THE ASSOCIATION OF WEIGHT PERCENTILE AND MOTOR VEHICLE CRASH INJURY AMONG 3 TO 8 YEAR OLD CHILDREN

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ABSTRACT –The use of age-appropriate child restraint systems significantly reduces injury and death associated with motor vehicle crashes (MVCs). Pediatric obesity has become a global epidemic. Although recent evidence suggests a possible association between pediatric obesity and MVC-related injury, there are potential misclassifications of body mass index from under-estimated height in younger children. Given this limitation, age- and sex-specific weight percentiles can be used as a proxy of weight status. The specific aim of this study was to determine the association between weight percentile and the risk of significant injury for children 3-8 years in MVCs. This was a cross-sectional study of children aged 3-8 years in MVCs in 16 US states, with data collected via insurance claims records and a telephone survey from 12/1/98-11/30/07. Parent-reported injuries with an abbreviated Injury Scale (AIS) score of 2+ indicated a clinically significant injury. Age- and sex-specific weight percentiles were calculated using pediatric norms. The study sample included 9,327 children aged 3-8 years (weighted to represent 157,878 children), of which 0.96% sustained clinically significant injuries. There was no association between weight percentiles and overall injury when adjusting for restraint type (p=0.71). However, increasing weight percentiles were associated with lower extremity injuries at a level that approached significance (p=0.053). Further research is necessary to describe mechanisms for weight-related differences in injury risk. Parents should continue to properly restrain their children in accordance with published guidelines.

INTRODUCTION

Background

In the United States, motor vehicle crashes (MVCs) injure over 200,000 children ages 0 to 15 years annually, and are the leading cause of pediatric death. The use of age-appropriate child restraint systems significantly reduces MVC-related morbidity and mortality [Durbin, et al., 2005; Durbin, Elliott, Winston, 2003; Elliott, et al., 2006].

Pediatric obesity has become a global epidemic with more than 155 million overweight children worldwide [Lobstein, Baur, Uauy, 2004]. In the United States, 34% of children are categorized as being 'overweight' (body mass index percentile [BMI-P] ≥95) or 'at risk for overweight' (BMI-P ≥ 85 to <95) [Ogden, et al., 2006]. The prevalence of being overweight among children has nearly tripled over the past two decades [Flegal, 2005].

The current literature suggests that there may be an association between obesity and MVC-related injuries in children. Our group recently completed an analysis of body mass as a risk factor for pediatric injury in MVCs. We found that while overweight children age 9-15 years in MVCs are not at an overall increased risk for injury, they are at increased risk of upper and lower extremity injury [Pollack, et al., 2008].

Another group examined the risk of crash-related injury in 2-17 year old children, using the National Automotive Sampling System Crashworthiness Data System (NASS/CDS); a database from a national probability sample of MVCs [Haricharan, et al., 2009]. They found that obese children had both a higher risk of severe overall injuries and particular body region-specific injuries than the non-obese. The limitations of this study included significant misclassification of BMI-P status, especially in younger children. NASS/CDS uses anthropometric data that is estimated by the driver or parent. While estimated weights are generally accurate [Akinbami, Ogden, 2009], the significant BMI-P misclassification is likely due to erroneous under-estimation of height, which overestimates childhood overweight status [Akinbami, Ogden, 2009]. This phenomenon is also seen in other databases where weight and height are estimated, including our crash database, the Partners for Child Passenger Safety (PCPS), as compared to a gold-standard database with measured data such as the National Health and Nutrition Examination Survey (NHANES) [Table 1].

A different group recently attempted to answer the same question using the Crash Injury Research and Engineering Network (CIREN) database [Zaveri, et al., 2009], a multi-institutional sample of injured occupants of crashes treated at level-one trauma centers. While the CIREN database has significantly fewer cases than NASS/CDS, it contains more comprehensive crash reconstruction information and medical data. Additionally, it is more likely to contain heights and weights that are measured. The group did not find a significant relationship between pediatric injuries and overweight status. However, in order to be sampled for the database, individuals must have sustained "severe" to "unsurvivable" injuries. Therefore, there is significant selection bias whereby risk estimation relies on controls that are not representative of all individuals in motor vehicle crashes [Elliott, et al., 2010].

Given these limitations, we sought to examine the association between weight status and the risk of crash-related injury in children 3-8 years old. Due to the misclassification of BMI from underestimation of height, and the relative accuracy of parent-reported weight, we approached the analysis by using weight percentile as a proxy of body size [Akinbami, Ogden, 2009].

