

INTRODUCTION

Several epidemiological studies have revealed a substantial increase in the incidence of fractures in children in the past few decades (Cooper et al., 2004; Mathison and Agrawal, 2010; Clark, 2014). Indeed, it has been estimated that around one third of children in the United Kingdom (UK) will suffer from at least one fracture during their childhood (Cooper et al., 2004). While bone health and fracture risk are relatively well understood in the adult population, and in particular in postmenopausal women (Borges and Brandao, 2006), less is understood about this issue in children (Farr et al., 2014). There are several factors that can influence bone health in children including non-modifiable factors such as genetics, age, ethnicity and sex, and modifiable factors such as calcium and vitamin D intake, and physical activity (Golden et al., 2014). Optimising the modifiable factors protects against poor skeletal health and thus reduces fracture risk. For instance, low intake of calcium and milk was found to increase fracture risk (Wyshak and Frisch, 1994; Goulding et al., 2004), while vitamin D supplementation was found to reduce fracture risk (Anderson et al., 2017) in children. In recognition of the importance of vitamin D for skeletal health, the Scientific Advisory Committee on Nutrition (SACN) on vitamin D in the UK has introduced a Reference Nutrient Intake (RNI) of 400 International Units (IU) of vitamin D per day (equivalent to 10 micrograms) for the general UK population aged 4 years and above throughout the year ((SACN), 2016). A final key factor in determining skeletal health is level of physical activity. For example, in a long-running study, a 4-year exercise program was found to increase bone mass (Löfgren et al., 2012).

Although calcium intake, vitamin D and physical activity are important modifiable lifestyle factors for bone health in children, the strength of their impact on fracture risk in children presenting to an Emergency Department (ED) is not clear. A fall on to the outstretched hand for example is a common occurrence; but it is not understood whether there is a difference in any of the modifiable factors between children who subsequently sustain a fracture compared to those who do not. Therefore, the purpose of this study was to determine calcium intake, vitamin D intake and physical activity among children aged between 6 and 15 years attending the Emergency Department (ED) of Sheffield Children's Hospital following injury to their wrist or ankle and to assess the strength of the association between injury outcome (fracture or no fracture) and these modifiable factors.

MATERIALS AND METHODS

This was a non-interventional, prospective, questionnaire-based observational study, with questionnaires administered independently by two researchers in the ED of Sheffield Children's Hospital between March and August 2015. Full patient and guardian assent/consent was obtained prior to enrolment and the study received Local Research Ethics Committee and NHS Research and Development approvals. The inclusion criteria were children aged between 6 and 15 years with no known underlying disease or long-term medication use. They had to be able to speak and read English and they were required to have undergone a wrist or ankle radiograph following acute injury to the relevant site. Patients were not eligible if they had been involved in high-energy trauma (e.g. road traffic accidents, falls from a significant height), because in such circumstances, fracture is more likely to occur regardless of other modifiable factors (Blades et al., 2010). Patients were guided through the questionnaire. Older children (aged 10 years and above) answered the questionnaire themselves, while younger children (aged under 10 years) answered the questionnaire with the aid of their parent(s)/guardian(s). A consultant radiologist with extensive experience in musculoskeletal imaging reported the radiographs, allowing patients to be classified into two groups: "fracture" or "no fracture". The consultant radiologist had no knowledge of the patients' intake of vitamin D and calcium, nor of their level of physical activity.

The questionnaire consisted of four parts. Part 1 related to patient demographics and the mechanism of injury. Patients' age and weight in kilograms were retrieved from their ED notes. Height was recorded to the nearest 0.1cm using a wall-mounted stadiometer. Body mass index (BMI) for each patient was then calculated as weight (kg)/height (m)^2. An age and sex specific BMI chart provided by the Royal College of Paediatrics and Child Health (RCPCH) was used to establish BMI percentiles for children (RCPCH, 2013). Patients' ethnic group was self-reported. Socioeconomic status was determined using the English index of multiple deprivation (IMD) 2015 (Department of Communities and Local Government), extracting patients' postcodes from their ED notes to determine their IMD scores. IMD scores for England are ranked from 1 (most deprived area) to 32,844 (least deprived area). IMD scores below 10,894 are considered areas of low socioeconomic status, IMD scores between 10,895 and 21,788 are considered areas of average socioeconomic status, and IMD scores above 21,789 are considered areas of high socioeconomic status. Site and side of injury were retrieved from patients' ED notes and confirmed by inspecting the imaging request cards/images.

