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Associations between childhood obesity and upper and lower extremity injuries

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Abstract

Objectives—To estimate the overall and age-specific associations between obesity and extremity musculoskeletal injuries and pain in children.

Methods—This cross-sectional study used information from electronic medical records of 913 178 patients aged 2–19 years enrolled in an integrated health plan in the period 2007–2009. Children were classified as underweight, normal weight, overweight, or moderately/extremely obese and, using multivariable logistic regression methods, the associations between weight class and diagnosis of upper or lower extremity fractures, sprains, dislocations and pain were calculated.

Results—Overweight (OR 1.18, 95% CI 1.15 to 1.20), moderately obese (OR 1.24, 95% CI 1.20 to 1.27) and extremely obese (OR 1.34, 95% CI 1.30 to 1.39) children had statistically significantly higher odds of lower extremity injuries/pain compared to normal weight, adjusted for sex, age, race/ethnicity and insurance status. Age-stratified analyses yielded similar results. No consistent association was observed between body mass index and injuries/pain of the upper extremities.

Conclusions—Greater body mass index is associated with increased odds of lower extremity injuries and pain issues. Because the benefits of physical activity may still outweigh the risk of injury, attention should be paid to injury prevention strategies for these children at greater risk for lower extremity injuries.

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Patient consent This study was exempt from consent requirements as it was observational only, using only data collected as part of routine healthcare encounters.

Ethics approval Ethics approval was provided by the Kaiser Permanente Southern California Institutional Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Information on the KPSC Children's Health Study is available at: <http://www.kp-scalresearch.org/Research/research.aspx>. Because the information contained in electronic health records is protected and confidential, it can be extremely difficult to exchange or share individual-level information. Therefore, individual-level information from several sources is usually managed, analysed and aggregated at the KPSC data center for projects with external collaborators. Active collaborations are welcome and the principal investigator of the study (CK) can be contacted for more information.

INTRODUCTION

Injury and obesity, two concurrent, but not necessarily coincident health issues challenge today's youth. In the USA, obesity rates are increasing rapidly among children and adolescents,¹² putting greater numbers of youth at risk for long-term health problems such as diabetes and cardiovascular conditions. These youth are also disproportionately affected by unintentional injuries, which ultimately cause more deaths in this age group than all other causes combined.³ Unintentional falls are the leading cause of non-fatal injuries and emergency department visits in this group.³

Several studies have documented associations between obesity and increased risk of musculoskeletal injury,^{4–6} particularly fractures,^{5,6} sprains,⁴ and lower extremity injuries.⁴ In addition, studies have observed that large proportions of overweight or obese children experience musculoskeletal pain, particularly back, knee and hip pain.^{7–9} Overweight and obese children may be less likely to participate in vigorous physical activity, which may be a cause of the overweight, or a result of being overweight. Some musculoskeletal injuries, particularly those that require a period of immobility or restricted activity, may then become an additional barrier to continuing or beginning physical activity, contributing to further weight gain.⁸

The incidence and types of injuries may also vary with the magnitude of overweight and obesity. Although several studies provide strong evidence that childhood obesity increases the risk for injuries,^{4, 5, 8, 10} most studies are not able to provide stable population-based estimates based on the degree of obesity. The aim of the present study was to evaluate the association of increasing weight with injuries occurring in specific body regions in a large population-based cohort of children and adolescents.

METHODS

Study design and subjects

For this cross-sectional study, we used a subset of patients enrolled in a large population-based cohort study, the Kaiser Permanente Southern California (KPSC) Children's Health Study 2007–2009.^{11, 12} The KPSC Children's Health Study includes more than 920 000 children and adolescents aged 2–19 who are enrolled as members of Kaiser Permanente Southern California, an integrated healthcare system serving a large, racially-diverse, ethnically-diverse and socioeconomically-diverse population. This cohort has been studied previously in investigations of obesity prevalence,¹² psoriasis,^{13,14} and obesity and gastroesophageal reflux disease.¹⁵

During the 3-year enrolment period for the present study (1 January 2007 through to 31 December 2009) KPSC provided coverage and care for 1 295 971 children and adolescents aged 2–19 years. After exclusion of 265 241 members who did not have any medical encounters during the study period, 1 030 730 patients were eligible for inclusion. Of these patients, 920 034 (89.2%) had at least one valid weight and height during the 3-year study period. After exclusion of patients who were pregnant (n=6856), 913 178 patients were included in the final cohort.

The study protocol was reviewed and approved by the Institutional Review Board of KPSC.

