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Original Research

# Do Forearm Fracture Characteristics and Outcomes Differ Between Obese and Non-Obese Children?

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**Abstract**

**Background:** Nearly one-third of children and adolescents are overweight or obese in the United States. This study aimed to explore the difference in injury characteristics and treatment outcomes between forearm fractures in children based upon weight status.

**Methods:** Four hundred and sixty-eight skeletally immature children sustaining forearm fractures between 2017-2019 were retrospectively reviewed. Demographics, injury characteristics, treatment methods, and complications were reviewed. Patients were analyzed by weight group: underweight, normal weight, overweight, and obese as defined by body mass index (BMI) percentile for age. Analyses were performed on dichotomized groups: underweight and normal weight (UN) versus overweight and obese (OO).

**Results:** The median age at injury was 10 years. The distribution of BMI categories was 4.1% underweight, 56.2% normal weight, 16.2% overweight, and 23.5% obese. OO individuals were less likely to have angulated (>10 degrees) fractures in any plane (34% vs. 45%) and less likely to require closed reduction (27% vs. 37%) compared to their UN peers. Those with an acceptable cast index (less than 0.8), regardless of weight, trended towards lower rates of loss of reduction compared to those with poor cast index (17% vs. 29%). No statistically significant differences were found in rates of open fracture, low energy mechanism, operative treatment, loss of reduction, or complications between OO and UN children.

**Conclusions:** Overweight and obese children sustain forearm fractures that are less angulated and require closed reduction at a lower rate. There are no differences in rates of open fracture, low energy mechanism, operative treatment, loss of reduction, or complications between overweight and normal-weight children treated for forearm fractures.

**Level of Evidence:** Level III – Retrospective Cohort Study

**Key Concepts**

- In our cohort, obese children were less likely to sustain an angulated forearm fracture greater than 10 degrees.
- Obese children underwent closed reduction at a lower rate.
- Both obese and non-obese children had an acceptable cast index 75% of the time.
- No statistically significant differences were found in rates of open fracture, low energy mechanism, operative treatment, loss of reduction, or complications between OO and UN children.

## Introduction

Childhood obesity is a national epidemic in the United States. The most recent Center for Disease Control (CDC) data demonstrates that 19.3% of all youth in the United States are classified as obese and 16.1% are overweight based on body mass index (BMI).[1,2] In pediatric populations, forearm fractures involving the radius and/or ulna are the most common long bone fractures, accounting for 40% of all fractures.[3] Biomechanical studies have shown that obese children may be at higher risk for forearm fractures from low energy mechanisms, particularly falls from standing height.[4] The literature on forearm fractures in obese children has demonstrated that overweight and obese children have different fracture characteristics than their normal-weight peers. Li et al. found that obese children more commonly fracture the distal third of the forearm and that obesity may be protective against open fractures; their data did not demonstrate an increase in complication rates or failure of closed treatment.[5] Auer et al. found that obese children undergoing closed reduction of forearm fractures had higher rates of malreduction and more than double the rate of closed reduction in the operating room compared to their normal-weight peers.[6] Several other studies have found a higher rate of treatment failure in obese children with forearm fractures treated nonoperatively.[7,8] The purpose of the study was to further evaluate differences in injury characteristics, treatment regimens, and outcomes in children sustaining forearm fractures stratified by weight status. Additionally, we investigated the relationship of weight to cast quality, as measured by cast index, and to rates of treatment failure. Our primary hypothesis was that OO patients would have higher rates of treatment failure and would require operative treatment more frequently based on criteria published in the existing literature.

## Materials and Methods

After obtaining approval from the Institutional Review Board, we identified all patients aged 2-18 years old who presented to our institution with a diagnosis of a radius and/or ulna fracture between 2017 and 2019. The initial cohort included 610 patients. A total of seven orthopaedic surgeons were involved in the treatment of these patients. Patients with undocumented height or weight, incomplete follow-up (less than 6 weeks), or underlying bone pathology (e.g., osteogenesis imperfecta, malignancy) were excluded. Patients who were skeletally mature based on initial imaging were excluded. After exclusions, 468 children met criteria for inclusion (Figure 1). Data from initial presentation, subsequent interventions, and clinic follow-up was retrospectively reviewed.

