



Original Contribution

Association between Body Mass Index and Acute Traumatic Workplace Injury in Hourly Manufacturing Employees

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In this study, the authors examined the distribution and odds of occupational injury among hourly employees of a US aluminum manufacturing company by body mass index (weight (kg)/height (m)²). In 2002, height and weight data on 7,690 workers at eight plants were extracted from medical records from annual physicals, and body mass index was categorized. Information on traumatic injuries recorded between January 1, 2002, and December 31, 2004, was obtained from a company injury surveillance system. Twenty-nine percent of the employees ($n = 2,221$) sustained at least one injury. Approximately 85 percent of injured workers were classified as overweight or obese. The odds of injury in the highest obesity group as compared with the ideal body mass index group were 2.21 (95% confidence interval: 1.34, 3.53), after adjustment for sex, age, education, smoking, physical demands of the job, plant process and location, time since hire, time in the job, and significant interaction terms. Injuries to the leg or knee were especially prevalent among members of this very obese group. Research findings support an association between body mass index and traumatic workplace injuries among manufacturing employees. Workplace safety personnel might consider adding policies or programs that address weight reduction and maintenance as part of ongoing comprehensive workplace safety strategies.

accidents, occupational; body mass index; obesity; overweight; risk factors; safety; workplace; wounds and injuries

Abbreviations: BMI, body mass index; CI, confidence interval; OSHA, Occupational Safety and Health Administration.

Approximately two thirds of US adults are either overweight or obese (1). Excess body weight is a risk factor for many chronic conditions, including hypertension, diabetes, heart disease, osteoarthritis, and psychological distress (2–7). Aside from chronic disease outcomes, obesity may also increase the risk of nonfatal traumatic injury. A body mass index (weight (kg)/height (m)²) in the obese range has been associated with an increased risk of injury resulting from motor vehicle crashes, falls, and sport activity (8–12).

In the workplace, obesity is an independent risk factor for certain work-related cumulative injuries, namely carpal tunnel syndrome (13–18). Existing studies suggest that the relation between obesity and carpal tunnel syndrome could be due to an excess of fatty tissue within the carpal canal, increased fluid and blood volume in the carpal canal during physical labor, or increased hydrostatic pressure in overweight and obese persons.

For traumatic, noncumulative workplace injuries, especially those occurring among employees in nonsedentary

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jobs, the association with obesity is less clear. Some studies of employees at nonoffice work sites have suggested that persons with increased BMI are at increased risk of traumatic occupational injury (19–27). However, many of the estimates from these studies were not statistically significant or the investigators were not able to control for potential workplace or sociodemographic confounders. Differences in the distribution of injuries by BMI have also not been thoroughly explored.

In this study, we used administrative data from a large, multisite manufacturer to determine whether increased BMI was an independent risk factor for workplace injury. We explored the distribution of BMIs by nature of injury and body part injured.

MATERIALS AND METHODS

Study sample

This study cohort comprised employees from a large, multisite aluminum manufacturing company in the United States. The eight plants in the study were located in the East, Midwest, and South. At four plants, workers engaged primarily in the production of aluminum (primary smelters); at four other plants, workers engaged in fabricating aluminum products (secondary smelters). Hourly manufacturing workers between 18 and 65 years of age who were on the payroll at any time during calendar year 2002 were included. A total of 9,101 eligible employees met the study-sample inclusion criteria. Of these eligible employees, height and/or weight data were missing for 15 percent, leaving 7,690 employees in the final study sample.

Databases

Five company databases were linked deterministically using an encrypted employee identification number created to maintain confidentiality. A human resources database, with a file on each employee created at the time of hire, was used to obtain information on demographic variables and jobs held within the company. Industrial hygiene data, collected as part of routine surveillance, were used to obtain information on plant location, processes, and job title, which was standardized across all plants. Data on employee height, weight, and smoking were obtained through abstraction of medical records from on-site health clinics.

The physical demand rating of each job was obtained as part of a job-demand survey. A single trained rater at each plant classified the physical strength required for each job. Information on workplace injuries was obtained from a company real-time incident surveillance system that was designed to capture all workplace injuries irrespective of the severity of the outcome. All of the data are regularly audited, by an outside firm, to maintain a high level of quality.