Exposure: weight class

Weight class was determined during the year in which an individual entered the study. Body weight and height measurements that were recorded on the same day during a healthcare encounter were abstracted from the electronic health records. Body mass index (BMI) was

calculated as weight in kg divided by the square of the height in m. For patients with multiple healthcare encounters (n=746 066, 81.7%) during their initial year in the study, median BMI-for-age was used in the analyses. A previous validation study of rules for identifying height and weight errors in the medical record reported a reduction of errors to 0.4% after removal of implausible height and weight values.¹⁶ These same rules were applied to the present study.

Definitions for overweight and obesity in children and adolescents are based on a combination of sex-specific BMI-for-age growth charts developed by the Centers for Disease Control (CDC) and WHO definitions for overweight and obesity in adults.^{17–19} We used a combination of the BMI-for-age categories and the adult classification to more accurately categorise the older adolescents who might be classified differently by the two systems (eg, be classified as overweight by the child/adolescent standards and obese by the adult standards). Children were categorised as underweight (BMI-for-age <5th percentile), normal weight (BMI-for-age 5th and <85th percentile), overweight (BMI-for-age 85th and <95th percentile or BMI 25 kg/m² and <30 kg/m²), moderately obese (BMI-for age 95th and <1.2×95th percentile or BMI 30 kg/m² and <35 kg/m²) and extremely obese (BMI-for age 1.2×95th percentile or BMI 35 kg/m²).

Outcomes: upper and lower extremity injuries and pain

We examined electronic health records of inpatient, outpatient and emergency department encounters for the first occurrence of an *International Classification of Diseases*, 9th edition (ICD-9) code for relevant injuries for each cohort member during the year of study enrolment. Healthcare encounters for lower extremity injuries and pain issues were identified and classified using the following codes: 820–829.1 (fracture of lower limb), 835–838.19 (dislocations of hip, knee, ankle, foot), 843–845.19 (sprains or strains of hip, thigh, knee, ankle, foot) and 719.45–719.47 (pain in lower extremities).

Encounters for upper extremity injuries and pain issues were identified and classified using these codes: 810–819.1 (fractures of upper limb, including clavicle and scapula), 831–834.1 (dislocation of shoulder, elbow, wrist, finger), 840–842.19 (sprains or strains of shoulder, upper arm, elbow, forearm, wrist, hand) and 719.41–719.44 (pain in shoulder, upper arm, forearm, hand).

Potential confounders

We included age at study entry, race and ethnicity, and socioeconomic status in the multivariable models as potential confounders of the relationship between weight class and injury. Age for each patient was obtained from enrolment records and was categorised as 2–5, 6–11, or 12–19 years. These groupings were chosen to reflect preschool, elementary school and middle/high school groups. We expected that within these school-based age groupings in-school and after-school activities would be most homogenous, even considering the relative breadth of the age groups. Race and ethnicity information were obtained from health plan administrative records and birth certificates. We categorised race/ethnicity as non-Hispanic White, Hispanic White, Black (regardless of ethnicity), Asian or Pacific Islander, other or multiple race/ethnicity and unknown due to missing information. A validation study compared race and ethnicity from health plan administrative records and birth certificate records of 325 810 children.²⁰ The positive predictive value for Hispanic ethnicity was 95.6%. Positive predictive value for White, Black, Asian/Pacific Islander and other was 89.3%, 86.6%, 73.8% and 1.2%, respectively. Details are described elsewhere.^{11,12}

Two measures of socioeconomic status were assessed as potential confounders. Neighbourhood education was estimated based on the linkage of health plan member's addresses with US census block data.²¹ Participation in Medi-Cal, the California state-subsidised programme providing healthcare coverage for low-income children and families as well as older, blind, or disabled individuals was determined from administrative records in the year of study enrolment.

Statistical analysis

Basic demographic characteristics were summarised and described using counts and proportions. Differences in the distribution of these factors across weight class were assessed with the χ^2 test.

The associations between weight class (underweight, normal weight (reference), overweight, moderate obesity, extreme obesity) and injuries were assessed using multiple logistic regression models to estimate ORs and 95% CIs. All models were adjusted for sex (male vs female), race (non-Hispanic White, Hispanic, Black, Asian or Pacific Islander, Other/Unknown), age and Medi-Cal benefit use (yes vs no).

Age was also considered as a potential effect modifier. We speculate that because of physiologic differences and differences in the types and intensities of activities in which children are engaged at different ages, the associations between weight class and injuries might be different by age. Analyses of upper and lower extremity injuries were stratified by age and possible interactions between age and weight class were examined using likelihood ratio tests. In all analyses, an α level of 0.05 was used to determine statistical significance. All analyses were conducted using SPSS release V.18.0 (SPSS, Chicago, Illinois, USA).