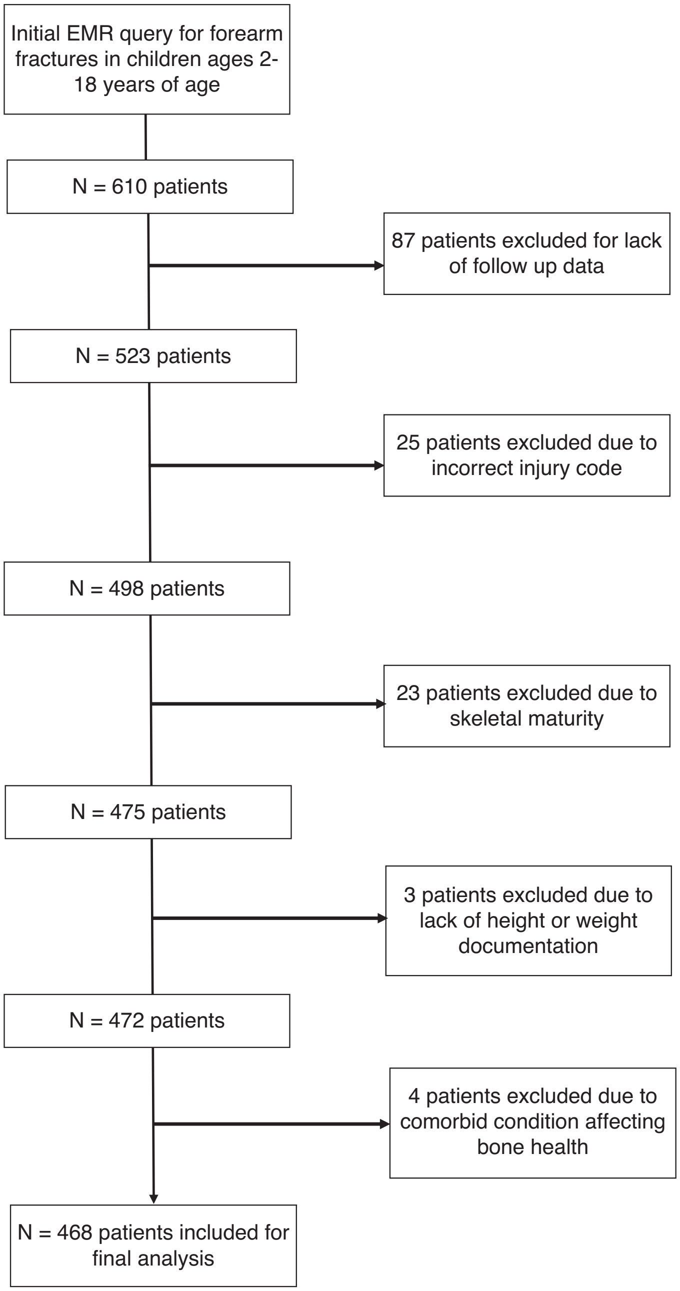


***Figure 1.*** *Initial cohort of patients with exclusion criteria applied.*

Demographic information including age, sex, and body mass index was reviewed. Patients were classified into BMI categories based on ideal BMI percentile for age. A BMI for age greater than 85th percentile was classified as overweight, greater than 95th percentile as obese, and less than 5th percentile as underweight, based upon the guidelines for ideal BMI from the CDC's Expert Committee on childhood obesity.[9] For purposes of this analysis, the weight groups were dichotomized as underweight/normal weight individuals and overweight/obese individuals. Injury characteristics were collected including mechanism of injury, location of fracture (proximal, middle, or distal third), and Salter-Harris type, if physeal. Mechanisms of injury were further divided into high and low-energy mechanisms with high-energy mechanisms comprising motor vehicle collisions, pedestrian versus auto, and downhill activities (skiing, skateboarding, etc.). Low energy mechanisms included ground level falls, playground injuries, and team sports injuries. Our primary outcomes included the need for closed reduction of forearm fracture, need for operative treatment, and failure of initial treatment method (defined as loss of reduction, repeat closed reduction, or unplanned change in treatment plan).