Pubertal stage was established in Part 2 of the questionnaire and was self-reported using the Tanner score (Carskadon and Acebo, 1993). Patients under 10 years old were assumed to have a Tanner stage of 0, because onset of puberty is not expected to occur before this age in apparently healthy girls and boys (Rubin et al., 2009; Sørensen et al., 2012). Parts 1 and 2 of the questionnaire were piloted to ensure that there were no issues with the format and that language was appropriate for children.

Part 3 used two previously validated questionnaires to assess vitamin D and calcium intake. The "validated short food frequency questionnaire" (SFFQ) - specifically designed for children - was used to assess vitamin D intake in IU (Nucci et al., 2013). The patients' daily calcium intake was assessed in milligrams (mg) using the "calcium calculator" created by the International Osteoporosis Foundation (IOF) (IOF, 2015). This calcium calculator is validated and accounts for age and sex of the child.

The final part of the questionnaire used the validated "previous day recall questionnaire" to assess physical activity (Children's Physical Activity Research Group, 2002). This generates a metabolic equivalent of task (MET) score from a table of MET scores provided by the Arnold School of Public Health (Ainsworth et al., 2000). Three variables are generated from this physical activity questionnaire: total MET score, number of 3-5 METS (moderate activity) and number of 6/6+ METS (vigorous activity).

Statistical analysis was carried out using the IBM Statistical Package for the Social Sciences (SPSS), version 23. Descriptive statistics were used to summarise the variables including means and standard deviations. To test for any association between the suggested risk factors and injury outcome, the Chi-squared test was used for categorical variables and an independent t-test for continuous variables. If data were not normally distributed, the non-parametric Mann-Whitney test was used. Finally, binary logistic regression was carried out to calculate odds ratios (ORs) and 95% CIs to assess the impact of individual risk factors on injury outcome. The logistic regression model contained 8 independent variables (vitamin D (IU/day), calcium intake (mg/day), total MET score, number of 3-5 METS (moderate activity), number of 6/6+ METS (vigorous activity), joint affected (wrist, ankle), sex (male, female), age (years). Since 85% of participants were Caucasian, ethnicity did not significantly contribute to the logistic regression model and hence was removed. Similarly, socioeconomic status did not significantly contribute to the logistic regression model and was removed.

RESULTS

A total of 134 interviews (each taking approximately 30 minutes) were conducted. All interviews were carried out while the patient was still in the ED setting. 4 patients were excluded (3 because the radiographs were of sites other than wrist or ankle, 1 because this was a re-attendance for a previously sustained injury). In total then, 130 datasets were analysed. Of the 130 patients, 53 (41%) sustained a fracture. Patient demographics are summarised in Table 1. Patients' age ranged from 6 to 15 years, and 110 (85%) were Caucasian, 19 (14.5%) Asian and only one (0.5%) was Afro-Caribbean. There were no significant differences between fracture and no fracture groups in terms of age (p=0.07) or ethnicity (p=0.23). However, sex was found to be have an impact on injury outcome, with boys sustaining more fractures than girls (p=0.05). The wrist accounted for 90 injuries (69%) and wrist injuries were significantly associated with an increased positive fracture outcome compared to ankle injuries (p <0.001). Among the 130 children recruited, 37 (28.5%) (16 in the fracture group) were from areas of high socioeconomic status, 38 (29.2%) (17 in the fracture group) were from areas of average socioeconomic status and 55 (42.3%) (20 in the fracture group) were from areas of low socioeconomic status. There was no significant difference in the socioeconomic status between the fracture and no fracture groups (p= 0.6). Moreover, there were no significant differences in vitamin D intake (p=0.7), calcium intake (p=0.5) and the level of physical activity (p=0.6) between the three socioeconomic classes.