RESULTS

The prevalence of patients who were underweight, normal weight, overweight, obese and extremely obese in our cohort was 3.0%, 60.4%, 17.4%, 13.0% and 6.2%, respectively. Patients who were overweight, moderately or extremely obese were more likely to be older ($p<0.001$), male ($p<0.001$) and Hispanic or Black ($p<0.001$), than those of normal weight (table 1). Higher proportions of Medi-Cal enrollees were in the moderately obese group (15.1%) or extremely obese group (14.5%) than in the normal weight group (12.8%). And compared to non-Medi-Cal enrollees, Medi-Cal enrollees were less likely to sustain lower extremity injuries (4.8% vs 6.0%, $p<0.001$) and upper extremity injuries (4.2% vs 5.2%, $p<0.001$).

Lower extremities

Lower extremity injuries or pain were identified in 53 026 patients (5.8% of the total cohort). Fractures occurred in 8629 patients (16.2% of those with lower extremity injuries); 30 197 (56.9%) had a sprain or strain of the hip, thigh, knee, ankle, foot; 2047 (3.9%) had a dislocation of the hip, knee, ankle, foot; and 20 704 (38.9%) patients had pain in the lower extremities.

Overall, the risk of having a lower extremity injury or pain issue of any sort increased as BMI increased (table 2). After adjustment for sex, age, race/ethnicity and Medi-Cal benefit status, patients who were extremely obese were 1.3 times as likely to have had any injury or pain of the lower extremities as compared to their normal weight counterparts (OR 1.34; 95% CI 1.30 to 1.39; p for trend <0.001). Similarly, greater body mass index was positively associated with lower extremity fractures, sprains/strains and pain, with risk increasing stepwise with increasing BMI. However, the while overweight, moderately obese and extremely obese classes were all associated with greater risk of lower extremity dislocations,

compared to normal weight subjects, the magnitude of the risk did not increase with each increase in BMI (overweight OR 1.51, 95% CI 1.35 to 1.68; moderately obese OR 1.50, 95% CI 1.33 to 1.70; extremely obese OR 1.47, 95% CI 1.25 to 1.72). Underweight children and adolescents were at reduced risk for sustaining any lower extremity injury or pain condition (OR 0.61, 95% CI 0.57 to 0.66), as well as having reduced risk for each of the specific lower extremity injury and pain categories (table 2).

To evaluate whether the association between body weight and injuries and pain of the lower extremities was modified by age, we repeated our analyses stratified by age group (2–5 years, 6–11 years, 12–19 years) (table 3). In the overweight and moderately obese groups, the children aged 6–11 years had the greatest increase in risk of all injuries and pain, except for dislocations. In the extremely obese group, and for dislocation injuries, it is the youngest children with the greatest increase in risk. Overall, the age-specific risk estimates are similar enough to each other within BMI categories to suggest that similar conclusions may be drawn across age groups: that as BMI increases above normal, risk for lower extremity injuries increases. The absolute risk, however, for lower extremity injuries and pain was consistently highest in the oldest age group with 1.3% of 2–5-year-olds, 3.9% of 6–11-year-olds and 9.5% of 12–19-year-olds having lower extremity injury or pain.

Upper extremities

Upper extremity injuries or pain were identified in 46 486 patients (5.1% of the total cohort). Fractures occurred in 22 265 patients (47.9% of the group with upper extremity injuries); 17 858 (38.4%) had a sprain or strain of the shoulder, upper arm, elbow, forearm, wrist, hand; 3104 (6.7%) had a dislocation of the shoulder, elbow, wrist, finger; and 10 546 (22.7%) patients had pain in the upper extremities (table 4).

Overall, moderately obese and extremely obese children appear to either be at reduced risk or have risk for upper extremity injuries similar to normal weight children (table 4), while overweight children appear to be at slightly increased risk for sprains/strains (OR 1.09, 95% CI 1.05 to 1.13), dislocations (OR 1.11, 95% CI 1.01 to 1.22) and pain (OR 1.09, 95% CI 1.04 to 1.15).