Table 1 - Rates of BMI ≥ 95th percentile for various databases

Age group (years)	Parent-reported height and weight				Measured height and weight
	NHIS 1999-2004	NSCH 2003-2004	NASS/CDS 1997-2006	PCPS 1998-2007	NHANES 2003-2006
2-5	~40%	~41%	37.5%	~45.7%	12.4%
6-9	~32.5%	~31.5%	42.0%	~37.4%	~17.0%
10-13	~21.5	~18.5%	19.1%	~22.9	~17.2%
14-17	~14%	~11.5%	10.1%	~12.9	~17.6%

NHIS: National Health Interview Survey [Akinbami, Ogden, 2009]
NSCH: National Survey of Children's Health [Akinbami, Ogden, 2009]
NASS/CDS: National Automotive Sampling System Crashworthiness Data System [Haricharan, et al., 2009]
PCPS: Partners for Child Passenger Safety
NHANES: National Health and Nutrition Examination Survey [Ogden, Carroll, Flegal, 2008]

METHODS

Study Population and Data Collection

Data from the Partners for Child Passenger Safety (PCPS) project from December 1, 1998 to November 30, 2007, were used for these analyses. PCPS consists of a large-scale, child-specific crash surveillance system: insurance claims from State Farm (Bloomington, IL) function as the source of subjects, with a validated telephone survey and on-site crash investigations serving as the primary sources of data [Durbin, et al., 2001]. The driver-reported telephone survey served as the source of data for the analyses performed.

Vehicles that qualified for inclusion were State Farm–insured, model year 1990 or newer, and involved in a crash with at least 1 child occupant who was ≤15 years of age. Qualifying crashes were limited to those that occurred in 15 states and the District of Columbia, representing 3 large regions of the United States (East: NY, NJ [until November 2001], PA, DE, MD, VA, WV, NC, and DC; Midwest: OH, MI, IN, and IL; West: CA, NV, AZ, and TX [starting June 2003]). The Partners for Child Passenger Study was limited to these 16 states and DC because it allowed for the fewest number of states that could provide a significant proportion of State Farm's claims volume. In addition, the states represent a diverse range of tort versus no-fault states that could affect driver reporting of a crash, as well as some geographic diversity (urban, suburban and rural regions). Policyholders from qualifying crashes were contacted by the insurance company and told that they were eligible for a motor vehicle safety study. They were given a very brief description of the study that explained that, with their consent, limited data from their claim would be transferred electronically to researchers at the Children's Hospital of Philadelphia and University of Pennsylvania. They were told to expect a telephone call from these researchers for additional data collection. Data in this initial transfer included contact information for the insured, the ages and genders of all child occupants, and a coded variable describing the level of medical treatment received by all child occupants (no treatment, physician's office or emergency department only, admitted to the hospital, or death). The median time from crash to the survey was 10 days.

A stratified cluster sample was designed to select vehicles for the conduct of a telephone survey with the driver of the vehicle in the sampled vehicle. Similar to other population-based crash surveillance systems like the National Automotive Sampling System (NASS), crashes were stratified into various categories based on the severity of the crash (i.e., driveable from the scene or not) and the medical treatment received by the child occupants (i.e., none, emergency department only, inpatient and fatality). A known-probability sample was then obtained from each stratum. The full interview involved a 30-minute telephone survey with the driver of the sampled vehicle.

Vehicles were stratified on the basis of the initial medical treatment received by child occupants and whether the vehicle was drivable, and a probability sample from each tow status/medical treatment stratum was selected. When a vehicle was sampled, the "cluster" of all child occupants in that vehicle was included in the survey. Drivers of sampled vehicles in which at least 1 child received medical treatment were contacted by telephone, consented for a telephone interview, and screened via an abbreviated survey to verify the presence of at least 1 child occupant with an injury. All vehicles with at least 1 child who screened positive for injury and a 10% random sample of vehicles in which all child occupants screened negative for injury were selected for a full interview. (The 2.5% of sampled vehicles in which no children were treated were also selected for a full interview.) The full interview involved a 30-minute telephone survey with the driver of the vehicle. We only included parent-drivers in the sample, as their estimation of anthropometric data was likely more accurate than non-parent drivers. On the basis of an analysis of data for the period of this study, claim representatives correctly identified 97% of eligible vehicles, and 80% of policyholders either consented for participation in this study or were not sampled for consent (the procedure to identify participants who required consent changed in June 2003). Of those who consented and were sampled for an interview, 79% were successfully contacted and screened for the full interview, representing an overall inclusion rate of 52% of eligible individuals. The included sample did not differ from known population values from State Farm claims with respect to geographic region, model year of vehicle, tow status of the vehicle, and age of the child occupant. In both the sample and the population; 40%, 36%, and 24% of the vehicles were located in the East, Midwest, and West, respectively, and 58% of the sampled vehicles were model 1996 or newer. In the sample, 53% were passenger cars, 20% were minivans, 18% were sport-utility vehicles, 6% were pickup trucks, and 2% were large passenger vans, compared with 55%, 18%, 18%, 7%, and 2% in the population, and 32% were non-drivable, compared with 30% of the population. The mean age of the child occupants in the sample was 6.9 years, compared with 7.3 years in the population.