Measures

The study outcome was the occurrence of any traumatic work-related injury between January 1, 2002, and December 31, 2004. Traumatic injuries included both those resulting in

first-aid attention only and those designated as recordable by the Occupational Safety and Health Administration (OSHA). OSHA-recordable injuries are those that require medical treatment, involve lost or restricted work time, or lead to loss of consciousness or death. The traumatic injuries included in this study were acute sprains and strains, falls, burns, contusions, abrasions, lacerations, eye injuries, fractures, amputations, blisters, foreign bodies, punctures, and bites or stings. There were no workplace fatalities during the study period. Information on the primary body part injured was also collected.

The independent variable was BMI. Using height and weight as measured during physical examinations in 2002, we categorized BMI for each employee according to the criteria developed by the National Institutes of Health (4). These criteria classify adult BMI, irrespective of sex, as follows: <18.5 is defined as underweight, 18.5–24.9 is defined as normal (ideal body weight), 25.0–29.9 is defined as overweight, 30.0–34.9 is defined as obesity level I, 35.0–39.9 is defined as obesity level II, and ≥ 40.0 is defined as obesity level III.

On the basis of prior studies, a number of sociodemographic variables were included as potential confounders. Employee age in years was measured at baseline (January 1, 2002) and was categorized as 18–24, 25–34, 35–44, 45–54, and 55–64. Employee race/ethnicity was reported as Black, White, Hispanic, Asian-American, or Native American. Because of small sample sizes, the Asian-American and Native American employees were combined and characterized as “other.” The highest level of education attained was either a high school diploma or some college education. Smoking status was classified as current, former, or never smoker.

Two tenure variables were calculated, starting from baseline. Time since hire, in years, was classified into the following categories: <1, 1–<2, 2–<3, 3–<5, and ≥ 5 . Time in the current job, in months, was classified as: <3, 3–<6, 6–<12, and ≥ 12 . These two measures of time of employment were not collinear, and both were included in the analysis.

For each employee, job at baseline was merged with the physical demand rating for that specific job, by plant. We used the physical demand ratings rather than the job titles as a more accurate measure of job tasks. Thus, each employee had a job physical demand rating of sedentary, light, medium, heavy, or very heavy. We also collected information on both the type of plant processes and the geographic location of the plant.

Statistical methods

Frequencies and percentages were calculated for each variable, according to BMI group. Analysis of variance was used for comparisons of continuous variables among BMI groups. All *p* values were two-tailed and were deemed statistically significant at the 0.05 level.

Since employee attrition was less than 3 percent during the study period, multivariable logistic regression was used to model the odds of sustaining an injury over the entire study period. Employees classified as having a BMI in the

normal range served as the reference group. Based on the distribution of BMIs, employees with BMIs between 30.0 and 39.9 (obesity categories I and II) were combined, and employees in the most severe obesity category (obesity category III) were analyzed separately. Workers considered underweight (BMI < 18.5 ($n = 22$)) were excluded from the analysis because of inadequate statistical power for comparisons.

The bivariate analysis showed that all of the variables except education and smoking were significantly correlated with injury ($p < 0.05$), and thus they were included as potential confounders. Since prior studies have shown associations of education and smoking with BMI and injury, we also decided to retain them for the final model. Interactions between continuous and categorical BMI and the covariates were also examined for inclusion in the multivariable model. The only statistically significant interaction was between BMI and age ($p = 0.04$). Thus, the final multivariable model included baseline BMI, age, sex, race/ethnicity, plant processes, plant geographic location, job physical demand, years since hire, number of months in the current job, smoking, education, and the BMI \times age interaction term.

To examine whether the strength of the association between BMI and injury varied by injury outcome, we stratified data in the multivariable model by type of injury—acute sprains and strains versus other traumatic injuries (falls, burns, lacerations, eye injuries, fractures, amputations, blisters, foreign bodies, punctures, and bites or stings). On the basis of prior studies that have explored risk factors for sprains and strains (most of which are to the back or shoulder), we hypothesized that the odds ratio would be highest for obese workers who sustained a sprain or strain injury, as compared with obese workers who sustained any other traumatic injury. Additionally, we hypothesized that this pattern would be consistent across all of the BMI groups. The estimates from these stratified models were compared with those from the full multivariable model for any traumatic injury.

All results are presented with their corresponding 95 percent confidence intervals and p values. Analyses were conducted using SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina). The entire study was approved by the human investigation committees at the participating institutions.