In the age-stratified analyses, the patterns of risk were less consistent across injury types than for lower extremity injuries. Within age groups, the youngest children, age 2–5, were at increasing risk for fracture with increasing BMI (see table 5). The extremely obese 2–5-year-olds were 28% more likely to sustain a fracture compared to normal weight peers (OR 1.28, 95% CI 1.03 to 1.57). Within the oldest age group, subjects in all BMI groups were less likely to sustain fractures than their normal BMI peers, with the lowest risk being among the extremely obese (OR 0.63, 95% CI 0.58 to 0.69). Within the underweight group, all age groups were at either reduced risk for all injury types, or had risk similar to the normal BMI comparison group. As seen with lower extremity injuries, the absolute risk of upper extremity injuries and pain was consistently highest in the oldest age group with 2.4% of 2–5-year-olds, 4.6% of 6–11-year-olds and 6.9% of 12–19-year-olds having lower extremity injury or pain.

DISCUSSION

In this study, we found that moderately obese children have almost 25% and extremely obese 35% more injuries of the lower extremities than normal weight children. The association between obesity and injuries was strongest for fractures, sprains/strains and dislocations of the lower extremities. We did observe some variation in the magnitude of risk across age groups, but the overall conclusions remained consistent, suggesting that age did not appreciably modify the associations to warrant age-specific recommendations. These

associations between degree of obesity and injuries of the lower extremities were not observed for injuries of the upper extremities.

Previous studies have indicated an increased risk of injuries, specifically extremity injuries and pain issues for obese children and adolescents compared to non-obese children.^{4–6,22–24} Among children admitted to a level-1 trauma centre, 55% of the obese children had sustained an extremity fracture compared to 40% of the non-obese children (p value <0.001),⁵ even while sex, injury severity and trauma mechanism were similar across the two groups. Overweight and obese children and adolescents injured in motor vehicle crashes were observed to have a 2.5-fold increase in risk of extremity injury compared to normal weight peers also involved in crashes, with more distal injuries associated with greater BMI.⁶ In a small cohort of children enrolled in paediatric clinical trials, the overweight children were 4.5 times as likely to have sustained a fracture compared to normal weight peers (OR 4.5, 95% CI 1.6 to 13.2) and were 4.0 times as likely to have documentation of musculoskeletal pain in their medical records (OR 4.0, 95% CI 1.5 to 10.6).²³ However, in a recent study of children and adolescents who presented at a paediatric emergency department of a level-1 trauma centre, the obese children were 2.3 times as likely to have sustained a sprain (OR 2.25, 95% CI 2.04 to 2.47), but were not more likely to have sustained fractures (OR 1.08, 95% CI 1.00 to 1.16) than their normal weight peers.⁴ In the Pomerantz *et al* study, however, investigators categorised children as obese or non-obese based on age-specific and sex-specific body weight charts; they were not able to calculate BMI, which may have resulted in misclassification, and thus biasing of results towards the null.

In our study, BMI was available for a very large cohort of children and adolescents including a large number of extremely obese, resulting in an ability to estimate associations between injuries and the degree of excessive body weight. More importantly, we have been able to estimate the associations between injury types and the degree of increased body mass index, compared to their normal weight peers. Our findings clearly suggest that for all lower extremity injury types there is an increased risk in patients who were overweight, moderately obese and extremely obese. In fact, with the exception of dislocations, this injury risk appears to increase in a very linear fashion.

Our results for upper extremity injuries are less consistent, and seem to suggest no associations between greater BMI and increased risk for injury. These findings may actually make sense when we consider that many of the hypothesised explanations for the increased susceptibility to injuries among obese children focus on biomechanics and are related to load-bearing on bones and joints. Hypothesised mechanisms include: decreases in bone density related to decreased activity levels in overweight and obese children; obesity-induced changes in biomechanical alignment and function of joints; greater loads imposed on bones and joints with increased weight; changes in gait and balance common in overweight and obese persons.^{8, 22, 24–26} We observed minimal or no association between body weight and upper extremity fractures—injuries of non-weight-bearing bones—which may lend credence to these biomechanical explanations or to different modes of injury. Additionally, while increased weight is associated with increased bone mineral density, and decreased activity is associated with decreased bone mineral density, it has been hypothesised that bone development may not be able to keep pace with increased weight.²⁷ Regardless, bone density that has been affected by decreased physical activity or by bone development that is overtaken by rapidly increasing weight, may contribute to a skeleton that is more susceptible to injuries from falls, collisions and crashes (whether sports related or not).

Our study is subject to some important potential limitations. First of all, this is a cross-sectional study, and as such, we are unable to assert any degree of causation from our results. We are not able to conclude that overweight or obesity lead to the injuries or caused them in any way. We can only state that the two factors are related in some way. Additionally, the manner in which we determined a subject's race and ethnicity may lead to some misclassification, especially for less common subgroups and where we needed to rely on health records, which may not have been based on patient self-report, or on imputation using surname lists and address information from the US Census.