Common indications for closed reduction and casting in the emergency department (ED) included fractures angulated greater than 10 degrees in any plane, malrotation compared to contralateral side by more than 30 degrees, or lack of bony apposition of fracture ends.[10] Post-reduction radiographs were obtained in the ED. Patients not requiring reduction did not receive repeat radiographs in the cast during their initial evaluation to limit the radiation exposure during their treatment course. The decision for long or short arm casting was based on patient age and fracture location. Institutional guidelines for long arm casting included patients aged less than 5 because these patients may be more likely to slip out of a short arm cast. Diaphyseal fractures were also treated in long arm casts to limit the amount of prono-supination in the cast. Additional treatment, including operative intervention or repeat closed reduction in the operating room, was under the discretion of one of seven attending orthopaedic surgeons. All forearm fractures treated at our institution were included regardless of the treating attending's fellowship training. A patient was deemed to have failed initial management if they had loss of reduction requiring additional intervention, including repeat closed reduction, cast wedging, or operative intervention. Loss of reduction was defined as angulation >10 degrees, malrotation >30 degrees, and loss of bony apposition on follow-up radiographs.

Cast index was measured on anteroposterior (AP) and lateral images of the wrist and or forearm when available. Cast index is calculated by measuring the inner width of a cast on a sagittal place radiograph and dividing this value by the inner width on a coronal plane radiograph.[11] An acceptable cast index was defined as a ratio less than 0.8. Only those patients who underwent reduction of their fracture had a post-casting radiograph during their initial evaluation. Patients not requiring a reduction were casted in situ and no post-casting radiographs were taken.

Patients were followed until clinical union as defined by the absence of pain with palpation at the fracture site or with motion of adjacent joints. Follow-up radiographs were also used to monitor fracture healing.[12] Treatment complications, total number of radiographs, and need for formal physical therapy were recorded. The indication for physical therapy referral was at the treating surgeon's discretion. Treatment complications included cast saw burns, skin irritation, persistent pain or stiffness beyond 90 days after injury, clinical deformity, and refracture. In addition, the length of treatment or immobilization was recorded for all patients.

Median (quartiles: Q1, Q3) were used to summarize continuous variables and frequencies. Percentages were used to summarize categorical variables. Chi-square or Fisher's exact test was used to compare univariable differences in categorical outcomes between the 2 BMI class variables. Wilcoxon test was used to compare univariable continuous outcomes. A multivariable logistic regression analysis was used to evaluate associations while adjusting for age, BMI, sex, race, and mechanism of injury to confirm independent associations of BMI and outcomes. Two-sided p-values <0.05 were deemed statistically significant.

## Results

There were 468 patients eligible for the analysis. The median age at injury was 10 years (Q1, Q3: 6, 12). Most patients were male (61%) and white (69%). Distribution of BMI categories was as follows: 4.1% underweight, 56.2% normal weight, 16.2% overweight, and 23.5% obese. In this cohort, fractures involved the radius only in 63% of cases, the ulna in 3% of patients, and both bones in 34%. The cohort's fracture characteristics and outcomes are summarized in Table 1.

Overweight and obese individuals were less likely to sustain fractures with angulation greater than 10 degrees in any plane at the time of presentation (34% vs. 45%, p=0.020, Table 1). These results remained consistent in multivariable analyses adjusted for other factors (OR 0.60, 95% CI, 0.41-0.89, Table 2). OO children were less likely to require closed reduction of their fracture compared to underweight and normal-weight individuals (27% vs. 37%, p=0.020, Table 1). This also remained consistent after adjusting for other factors (OR 0.59, 95% CI, 0.39-0.90, Table 2). Of children who did not undergo a reduction with an initial angulation greater than 10 degrees (35/189), the majority were distal fractures (86%), and there was no difference between OO and UN children. OO children also required fewer radiographs (Median (IQR): 3(4) vs. 4 (5), p=0.03, Table 1). No significant differences were found in the overall rate of complications between OO and UN children (12% vs. 16%, p=0.90, Table 1). No significant differences were found between OO and UN groups for the type of complication including stiffness (5% vs. 3%), skin complications such as cast saw burns or skin irritation (5% vs. 5%), and clinical deformity or refracture (2% vs. 8%) (p=0.17, Table 1). No significant differences were found in the rate of physeal fracture between the UN and OO groups in either univariable or adjusted analyses (17% vs. 18%, OR 1.09, 95% CI, 0.66-1.81, Table 1 and Table 2).

