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Association between upper extremity fractures and weight status in children

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Introduction

Upper extremity fracture (UEF) is a common pediatric injury resulting in substantial morbidity^{1–10} with annual costs estimated to exceed \$2 billion dollars in the United States.^{11,12} The forearm is the most common location of UEF in childhood, and fracture rates appear to be increasing.¹³ The highest rates of forearm fracture in childhood are present in the 5 to 14 years of age group.¹¹

The prevalence of overweight is also increasing in children. The relationship between pediatric overweight and overall injury risk has been well described. For instance, overweight children have 15% to 48% increase in odds of sustaining an injury compared to their normal weight peers.¹⁴ Not only do overweight children have higher rates of injury, they also have increased severity of injuries,¹⁴ longer lasting effects from those injuries,¹⁵ and increased post-operative complications¹⁶ in the treatment of injuries compared to non-overweight children.

Overweight children may also have an increased risk of fracture. Although childhood bone mass density (BMD) may be increased in overweight children¹⁷, several factors may counteract the “protective” effect of a higher BMD in this population. Overweight children have poorer balance and impaired mobility in comparison to their non-overweight counterparts which is likely to increase the risk of falling and exposure to fall-related injury, including fracture.¹⁸ Additionally, overweight children fall with greater force at low-fall heights than normal weight children which may also increase risk for fracture.¹⁹ Specifically, the non-weight bearing upper extremity may be a location that is particularly vulnerable to fracture when subject to an increased weight load during a fall.

A relationship between obesity and risk of UEF has been recognized in adult populations. Obese adult patients may be predisposed to specific injury patterns during trauma such as

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lower risk of head injury and an increased risk of UEF.^{20,21} A study of adolescents and young adults ages 11 to 20 years of age also demonstrated a predisposition to specific injury patterns related to obesity.²² However, in this study, while obesity was associated with a lower risk of head injury, there was no increased risk of extremity fracture for obese patients. There are no comparable studies of the relationship between weight status and UEF in younger children focusing on the specific age group (5–14 years) in which the highest rates of UEF are noted.

Our objective was to determine the relationship between weight status and UEF in children 5 to 14 years of age in comparison to three age-matched control groups without UEF. The three control groups represent two groups with injuries that were not UEFs and one non-injured group with medical illnesses. Weight status was evaluated using weight for age/sex percentiles as a proxy for body mass index (BMI). We hypothesized that the odds of having an increased weight status would be significantly greater among those patients with UEF compared to controls.

Materials and Methods

This study represents secondary analyses of data from two national studies which were collected for the purpose of developing the Pediatric Risk of Admission Scales (PRISA and PRISA II)^{23,24}. These are severity of illness scores for pediatric emergency department (ED) patients which provide the probability of hospital admission as a measure of illness severity. The details of the methodology used to create the PRISA data set are described in the original publications.^{23,24} A brief summary of the data set is given below.

PRISA contains data from 3273 patients from five academic hospitals with pediatric emergency departments (EDs). Two patients per day were randomly selected from ED arrival logs in the academic year 1998–1999. PRISA II contains data from 11,664 randomly selected pediatric patients from 16 US EDs selected to broadly represent variable volumes and the presence of pediatric specialists and residents in a 2³ factorial design with duplication. For 375 consecutive days starting January 1, 2000, the hospital records of two patients per day from each site were randomly selected for historical, laboratory, radiologic, and clinical data abstraction.

From these two databases, we selected the following study and control groups from patients without chronic illness between the ages of 5 to 14 years: 1) UEF study group, 2) upper extremity non-fracture (UEnF) injured control group, 3) minor head injured control group and 4) non-injured control group. The UEF group included patients with a radiographic diagnosis of an upper extremity fracture, as indicated by documentation of a hand xray or arm xray with fracture. The upper extremity non-fracture injured control group included patients with upper extremity injuries and a negative hand xray or arm xray. In both groups, the “hand” location included injuries to the phalanges, metacarpals and/or carpals and the arm location included injuries to the radius, ulna and/or humerus. The minor head injured control group included patients with a minor head injury indicated by a diagnosis of “concussion,” “closed head injury,” “minor head injury” and “head contusion”. Finally, the non-injured control group included patients with a diagnosis of “fever” or “upper respiratory infection”. Because each patient could have up to three diagnoses listed, it was possible for a patient to be included in more than one group.

All chronic diseases were excluded except asthma, gastroesophageal reflux disease and psychiatric illness. Additional inclusion criteria were the presence of medical record documentation of date of birth, weight and sex.