Our method of injury ascertainment was also subject to limitations. We classified each child as having an injury outcome based upon the presence of a relevant diagnosis code in the electronic health record. We looked only for the first apparent injury event during the study period and, therefore, did not take into account repeat or multiple injuries. It is unlikely that overweight or obese children had visits for possible injuries coded in a systematically different manner than their normal weight or underweight peers. Therefore, this is unlikely to affect the validity and generalisability of our results. We also did not assess potential differences in injury severity, treatment settings, or differences in course of care, nor did we assess these factors for potential confounding effects on the association between weight class and extremity injury.

We were also not able to incorporate any information about exposure to risk for injury. Many of these children were likely injured during sports or physical education activities, but we do not have information about the magnitude of those exposures. Obese children do appear to be at greater risk for sustaining lower extremity injuries, and these injuries may come while also simultaneously being less physically active than their lower BMI peers. Therefore, the risk 'per exposure' may actually be greater than the 35% observed in our study.

Finally, our study also excluded nearly 200 000 children and adolescents who had not had a healthcare encounter during the study period. These children were somewhat different from the subjects who were included in our study in that they tended to be older (57.4% of the excluded were aged 12–19 years vs 45.7% of the cohort members), were of unknown or 'other' race (24.5% vs 13.6%), and were less likely to be on Medi-Cal (4.0% vs 13.3%). We do not know the distribution of BMI for this group nor for certain their injury status (they may have had injuries treated elsewhere), so it is difficult for us to speculate about how their inclusion or exclusion might have affected our results and conclusions.

In conclusion, our study suggests that increasing BMI is associated with increased risk of lower extremity injuries and pain issues in children and adolescents, but not necessarily with upper extremity injuries. Obese children may be less likely to engage in physical activities in general, and this moderate increase in risk of injuries should not serve to discourage increased activity. Additionally, some children were likely injured during sports activities. Ultimately, though, the benefit of increased activity may still outweigh the risks of injury, especially if appropriate attention is paid to injury prevention strategies for these children at greater risk for injury.

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What is already known on this subject

- Obesity and lower extremity injuries appear to be associated, though the mechanism remains unclear.
- Previous studies, however, have compared only obese and non-obese children.

What this study adds

- In the present work we have a population-based cohort of over 900 000 children and adolescents for which we have detailed BMI measurements, allowing us to estimate the association between magnitude of overweight/obesity and injury likelihood for a number of injury types.
- We are also able to estimate age-specific risks in a racially-diverse and economically-diverse patient population.

Table 1

Demographic characteristics of the study population according to weight class*

	Underweight n=27447, n (%)	Normal weight n=551 676, n (%)	Overweight n=159 064, n (%)	Moderately obese n=118 789, n (%)	Extremely obese N=56 202, n (%)	p Value
Male	14 063 (51.2)	268 912 (48.7)	78 337 (49.3)	65 728 (55.3)	32 109 (57.1)	<0.001
Age group						
2–5 years	11 818 (43.1)	162 171 (29.4)	30 093 (18.9)	22 648 (19.1)	5284 (9.4)	<0.001
6–11 years	6303 (23.0)	149 355 (27.1)	47 019 (29.6)	42 057 (35.4)	19 100 (34.0)	
12–19 years	9326 (34.0)	240 150 (43.5)	81 952 (51.5)	54 084 (45.5)	31 818 (56.6)	
Race/ethnicity						
Non-Hispanic White	6920 (25.2)	130 514 (23.7)	30 933 (19.4)	17 743 (14.9)	7165 (12.8)	<0.001
Hispanic	11 155 (40.6)	259 833 (47.1)	86 497 (54.4)	72 344 (60.9)	34 918 (62.1)	
Black	1874 (6.8)	40 699 (7.4)	12 075 (7.6)	8375 (7.1)	5348 (9.5)	
Asian or Pacific Islander	3451 (12.6)	42 801 (7.8)	8706 (5.5)	5515 (4.6)	1932 (3.4)	
Other/unknown	4047 (14.7)	77 829 (14.1)	20 853 (13.1)	14 812 (12.5)	6839 (12.2)	
Medi-Cal	3151 (11.5)	70 667 (12.8)	21 394 (13.4)	17 946 (15.1)	8136 (14.5)	<0.001

* Definition of weight class: underweight was defined BMI-for-age 5th percentile, overweight as BMI-for-age 85th percentile or a BMI 25 kg/m², moderate obesity as 95th percentile or a BMI 30 kg/m² and extreme obesity 1.2×95th percentile or a BMI 35 kg/m².

BMI, body mass index.