Our primary outcomes included the need for closed reduction of an angulated forearm fracture, need for operative treatment, and failure of initial treatment method (defined as loss of reduction, repeat closed reduction, or unplanned change in treatment plan). There were no significant differences in the rate of operative treatment between the UN and OO groups in univariable

**Table 1. Univariable Associations of Fracture Characteristics and Outcomes Between Weight Groups**

| | Normal/Underweight (n = 282) | Obese/overweight (n =186) | *P* |
|---|---|---|---|
| **Fracture Characteristics** | | | |
| Mechanism of Injury (%) | | | 0.36 |
| Low Energy | 256 (90.8) | 164 (88.2) | |
| High Energy | 26 (9.2) | 22 (11.8) | |
| Bones involved | | | 0.38 |
| Radius | 172 (61.0) | 124 (66.7) | |
| Ulna | 8 (2.8) | 3 (1.6) | |
| Radius & Ulna | 102 (36.2) | 59 (31.7) | |
| Physeal Injury n (%) | | | 0.80 |
| Yes | 49 (17.3) | 34 (18.2) | |
| No | 233 (86.7) | 152 (81.8) | |
| Location | | | 0.057 |
| Distal | 245 (87) | 172 (92) | |
| Midshaft | 37 (13) | 14 (8) | |
| Angulation n (%) | | | **0.02** |
| Greater than 10 degrees | 126 (44.7) | 63 (33.9) | |
| Less than 10 degrees | 156 (55.3) | 123 (66.1) | |
| **Outcomes** | | | |
| Closed Reduction n (%) | | | **0.02** |
| Yes | 104 (36.8) | 50 (26.9) | |
| No | 178 (63.2) | 136 (73.1) | |
| Operative n (%) | | | 0.51 |
| Yes | 45 (16.0) | 34 (18.2) | |
| No | 237 (84.0) | 152 (81.8) | |
| Initial Treatment Method Failure n (%) | | | 0.92 |
| Yes | 22 (7.8) | 15 (8.1) | |
| No | 260 (92.2) | 171 (91.9) | |
| **Follow-up** | | | |
| Number of x-rays taken Median (Q1, Q3) | 4 (2, 7) | 3 (2, 6) | **0.03** |
| Length of treatment (wks) Median (Q1, Q3) | 6 (4, 8) | 6 (5, 8) | 0.84 |
| Complications n (%) | | | 0.90 |
| Yes | 16 (5.7) | 12 (5.9) | |
| No | 266 (94.3) | 174 (94.1) | |

**Table 1. Continued**

| | Normal/Underweight (n = 282) | Obese/overweight (n =186) | *P* |
|---|---|---|---|
| Complication Type n (%) | | | 0.17 |
| Stiffness | 3 (18.8) | 5 (41.7) | |
| Skin | 5 (31.3) | 5 (41.7) | |
| Deformity/Refracture | 8 (50.0) | 2 (16.7) | |

*Significant values in bold. Table comparing findings of injury and treatment characteristics between the two weight groups. Values are represented as number and percentage in parentheses (%). Median (Q1, Q3) are used to summarize continuous patient characteristics. Non-parametric tests such as Wilcoxon Rank-rum test, Chi-sq test, or Fisher's exact test were used to compute univariate p-values as appropriate.*

**Table 2. Adjusted Associations of Fracture Characteristics and Outcomes Between Weight Groups**

| Fracture Characteristic | Odds Ratio (95% CI) | *P* |
|---|---|---|
| High-Energy Mechanism | 1.37 (0.73, 2.48) | 0.34 |
| Both Bone Fracture | 0.79 (0.52, 1.18) | 0.25 |
| Physeal Injury | 1.09 (0.66, 1.81) | 0.73 |
| Distal vs. Midshaft | 1.68 (0.85, 3.31) | 0.13 |
| Greater than 10 Degrees of Angulation | 0.60 (0.41, 0.89) | **0.01** |
| **Outcomes** | | |
| Closed Reduction Performed | 0.59 (0.39, 0.90) | **0.01** |
| Operative Treatment | 1.18 (0.72, 1.94) | 0.50 |
| Treatment Failure | 1.01 (0.51, 2.00) | 0.98 |

*Odds ratios compare odds of each outcome for Overweight/Obese compared to Normal/Underweight. Significant values in bold. P-values were calculated with multivariable logistic regression model for each outcome with predictors of BMI class, age (>10), sex, and race (white vs. other). Odds ratios for adjusters of age, sex, and race are not reported.*

or adjusted analyses (16% vs. 18%, OR 1.18, 95% CI 0.72-1.94, Table 1). Of the 79 patients who were treated in the operating room, those who were overweight or obese had a higher incidence of surgical treatment involving closed reduction and percutaneous pinning (CRPP) or open reduction and internal fixation (ORIF) versus closed reduction alone in comparison to underweight/normal individuals (41% vs. 31%). However, this difference did not reach statistical significance (p=0.35).