Weight status was evaluated using weight for age/sex percentiles as a proxy for BMI. As heights were not systematically recorded, BMI could not be calculated. The weight for age/sex percentile was calculated for each patient based on Centers of Disease Control growth chart values. Weight for age/sex percentile provides a percentile ranking of a child's weight in comparison to US children of the same age and sex.²⁵ Patients with weight for age/sex percentiles greater than twice the 95th percentile or less than twice the 5th percentile were not included in the final analysis. Data was stratified by age (5–9 years and 10–14 years) to delineate prepubescent and peripubescent groups.

The proportions of patients with weight for age/sex >50th, 85th and 95th percentiles were determined for each stratified age group. Analysis of variance and Tukey's test were used to analyze the differences in mean age, gender and race among the study groups within each age category. Statistical analysis was complete using logistic regression to generate odds ratios for each weight for age/sex percentile comparing the UEF group to each control group. A Mantel Haenszel estimate of the summary odds ratio was determined for the UEF study group and the upper extremity non-fracture injured control group to adjust for injury location.

Data analysis was performed with SPSS Statistics 17.0 (SPSS Inc., Chicago, IL).

The study was approved by our Institutional Review Board.

Results

A total of 762 out of 14,937 patients were eligible for inclusion in the study based on diagnostic criteria and age. Of these patients, 518 patients were eligible for inclusion in the study based on documentation criteria. After excluding 3 patients with weight for age/sex percentiles greater than twice the 95th percentile or less than twice the 5th percentile, there were 515 patients included in the analysis. This final analysis included 308 patients in the 5 to 9 year age group and 207 patients in the 10 to 14 year age group. Because multiple discharge diagnoses were listed (i.e. "closed head injury" and "upper respiratory infection"), one patient in the 5 to 9 year age group was included in both the minor head injured control group and the non-injured control group. Similarly, two patients in the 10 to 14 year age group were included in both the UEnF group and the minor head injured control group.

Demographics for each study group are summarized in Table 1. In the 5–9 year age category, the proportion of males in the minor head injury group was significantly larger than the proportion of males in the UEnF group ($p < 0.05$). There were otherwise no significant differences in mean age in months, proportion of males or proportion of white patients among the study groups within each age category. Specific injury location for UEF group and the upper extremity non-fracture study groups is detailed in Table 2.

The proportions of patients with weight for age/sex >50th, 85th and 95th percentiles were determined for each group stratified by age (5 to 9 years and 10 to 14 years). The odds ratio of weight for age/sex >50th percentile comparing the UEF group to each control group are displayed in Table 3. The odds of having a weight >50th percentile for age/sex were significantly increased among children with UEF aged 5 to 9 years compared to both of the injured and to the non-injured control groups. There were no significant differences in the corresponding odds ratios for children with UEF aged 10 to 14 years compared to controls.

The odds ratio of weight for age/sex >85th percentile comparing the UEF group to each control group are displayed in Table 4. The odds of having a weight >85th percentile for age/sex were not significantly increased among children with UEF aged 5 to 9 years compared to all control groups. The odds of having a weight >85th percentile for age/sex were

significantly increased among children with UEF aged 10 to 14 years compared only to the non-extremity injured control group. There was no significant difference in the corresponding odds ratio for children with UEF aged 10 to 14 years compared to the other control groups.

Finally, the odds ratio of weight for age/sex >95th percentile comparing the UEF group to each control group are displayed in Table 5. The odds of having a weight >95th percentile for age/sex were not significantly increased among children with UEF aged 5 to 9 years or 10 to 14 years compared to injured and non-injured control groups.

Discussion

Our study sought to determine the odds of having an increased weight status among patients with UEF compared to three control groups without fractures in the age ranges at highest risk for fracture. We examined two different age groups; prepubescent (5 to 9 years) and peripubescent (10 to 14 years) children. Overall, our study demonstrates a consistent and significantly increased odds of having a weight >50th percentile for age/sex among patients with UEF in the 5 to 9 year age group compared to all three control groups. There were no such significant associations for children in this age group with weights >85th or 95th percentiles. Finally, the only significant association between weight and increased odds of fracture in the 10 to 14 year age group was for children with UEF compared to those with minor head injuries.