While current child restraint laws vary by state, many include children through 8 years of age. Therefore, these analyses were restricted to children who were aged 3 to 8 years and 30-99 pounds.

Variable Definition

We found significant variability in BMI percentile distribution in our sample as compared to national samples (Table 1). Given the concern for BMI misclassification secondary to parental underestimation of heights, we calculated age- and sex-specific weight percentiles based on pediatric growth charts from the Centers for Disease Control and Prevention (CDC). Weight percentile was considered as a continuous variable, and not a categorical variable. While weight percentile categories have been used as a proxy of body mass when heights are unavailable [Pomerantz, Timm, Gittelman, 2010], these categories should be interpreted cautiously as they may not be as clinically meaningful as traditional BMI percentile categories.

Survey questions regarding injuries to children were designed to provide responses that were classified by body region and severity on the basis of the Abbreviated Injury Scale (AIS) score and were previously validated to distinguish AIS 2+ injuries from those less severe [Durbin, et al., 1999]. For the purposes of these analyses, children were classified as injured when they had a clinically significant injury corresponding to injuries with an AIS score of 2+ (concussions and more serious brain injuries, internal organ injuries, spinal cord injuries, and extremity fractures). Children who sustained only minor injuries generally corresponding to an AIS score of 1, such as lacerations, contusions, and abrasions, were not considered injured for these analyses.

Data Analysis

To account for the potential clustering of multiple children in a single sampled vehicle and the disproportional probability of selection of the study sample design, we used SAS-callable SUDAAN: Software for the Statistical Analysis of Correlated Data 9.0 (Research Triangle Institute, Research Triangle Park, NC) for the data analyses. Frequency distributions of several child, vehicle, and impact characteristics among the sample were determined. Logistic regression was used to assess the relationship between weight percentile and clinically significant injury, adjusting for restraint status.

RESULTS

Between December 1, 1998, and November 30, 2007, interviews were completed on 34,732 children in 21,943 crashes, representing 531,193 children in 346,485 crashes. From the overall sample, 9,327 children in 7,574 crashes met the inclusion criteria (aged 3–8 years, driven by a parent), representing 157,878 children in 129,008 crashes. Table 2 provides the distribution of age, weight, gender, restraint use, and seating position for the children; driver characteristics including gender and restraint status; and crash characteristics including vehicle type, model year, crash severity, and direction of impact.

Clinically significant injuries occurred in 0.96% of the sample. There was a higher risk of clinically significant injury for those children in seats belts (OR=2.96, 95% CI: 2.09-4.20) or unrestrained (OR=8.19, 95% CI: 4.96-13.53) as compared to children in child restraint systems, regardless of weight percentile. There was no association between weight percentile and overall clinically significant injury when adjusting for restraint type (p=0.71). When considering body region-specific injuries, weight percentile was associated with increased lower extremity injuries after adjusting for restraint type at a level that approached significance (p=0.053).

Table 2 - Child, driver, and crash characteristics of the study sample

Characteristic	**Weighted % (Unweighted n) Total n=9,327**
Age (years)	
3	17.6% (1,452)
4	18.9% (1,653)
5	18.3% (1,648)
6	15.0% (1,496)
7	15.7% (1,554)
8	14.6% (1,524)
3 to 5	54.8% (4,753)
6 to 8	45.2% (4,574)
Weight percentile	
<50th	38.7% (61,070)
50th to 85th	34.5% (54,493)
>85th	26.8% (42,314)
Restraint Status	
Child Restraint System (CRS)	23.2% (1,713)
Booster seat	27.6% (1,982)
Seat belt	47.8% (5,333)
Unrestrained	1.4% (299)
Seating Row (Front)	8.2% (1,243)
Age of Driver (< 25 yr)	5.1% (528)
Driver Gender (Male)	27.8% (2,525)
Driver Restrained	96.5% (8,827)
Vehicle Type	
Passenger Car	41.0% (4,308)
Large Van	2.1% (208)
Pickup Truck	6.0% (576)
SUV	24.3% (1,946)
Minivan	26.6% (2,289)
Model Year	
1990 - 1997	38.8% (4,521)
1998 - 2001	38.1% (3,208)
2002 - 2008	23.1% (1,598)
Crash Severity	
Any intrusion	7.4% (1,833)
Towaway, no intrusion	26.6% (3,886)
None	66.0% (3,608)
Direction of Initial Impact	
Front	46.5% (4,452)
Near-side	9.6% (978)
Far-side	11.1% (1,126)
Rear	30.4% (2,489)
Other/ Misc/ Unknown	2.4% (282)