Table 1: Patient demographics

	Fracture	No Fracture	Total	p value
Number	53	77	130	
Number of boys	36 (28%)	39 (30%)	75 (58%)	0.99
Number of girls	17 (13%)	38 (29%)	55 (42%)	0.73
Mean age in years (SD)	10 (2.5)	11 (2.4)	10.6 (2.5)	0.07
Boys mean age in years (SD)	10.5 (2.5)	11.3 (2.5)	10.9 (2.5)	0.18
Girls mean age in years (SD)	9.2 (2.1)	10.5 (2.3)	10 (2.3)	0.06

A total of 96 (74%) patients from both fracture and non-fracture groups were in the healthy weight range (9th to 90th BMI centile), 17 (13%) were in the 91st to 97th centile, 9 (7%) in the 0.04th to -8.99th centile, 4 (3%) were in the 98th to 99.5th centile and 4 (3%) in the 99.6th centile. There was no significant difference in BMI centile between the two groups (p= 0.7). A pubertal score of 0 was the most common Tanner stage (48%). The distribution of Tanner staging was similar across the two groups (p =0.5).

Mean daily calcium intake for both groups was 713 mg (SD= 283). Overall daily calcium intake was greater in the no fracture group (Figure 1) but did not reach statistical significance (p=0.08). The overwhelming majority of children (98%) did not consume the recommended dietary amount of vitamin D (400 IU/ day), with mean daily vitamin D intake for both groups being 145 IU (SD= 201). Since dietary Vitamin D intake was negatively skewed, the Mann Whitney test was used to investigate any difference between the fracture and no fracture groups. There were no significant difference (p=0.8) in the median vitamin D intake between the two groups (Figure 2).

Most children achieved a low total MET score. The distribution of MET scores was similar between the fracture and no fracture groups (Figure 3). 72 (55%) patients did not attain any 30-minute blocks of 3-5 MET (moderate activity), while 61 (47%) patients did not attain any 30-minute blocks of 6/6+ MET (vigorous activity) during the day before their injury. There was no significant difference between the two groups in terms of total MET (p=0.07), the number of undertaken moderate activities (p=0.8), or the number of undertaken vigorous activities (p=0.08).

Logistic regression was performed to determine the association between 8 explanatory variables and fracture risk. Multicollinearity between the explanatory variables was checked; high correlation was not found between any variables. The logistic regression model indicated that there was a significant relationship between 4 variables (age, sex, site of injury and calcium intake) and fracture risk (Table 2). Site of injury was the strongest predictor of injury outcome (p=0.001), with injury to the wrist being 12 times more likely to cause fracture than ankle injuries. Sex was also a significant predictor of injury outcome (p=0.016). Males were almost 3 times more likely to fracture than females after adjusting for all other variables in the model. The regression model also showed that for every year increase in age, the likelihood of fracture decreases by 0.21 (p=0.016). Every additional unit of calcium consumption (mg/day) was found to decrease the likelihood of fracture by 0.002 (p=0.021).

Table 2: Logistic regression model (8 independent variables)

Variables	p value	OR	95% C.I. for OR	
			Lower	**Upper**
Age (years)	0.016*	0.791	0.653	0.957
Sex (female)	0.032*	2.650	1.087	6.459
Joint (ankle)	0.001*	11.884	3.442	41.028
Total MET score	0.862	0.996	0.949	1.045
Moderate activity	0.994	0.999	0.799	1.249
Vigorous activity	0.341	0.864	0.639	1.168
Calcium intake (mg/day)	0.021*	0.998	0.997	0.999
Vitamin D intake (IU/day)	0.174	1.002	0.999	1.004

Variables were considered significant predictors for fracture if p value <0.05.
* indicates a significant p value
OR = odds ratio