Table 2

Multivariable model for lower extremity injuries and pain by body weight class

	Injury type				
	All injuries/pain, N=53 026	Fracture, N=8629	Sprain or strain, N=30 197	Dislocation, N=2047	Pain, N=20 622
Weight class					
Underweight	0.61 (0.57 to 0.66)	0.85 (0.73 to 0.99)	0.51 (0.46 to 0.56)	0.59 (0.39 to 0.88)	0.63 (0.56 to 0.71)
Normal weight	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Overweight	1.18 (1.15 to 1.20)	1.18 (1.12 to 1.25)	1.18 (1.15 to 1.22)	1.51 (1.35 to 1.68)	1.15 (1.10 to 1.19)
Moderately obese	1.24 (1.20 to 1.27)	1.22 (1.15 to 1.30)	1.25 (1.20 to 1.29)	1.50 (1.33 to 1.70)	1.18 (1.13 to 1.23)
Extremely obese	1.34 (1.30 to 1.39)	1.40 (1.29 to 1.51)	1.37 (1.32 to 1.43)	1.47 (1.25 to 1.72)	1.24 (1.18 to 1.31)
Age group					
2–5 years	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
6–11 years	3.01 (2.95 to 3.21)	2.40 (2.22 to 2.60)	3.82 (3.59 to 4.07)	7.26 (4.09 to 12.88)	2.95 (2.75 to 3.16)
12–19 years	7.72 (7.44 to 8.03)	3.48 (3.23 to 3.75)	10.46 (9.90 to 11.08)	73.69 (42.71 to 127.12)	8.23 (7.73 to 8.77)
Sex					
Male	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Female	0.84 (0.83 to 0.86)	0.59 (0.57 to 0.62)	0.83 (0.81 to 0.85)	0.79 (0.73 to 0.86)	1.00 (0.97 to 1.03)
Race/ethnicity					
Non-Hispanic White	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Hispanic	0.69 (0.67 to 0.70)	0.61 (0.58 to 0.64)	0.70 (0.68 to 0.72)	0.67 (0.60 to 0.74)	0.70 (0.68 to 0.72)
Black	0.94 (0.91 to 0.97)	0.81 (0.75 to 0.88)	1.03 (0.98 to 1.07)	1.02 (0.87 to 1.19)	0.86 (0.81 to 0.90)
Asian or Pacific Islander	0.63 (0.61 to 0.66)	0.54 (0.48 to 0.60)	0.71 (0.67 to 0.75)	0.69 (0.56 to 0.84)	0.54 (0.50 to 0.58)
Other/unknown	0.66 (0.64 to 0.69)	0.56 (0.52 to 0.60)	0.67 (0.64 to 0.70)	0.46 (0.39 to 0.54)	0.70 (0.67 to 0.74)
Medi-Cal					
Yes	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
No	1.03 (1.00 to 1.06)	1.06 (0.99 to 1.13)	1.05 (1.01 to 1.09)	1.29 (1.10 to 1.51)	0.98 (0.94 to 1.03)

Data shown as OR (95% CI).

Table 3
Age-stratified multivariable model* for lower extremity injuries and pain by body weight class