Cast index has been previously shown to be protective against a loss of reduction when treating fractures nonoperatively.[11] There was no difference in the percentage of patients with an acceptable cast index (less than 0.8) between the two weight groups. In total, 178 patients had the necessary radiographs in a cast, enabling a measurement of cast index. Those with an acceptable cast index were less likely to have loss of reduction compared to those with poor cast index (17% vs. 29%);

however, this may be due to chance alone, as this difference did not reach statistical significance (p=0.09).

## Discussion

Understanding the unique challenges that arise when treating fractures in overweight and obese children has become increasingly important as the world's obesity epidemic becomes more prevalent. Additionally, weight status has serious implications for all phases of care from the emergency department to the operating room; previous anesthesia literature has shown obese children to be at higher risk for adverse cardiorespiratory events from both procedural sedation[13] and general anesthesia.[14] In our cohort, the data suggest that overweight and obese children may be at a lower risk of sustaining angulated fractures and as a result, a lower rate of requiring closed reduction. The difference may be due to the force-dissipating soft tissue envelope surrounding the radius and ulna. Despite previous findings suggesting otherwise, we did not find that overweight and obese patients more commonly sustain forearm fractures from low-energy mechanisms.[15] Additionally, there was no statistically significant difference in rates of surgical intervention (CRPP or ORIF) between the UN and OO groups. The findings of our study are contrary to previously published studies that demonstrate higher rates of malreduction, loss of initial reduction, failure of nonoperative management, and need for additional intervention in obese children.[4-8]

Differences in study design between this study and previous studies may account for the contrasting findings. Of these studies, only one reported on cast index. Auer et al. found there was no difference in cast index between obese and non-obese children who failed nonoperative management with an average cast index of 0.85 and 0.82, respectively, but did not measure cast index subjects that had successful nonoperative management.[6] Their data suggests that regardless of weight status, an unacceptable cast index was associated with treatment failure. Additionally, our study only reports on clinical outcomes rather than radiographic outcomes, which may account for some differences in results.

An acceptable cast index was defined as a cast index less than 0.8 as measured on post-casting AP and lateral radiographs of the forearm and/or wrist. Both UN and OO groups had the same rate of acceptable initial cast indices at 75%. The difference in rates of unplanned changes in treatment, repeat closed reduction, and post-treatment complications were not statistically significant between the groups. We theorize that if OO children are treated in a properly placed cast (cast index <0.8), they may not be at an increased risk for closed treatment failure or complications.

Our study was limited by the retrospective nature of the data and that all patients were seen and treated at a single medical center. A large portion of patients were excluded due to incomplete documentation, which decreased the overall power of the study. Many patients (62%) did not have radiographs in their initial cast, particularly when no formal reduction was performed. This limited our ability to draw conclusions about the importance of cast index in closed management of forearm fractures in the overweight or obese child. Although there are protocols at our institution for treatment of these injuries, there are inherent differences in treatment and clinical decision-making when involving multiple treating surgeons; this may have introduced biases within the data. Ultimately, the decision for repeat reduction or further intervention is at the discretion of the treating surgeon, though this was based on similar tolerances for acceptable reduction as previously defined in this study. Additionally, this study does not report on final radiographic parameters at the conclusion of fracture treatment.

In conclusion, obese and overweight children sustained less angulated fractures of the forearm and required closed reduction at a reduced rate in comparison with underweight and normal-weight peers. In contrast to other previous studies,[4-8] overweight and obese children were not at increased risk for physeal fracture, malreduction, loss of reduction, or post-treatment complications after sustaining forearm fractures.

## Additional Links

- OrthoInfo: Impact of Childhood Obesity on Bone, Joint, and Muscle Health
- AAOS Information Statement: Obesity and Musculoskeletal Care

## Disclaimer

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