DISCUSSION

The present study indicates that among three modifiable factors for bone health, namely vitamin D intake, calcium intake, and physical activity, only one (calcium intake) has a small but statically significant association with reduced risk of fractures. However, there were significant associations between the non-modifiable factors, sex and site of injury. We showed that girls were less prone to have an injury and, if injured, less likely to fracture (boys' relative risk of fracture was approximately 3 times that of girls). This finding is consistent with the literature, which indicates that boys are more prone to fracture (Khosla et al., 2003; Cooper et al., 2004; Clark, 2014). While this may be due to the fact that males are more inclined towards dangerous activities which then increases their risk of injury and fractures as a result of high impact accidents (Rennie et al., 2007), we specifically excluded children who attended following major trauma, suggesting that it is the tendency towards risky behaviour rather than the severity of the trauma that is important. Socioeconomic status may have a role in determining fracture risk, as children from deprived areas potentially have an unhealthier diet and may be less engaged in sports activities. However, we found no significant differences in vitamin D intake, calcium intake and physical activity between children from the most deprived areas and children from least deprived areas neither was there an association between socioeconomic status and injury outcome.

It has previously been concluded that upper limb fractures are more prevalent than lower limb fractures in children and adolescents (Mathison and Agrawal, 2010; Rennie et al., 2007). Our study showed that injury to the wrist is 12 times more likely to be associated with fracture than injury to the ankle. This probably reflects the different mechanisms of injury of the wrist and ankle: the majority of wrist injuries occur as a result of falls onto an outstretched hand, conferring significantly more force to the wrist than that conferred to the typical ankle injury (most commonly an inversion injury).

As expected, the mean calcium intake in the fracture group was lower than in the no fracture group (Figure 1). However, this did not reach statistical significance (p=0.08), which may reflect our relatively small sample size. In the regression model, for each additional unit of calcium intake (mg/day), the likelihood of fracture decreased by 0.002 when controlling for all other variables. This finding needs to be further investigated in a larger study. The low calcium intake may increase the risk of future fracture (Bachrach, 2001), particularly in the fracture group, given that Manias et al. (2006) found lower calcium intake among children with recurrent fractures.

Similarly, we found that children did not consume the recommended amount of dietary vitamin D, with no significant differences between children in the fracture and no fracture groups. The low dietary vitamin D intake may be partially mitigated because sunlight is a major source of vitamin D; however, vitamin D synthesis from sunlight depends on several factors including local climate, time of day, age, skin pigmentation and sunscreen use (Lips et al., 2014). The recent introduction of 400 IU of daily vitamin D as the reference nutrient intake (RNI) by SACN highlights the importance of adequate vitamin D intake. Although the SACN recommendation is 200 IU below the recommendation of the Institute of Medicine (IOM) in the United States (Prentice, 2008), the average daily vitamin D intake in both groups in our study was similar and well below even the SACN guideline levels. Based on our results, we conclude that as far as the skeletal effects of isolated low vitamin D are concerned (none of our patients showed radiographic rickets and we excluded patients with known underlying disease), increased fracture risk does not appear to be an issue.

Physical activity has been proven to increase bone mass, thus reducing fracture risk (Tan et al., 2014). Therefore, we sought to establish whether this impacts upon the outcome of injury. For all three measures of exercise within this study, (total MET score, 3-5 METS and 6/6+ METS), there were no significant differences observed between the two groups.

We have shown no major association between these modifiable factors and fracture risk, however, our results should be interpreted with caution, since any associations (particularly between calcium intake and fracture risk) may become significant in a larger sample size.

Apart from the sample size, the further limitation of this study was the questionnaire format, which may have introduced bias in terms of dietary and exercise recall, with parents/patients overestimating their consumption of healthy foods and physical activity (Cade et al., 2002). It is also possible (but less likely) that values were underestimated. However, a questionnaire design was felt to be the most pragmatic and (using the results from this study), we can now power a larger definitive study, in which food intake and exercise can be recorded prospectively in relevant diaries or perhaps even on an app. To improve the robustness of our results, all questionnaires used have previously been validated in children.

To conclude, although a majority of children and adolescents were below recommended guidelines for exercise levels and vitamin D and calcium intake, only increased calcium intake showed a small but statistically significant relationship with reduced fracture risk.

Declaration of Conflicting Interests:

The authors have no conflicting interests to declare.

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Figures:

Fig. 1 Calcium intake by group

Fig. 2 Vitamin D intake by group

Fig 3. Distribution of the Total MET's Score intake among the two groups