	Weight class			p Value		
	Underweight (n=27 447)	Normal weight (n=551 676)	Overweight (n=159 064)	Moderately obese (n=118 789)	Extremely obese (n=56 202)	Interaction
All injuries/pain (n=53 026)						
2-5 years (n=2918)	0.87 (0.72 to 1.04)	1.0 (reference)	1.06 (0.95 to 1.18)	1.22 (1.09 to 1.38)	1.87 (1.55 to 2.26)	<0.001
6-11 years (n=10 404)	0.77 (0.65 to 0.90)		1.25 (1.19 to 1.32)	1.32 (1.25 to 1.40)	1.55 (1.45 to 1.67)	<0.001
12-19 years (n=39 704)	0.53 (0.48 to 0.58)		1.15 (1.12 to 1.18)	1.19 (1.15 to 1.22)	1.26 (1.21 to 1.31)	<0.001
Fracture (n=8629)						
2-5 years (n=825)	1.00 (0.73 to 1.36)	1.0 (reference)	1.01 (0.81 to 1.25)	1.22 (0.97 to 1.53)	2.20 (1.53 to 3.09)	<0.001
6-11 years (n=2338)	1.01 (0.75 to 1.36)		1.48 (1.33 to 1.65)	1.57 (1.40 to 1.75)	2.12 (1.85 to 2.42)	<0.001
12-19 years (n=5466)	0.74 (0.60 to 0.91)		1.01 (0.81 to 1.25)	1.04 (0.96 to 1.13)	1.12 (1.01 to 1.24)	0.001
Sprain or strain (n=30 197)						
2-5 years (n=1224)	0.85 (0.64 to 1.13)	1.0 (reference)	1.08 (0.91 to 1.28)	1.25 (1.05 to 1.50)	2.05 (1.55 to 2.71)	<0.001
6-11 years (n=5514)	0.63 (0.50 to 0.79)		1.25 (1.17 to 1.35)	1.30 (1.21 to 1.40)	1.54 (1.40 to 1.69)	<0.001
12-19 years (n=23 459)	0.44 (0.39 to 0.50)		1.16 (1.12 to 1.20)	1.21 (1.16 to 1.26)	1.31 (1.25 to 1.37)	<0.001
Dislocation (n=2047)						
2-5 years (n=13)	2.64 (0.31 to 22.23)	1.0 (reference)	1.61 (0.32 to 8.06)	3.09 (0.76 to 12.60)	3.68 (0.43 to 31.55)	0.874
6-11 years (n=116)	No cases		1.26 (0.78 to 2.03)	1.54 (0.96 to 2.48)	1.37 (0.69 to 2.70)	0.027
12-19 years (n=1918)	0.57 (0.38 to 0.87)		1.48 (1.33 to 1.66)	1.50 (1.32 to 1.71)	1.43 (1.22 to 1.69)	<0.001
Pain (n=20 622)						
2-5 years (n=1046)	0.80 (0.58 to 1.10)	1.0 (reference)	1.02 (0.85 to 1.22)	1.09 (0.89 to 1.33)	1.60 (1.16 to 2.20)	<0.001
6-11 years (n=3619)	0.85 (0.67 to 1.09)		1.17 (1.07 to 1.28)	1.24 (1.13 to 1.35)	1.31 (1.16 to 1.48)	<0.001
12-19 years (n=15 957)	0.56 (0.49 to 0.65)		1.13 (1.08 to 1.18)	1.16 (1.10 to 1.21)	1.20 (1.13 to 1.27)	<0.001

* ORs (95% CI) are adjusted for sex (male vs female), race (non-Hispanic White, Hispanic, Black, Asian or Pacific Islander, Other/unknown race), age and Medi-Cal benefit use (yes vs no).

Table 4

Multivariable model for upper extremity injuries and pain by body weight class

	Injury type				
	All injuries/pain, N=46 486	Fracture, N=22 265	Sprain or strain, N=17 858	Dislocation, N=3104	Pain, N=10 546
Weight class					
Underweight	0.81 (0.76 to 0.86)	0.79 (0.72 to 0.87)	0.69 (0.62 to 0.78)	1.14 (0.95 to 1.35)	0.88 (0.77 to 1.01)
Normal weight	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Overweight	1.03 (1.00 to 1.06)	0.97 (0.94 to 1.01)	1.09 (1.05 to 1.13)	1.11 (1.01 to 1.22)	1.09 (1.04 to 1.15)
Moderately obese	1.00 (0.97 to 1.03)	0.94 (0.90 to 0.98)	1.05 (1.00 to 1.10)	0.93 (0.82 to 1.04)	1.06 (1.00 to 1.12)
Extremely obese	0.89 (0.85 to 0.92)	0.79 (0.75 to 0.84)	0.97 (0.91 to 1.03)	0.69 (0.56 to 0.84)	0.95 (0.88 to 1.03)
Age group					
2–5 years	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
6–1 years	1.95 (1.89 to 2.01)	2.23 (2.14 to 2.33)	4.31 (4.00 to 4.62)	0.09 (0.07 to 0.10)	2.39 (2.19 to 2.61)
12–19 years	2.95 (2.86 to 3.04)	2.30 (2.20 to 2.39)	7.73 (7.22 to 8.28)	0.44 (0.41 to 0.48)	6.11 (5.66 to 6.61)
Sex					
Male	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Female	0.58 (0.57 to 0.59)	0.45 (0.43 to 0.46)	0.67 (0.65 to 0.69)	0.72 (0.67 to 0.77)	0.72 (0.70 to 0.75)
Race/ethnicity					
Non-Hispanic White	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
Hispanic	0.65 (0.63 to 0.66)	0.67 (0.65 to 0.70)	0.62 (0.59 to 0.64)	0.68 (0.62 to 0.74)	0.59 (0.57 to 0.62)
Black	0.76 (0.74 to 0.79)	0.72 (0.68 to 0.76)	0.83 (0.79 to 0.88)	0.95 (0.83 to 1.09)	0.68 (0.63 to 0.74)
Asian or Pacific Islander	0.53 (0.51 to 0.55)	0.51 (0.48 to 0.55)	0.49 (0.46 to 0.53)	0.88 (0.76 to 1.01)	0.49 (0.44 to 0.54)
Other/unknown	0.61 (0.59 to 0.63)	0.59 (0.56 to 0.62)	0.60 (0.57 to 0.63)	0.69 (0.61 to 0.78)	0.66 (0.62 to 0.70)
Medi-Cal					
Yes	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)	1.0 (reference)
No	1.09 (1.06 to 1.12)	1.08 (1.04 to 1.13)	1.07 (1.02 to 1.12)	1.10 (0.98 to 1.22)	1.12 (1.05 to 1.20)