Interestingly, the increased odds of having increased weight status seen in the prepubescent population was not as clearly demonstrated in the peripubescent population. There are several potential explanations for these results. First, these findings may be related to differential injury mechanisms between age groups. Specifically, younger children may be more likely to engage in activities placing them at increased risk for UEF related to increased weight status. For instance, fractures resulting from a fall onto an outstretched hand and/or from a height may be more influenced by the weight of the patient compared to fractures resulting from direct trauma. Data to evaluate this hypothesis is limited. However, data does demonstrate that children aged 5–9 years have the highest number of playground falls resulting in ED visits²⁶ and the highest rates of hospitalization related to playground equipment falls.²⁷ Falls from playground apparatus such as “monkey bars” are recognized as common mechanisms resulting in UEF in children.¹

Second, these findings may also reflect age-related variation in mobility patterns. Many pediatric studies demonstrate that physical activity decreases with advancing age during childhood.^{28–30} Decreased levels of physical activity may decrease exposure to injury and subsequently reduce risk for UEF compared to the other control injuries evaluated in our study. Further details are needed regarding the mechanisms resulting in UEF in childhood, stratified by age, to better understand the role of both factors in UEF risk.

Finally, these findings may represent differential vulnerability to fracture related to bone characteristics in prepubescent versus peripubescent populations. It is known that the qualities of bone change as children progress into puberty and adolescence but it is less defined how these variations related to fracture risk. For instance, areal BMD in puberty accumulates at both the lumbar spine and femoral neck levels four- to six-fold over a 3- and 4-year period.³¹ However, during the same pubertal period, the ratio of cortical to trabecular bone volume decreases transiently starting at mid-puberty (12 to 14 years). Although there are clear differences in bone mineral content, further research is necessary to elucidate how these regional deficits in cortical bone and associated reduction in areal BMD³² may influence UEF risk and specifically be influenced by weight status.³³

Our study did not demonstrate significantly increased odds of elevated weight status in the highest weight for age percentiles (i.e. > 85th percentile or >95th percentile) compared to injured and non-injured control groups. The small sample sizes in the analysis may have limited its ability to discern significant associations in these subgroups. The one exception to these results was the significantly increased odds of having a weight >85th percentile for age/sex among 10 to 14 year old children with UEF compared to the control group with minor head injuries. The significance of this isolated finding is unclear given the small sample size of this control group. Of note, in the 5–9 year old age group, all the odds ratios of having an elevated weight status >85th, and >95th percentiles comparing those children with UEFs to controls, while not significant, were >1.

Consistent with our results, adult studies have also demonstrated a pattern of decreased fracture risk associated with the highest ranges of BMI. This may be related to a decrease in exposure to injury resulting from decreased levels of physical activity which may subsequently reduce risk for UEF as discussed above. Several pediatric studies support an inverse relationship between physical activity and a BMI for age at the 85th percentile or higher.^{34,35}

The major limitation of this study is that, because heights were not systematically recorded in the database, BMI could not be calculated. Instead, we determined weight for age/sex percentiles based on 2000 CDC growth charts and utilized this measure to evaluate increased weight status. These growth charts consist of a series of percentile curves that illustrate the distribution of selected body measurements, including weight, height and head circumference in U.S. children.²⁵ Pediatric growth charts, originally developed in 1977 by the National Center for Health Statistics (NCHS), have been used by health care professionals as a clinical tool to determine if the growth of a child is adequate. The 2000 CDC growth charts represent the revised version of the 1977 NCHS growth charts.²⁵

Although growth charts remain widely used in pediatric practice, BMI measurement, not weight for age/sex percentile, is the standard measure of overweight as defined by the CDC.³⁶ However, the CDC describes growth charts as “tools that contribute to forming an overall clinical impression for the child being measured”.²⁵

Conclusions

In conclusion, our study demonstrates that the odds of having a weight >50th percentile for age/sex were significantly increased among a nationally representative sample of children with UEF aged 5 to 9 years compared to injured and non-injured control groups. There was no significant difference in the corresponding odds ratio for children with UEF aged 10 to 14 years. These findings may be related to differential injury mechanisms, mobility patterns, or underlying patient vulnerability to fracture based on weight status and bone qualities in prepubescent versus peripubescent populations.

Further investigation should explore fracture epidemiology and fracture risk in children stratified by age. Although most fractures are believed to occur in childhood due to falls and other injuries, further research is needed to evaluate underlying skeletal fragility which may be related to increased weight status, particularly in prepubescent children with UEF. Finally, these data provide additional rationale for aggressively addressing overweight among prepubescent children.

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Table 1

Demographic characteristics of study groups

Age Group	Variable	UEF	UEnF	Minor head injury	Non-injury
5–9 years	n	47	49	73	139
	Mean age in months ($\pm$ SD)	91 (17.9)	90 (19.4)	87 (15.8)	84 (16.0)
	Proportion of males (%)	21/47 (45%)	19/49* (39%)	47/73* (64%)	79/139 (57%)
	Proportion of white race patients (%)	17/47 (36%)	16/49 (33%)	26/73 (36%)	36/139 (26%)
10–14 years	n	67	64	30	46
	Mean age in months ($\pm$ SD)	148 (17.4)	144 (16.6)	145 (18.2)	141 (16.5)
	Proportion of males (%)	42/67 (63%)	35/64 (55%)	15/30 (50%)	27/46 (59%)
	Proportion of white race patients (%)	30/67 (45%)	30/64 (47%)	10/30 (33%)	15/46 (33%)

* In the 5–9 year age category, the proportion of males in the minor head injury group was significantly larger than the proportion of males in the upper extremity non-fracture (UEnF) group ($p < 0.05$). There were otherwise no significant differences in mean age in months, proportion of males or proportion of white patients among the study groups within each age category.