DISCUSSION

In our analysis of a child-specific crash database, while there were no differences in overall clinically significant injury between children of various weight percentiles, adjusted for restraint type, there was an increased risk for lower extremity injuries. This is consistent with our previous analysis of children 9-15 years old using the same crash database, which found an increased risk of extremity injuries in the overweight versus normal weight [Pollack, et al., 2008]. Additionally, a recent study by Haricharan and colleagues demonstrated a higher risk of overall crash related injury in children 2-17, and increased head, thorax, and lower extremity in a booster-age group, with a BMI percentile of ≥ 95 [Haricharan, et al., 2009]. The primary limitation of the Haricharan analysis was the significant discrepancy in BMI percentile distribution as compared to the general population, especially in younger children, likely from parental underestimation of child heights (Table 1). Given these findings, the risk of significant injury reported by the authors may be overestimated, or altogether inaccurate. Zaveri and colleagues used the CIREN database to estimate the risk of crash-related injury in children with a BMI percentile ≥ 85 versus < 85 [Zaveri, et al., 2009]. While they did not find any association between significant injury and overweight status, they used a much smaller database that may have been underpowered to detect a difference. Additionally, inclusion in the CIREN database requires an injury to have occurred, therefore there was significant selection bias whereby controls in their study did not reflect the general population of children in motor vehicle crashes [Elliott, et al., 2010]. We attempted to overcome the limitations from these recent analyses with a large, population-based source of child-involved crashes, and with weight percentiles used as a proxy of body mass. Weight percentiles have been used for similar analyses of body mass and injury risk when height was unavailable [Pomerantz, Timm, Gittelman, 2010].

These findings are plausible, as an increased risk of lower extremity injuries in overweight children has also been seen in other studies not specific to MVC-related injuries [Goulding, 2007; Krul, et al., 2009; Pomerantz, Timm, Gittelman, 2010; Zonfrillo, et al., 2008]. While exact mechanisms for increased lower extremity injuries among overweight children have not been determined, proposed contributing factors include additional loading forces, differences in soft tissue structures, and variation in bone mineral density [Goulding, 2007; Wearing, et al., 2006].

Our analysis does have some potential limitations. A proportion of eligible subjects declined to participate in the telephone survey, therefore the potential for selection bias cannot be excluded. Additionally, the study relies on driver report of information about injuries, and is potentially subject to information bias. Any misclassification in weight or injury status is likely to be random with respect to the associations of interest. Therefore, it is possible that an association between weight percentile and injury risk exists that we were unable to detect. Similarly, the study relies on self-report of weight, although a recent study using a similar database found that survey and crash investigation parameters to correlate well [Pollack, et al., 2008], and parental estimates of weight are accurate for epidemiologic purposes [Akinbami, Ogden, 2009]. Finally, since our study only includes passengers of insured vehicles with a model year greater than 1990, the results may not be generalizable to children in older or uninsured vehicles.

Given the differences in crash databases, analytic approach, and conclusions of recent work including this current study, further research is needed to clarify the association of body mass and crash-related injury in the booster-age population. The limitations for each of these studies highlight the challenging nature of using BMI percentiles in children. More specifically, BMI misclassification from parent-estimated anthropometric measurements can confer inaccurate estimations of differences in injury risk. Prospective study of crash injuries using measured heights and weights may more accurately estimate the difference in injury risk for children of varying body mass. Furthermore, study of static and dynamic belt fit of children and/or anthropomorphic test devices could serve as an adjunct to determine possible mechanisms of any variation in injury risk by body size.

CONCLUSION

We did not find an overall association between body weight percentiles and injury risk among 3-8 year old children in crashes. However, heavier children were at an elevated risk of lower extremity injuries when compared to smaller children. Children in proper restraint devices had a lower relative risk of significant injury, regardless of weight status. Parents should continue to properly restrain their children in accordance with published guidelines. Specifically, children of this age should be in either a forward-facing car safety seat or a belt-positioning booster seat until they are at least 57 inches (145 centimeters) tall. Further study of pediatric body mass and crash-related injury should be ideally based on measured height and weight in order to fully understand any associations and specific mechanisms of injury.

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