Data shown as OR (95% CI).

Table 5
Age-stratified multivariable model for upper extremity injuries and pain by body weight class

	Weight class			p Value		
	Underweight (n=27 447)	Normal weight (n=551 676)	Overweight (n=159 064)	Moderately obese (n=118 789)	Extremely obese (n=56202)	Trend Interaction
All injuries/pain (n=46 486)						
2–5 years (n=5582)	1.03 (0.20 to 1.16)	1.0 (reference)	0.99 (0.91 to 1.07)	1.01 (0.92 to 1.11)	1.30 (1.10 to 1.54)	0.550 <0.001
6–11 years (n=12 075)	0.77 (0.67 to 0.88)		1.07 (1.02 to 1.12)	1.07 (1.02 to 1.13)	1.00 (0.93 to 1.08)	<0.001
12–19 years (n=28 829)	0.71 (0.65 to 0.78)		1.01 (0.98 to 1.05)	0.93 (0.89 to 0.96)	0.80 (0.77 to 0.85)	<0.001
Fracture (n=22 265)						
2–5 years (n=2953)	1.09 (0.92 to 1.29)	1.0 (reference)	0.96 (0.86 to 1.07)	0.92 (0.81 to 1.05)	1.28 (1.03 to 1.57)	0.137 <0.001
6–11 years (n=7286)	0.71 (0.60 to 0.86)		1.07 (1.01 to 1.14)	1.07 (1.00 to 1.14)	1.00 (0.91 to 1.10)	0.008
12–19 years (n=12 026)	0.74 (0.65 to 0.85)		0.92 (0.87 to 0.96)	0.80 (0.76 to 0.85)	0.63 (0.58 to 0.69)	<0.001
Sprain or strain (n=17 858)						
2–5 years (n=891)	0.77 (0.55 to 1.08)	1.0 (reference)	0.94 (0.77 to 1.16)	1.16 (0.94 to 1.44)	1.25 (0.83 to 1.89)	0.160 0.114
6–11 years (n=4366)	0.75 (0.59 to 0.94)		1.08 (0.99 to 1.17)	1.09 (1.00 to 1.18)	1.02 (0.90 to 1.15)	0.005
12–19 years (n=12 601)	0.66 (0.57 to 0.76)		1.08 (1.03 to 1.13)	0.99 (0.94 to 1.05)	0.93 (0.87 to 1.00)	0.986
Dislocation (n=3104)						
2–5 years (n=1639)	0.98 (0.81 to 1.20)	1.0 (reference)	1.19 (1.03 to 1.38)	1.09 (0.91 to 1.31)	1.10 (0.73 to 1.67)	<0.001 <0.001
6–11 years (n=158)	2.22 (1.12 to 4.40)		0.59 (0.36 to 0.98)	0.89 (0.57 to 1.40)	0.73 (0.36 to 1.44)	0.048
12–19 years (n=1307)	0.49 (0.31 to 0.80)		1.24 (1.09 to 1.42)	0.97 (0.82 to 1.15)	0.64 (0.50 to 0.83)	0.518
Pain (n=10 546)						
2–5 years (n=700)	1.32 (0.98 to 1.78)	1.0 (reference)	0.88 (0.69 to 1.12)	0.97 (0.74 to 1.26)	1.51 (0.98 to 2.32)	0.360 <0.001
6–11 years (n=1912)	0.86 (0.62 to 1.19)		1.18 (1.05 to 1.33)	1.18 (1.04 to 1.33)	1.06 (0.88 to 1.26)	0.011
12–19 years (n=7934)	0.76 (0.65 to 0.90)		1.07 (1.01 to 1.13)	1.03 (0.96 to 1.10)	0.90 (0.82 to 0.98)	0.250

* ORs (95% CI) are adjusted for sex (male vs female), race (non-Hispanic White, Hispanic, Black, Asian or Pacific Islander, Other/unknown race), age and Medi-Cal benefit use (yes vs no).