Table 2

Summary of specific injury location for upper extremity fracture (UEF) and upper extremity non-fracture study (UEnF) groups

Age group	Injury Location	UEF	UEnF
5–9 years	Hand	12/47 (26%)	34/49 [*] (69%)
	Arm	35/47 (74%)	17/49 [*] (35%)
10–14 years	Hand	24/67 (36%)	42/64 ^{**} (65%)
	Arm	43/67 (64%)	26/64 ^{**} (41%)

* Two patients in this group had injuries to both the hand and arm.

** Four patients in this group had injuries to both the hand and arm.

Table 3

Odds Ratio of weight for age/sex > 50th percentile for children with UEF compared to age-matched control groups

Age group	Variable	UEF vs upper extremity non-fracture injury	UEF vs minor head injury	UEF vs non- injured control group
5–9 years	Proportion of weight for age/sex >50th percentile in UEF (%)	42/47 (89%)	42/47 (89%)	42/47 (89%)
	Proportion of weight for age/sex >50th percentile in control groups (%)	34/49 (69%)	51/73 (70%)	86/139 (62%)
	Odds Ratio (95% CI)	4.56 * (1.30–16.04)	3.62 (1.26–10.39)	5.18 (1.92–13.90)
10–14 years	Proportion of weight for age/sex >50th percentile in UEF (%)	41/67 (61%)	41/67 (61%)	41/67 (61%)
	Proportion of weight for age/sex >50th percentile in control groups (%)	48/64 (75%)	19/30 (63%)	34/46 (74%)
	Odds Ratio (95% CI)	0.48 * (0.22–1.04)	0.91 (0.37–2.22)	0.56 (0.24–1.26)

* Mantel Haenszel estimate of the summary odds ratio to adjust for injury location.

Table 4

Odds Ratio of weight for age/sex > 85th percentile for children with UEF compared to age-matched control groups

Age group	Variable	UEF vs upper extremity non-fracture injury	UEF vs minor head injury	UEF vs non-injured control group
5–9 years	Proportion of weight for age/sex >85th percentile in UEF (%)	21/47 (45%)	21/47 (45%)	21/47 (45%)
	Proportion of weight for age/sex >85th percentile in control groups (%)	16/49 (33%)	22/73 (30%)	51/139 (37%)
	Odds Ratio (95% CI)	1.92 * (0.77–4.79)	1.87 (0.87–4.01)	1.39 (0.71–2.72)
10–14 years	Proportion of weight for age/sex >85th percentile in UEF (%)	27/67 (40%)	27/67 (40%)	27/67 (40%)
	Proportion of weight for age/sex >85th percentile in control groups (%)	31/64 (48%)	5/30 (17%)	17/46 (37%)
	Odds Ratio (95% CI)	0.70 * (0.34–1.42)	3.38 (1.15–9.91)	1.15 (0.53–2.49)

* Mantel Haenszel estimate of the summary odds ratio to adjust for injury location.

Table 5

Odds Ratio of weight for age/sex > 95th percentile for children with UEF compared to age-matched control groups

Age group	Variable	UEF vs upper extremity non-fracture injury	UEF vs minor head injury	UEF vs non-injured control group
5–9 years	Proportion of weight for age/sex >95th percentile in UEF (%)	13/47 (28%)	13/47 (28%)	13/47 (28%)
	Proportion of weight for age/sex >95th percentile in control groups (%)	12/49 (24%)	13/73 (18%)	25/139 (18%)
	Odds Ratio (95% CI)	1.66 * (0.60–4.59)	1.76 (0.73–4.24)	1.74 (0.80–3.77)
10–14 years	Proportion of weight for age/sex >95th percentile in UEF (%)	14/67 (21%)	14/67 (21%)	14/67 (21%)
	Proportion of weight for age/sex >95th percentile in control groups (%)	18/64 (28%)	3/30 (10%)	8/46 (17%)
	Odds Ratio (95% CI)	0.62 * (0.27–1.43)	2.38 (0.63–8.99)	1.25 (0.48–3.29)

* Mantel Haenszel estimate of the summary odds ratio to adjust for injury location.