RESULTS

Approximately 85 percent of hourly employees in this sample were either overweight or obese. The mean BMI for all workers was 29.8 (range, 18.0–65.5). Forty-two percent of the employees were overweight; 38 percent were at obesity level I or II, and 4 percent were at obesity level III. Among the sociodemographic variables, mean BMIs differed statistically by age, race/ethnicity, and smoking ($p < 0.01$) (table 1). The distribution of BMIs was similar between men and women.

A total of 2,221 employees (29 percent) sustained at least one traumatic injury during the study period. Nearly 70 percent of these were first-aid injuries, and 30 percent were OSHA-recordable injuries. Twenty-eight percent of injuries occurred among employees in the normal BMI range,

TABLE 1. Mean body mass index according to sociodemographic and workplace variables among 7,690 hourly aluminum manufacturing employees from eight US plants,* 2002

Variable	No. of employees	Mean body mass index†	p value‡
All employees	7,690	29.8 (5.2)§	
Sex			
Men	7,041	29.7 (5.1)	
Women	649	29.4 (6.1)	0.14
Age group (years)			
18–24	171	27.0 (5.2)	
25–34	1,161	29.2 (5.4)	
35–44	2,026	29.6 (5.0)	
45–54	312	30.0 (5.2)	
55–64	1,209	30.0 (5.4)	<0.01
Race/ethnicity			
White	6,449	29.6 (5.2)	
Black	767	30.9 (5.5)	
Hispanic	261	30.0 (5.3)	
Other	58	29.3 (4.3)	<0.01
Education			
High school diploma or less	5,428	29.9 (5.2)	
Some college or more	1,758	29.8 (5.2)	0.20
Smoking			
Never smoker	2,875	30.3 (5.3)	
Ever smoker	1,674	30.1 (5.1)	
Current smoker	2,256	28.1 (5.0)	<0.01
Type of plant			
Primary smelter	3,591	30.0 (5.1)	
Secondary smelter	4,099	29.4 (5.3)	<0.01
Job demand			
Sedentary	361	29.2 (4.8)	
Light	2,123	29.8 (5.0)	
Medium	3,297	29.7 (5.3)	
Heavy	1,423	29.4 (5.2)	
Very heavy	240	30.4 (5.7)	0.04
Time since hire (years)			
<1	284	29.1 (5.3)	
1–<2	363	28.7 (5.0)	
2–<3	196	29.1 (4.7)	
3–<5	577	29.1 (5.2)	
≥ 5	6,270	29.8 (5.2)	<0.01
Time in the current job (months)			
0–<3	1,706	29.8 (5.5)	
3–<6	663	30.3 (5.4)	
6–<12	4,463	29.8 (5.1)	
≥ 12	858	28.9 (4.9)	<0.01

* Plants were located in Illinois, Indiana, New York, North Carolina, Ohio, Pennsylvania, Tennessee, and Texas.

† Weight (kg)/height (m)².

‡ Two-sided p value from analysis of variance.

§ Numbers in parentheses, standard deviation.

TABLE 2. Distribution of traumatic injuries* (%) in 2,221 hourly aluminum manufacturing employees from eight US plants,† by body mass index and injured body part, 2002–2004

Body part	No. of employees	Body mass index‡ category			
		Normal (18.5–24.9) (n = 337)	Overweight§ (25.0–29.9) (n = 905)	Obesity I and II§ (30.0–39.9) (n = 875)	Obesity III (≥40.0) (n = 104)
Head/face/neck	389	13.4	10.8	12.2	8.7
Back	259	6.5	9.0	9.0	10.6
Trunk	79	3.3	3.3	4.0	2.9
Shoulder	157	35.0	32.8	26.9	29.8
Forearm/elbow	193	18.7	18.3	16.8	12.5
Hand/wrist/finger	681	10.4	12.6	15.3	22.1
Leg/knee	306	6.8	7.2	6.7	9.6
Toe/foot/ankle	149	5.9	5.6	8.5	3.9
Total		100	100	100	100

* Any traumatic injury (includes Occupational Safety and Health Administration-recordable injuries and first-aid injuries).

† Plants were located in Illinois, Indiana, New York, North Carolina, Ohio, Pennsylvania, Tennessee, and Texas.

‡ Weight (kg)/height (m)².

§ Because eight injuries to the “whole body” were excluded, percentages do not sum to 100.

28.3 percent in the overweight range, 30.0 percent in the obese I and II category, and 33.9 percent in the obese III category. There were no significant differences in BMI between injuries that required first aid only and OSHA-recordable injuries (data not shown).

There were statistically significant differences between BMI categories for the primary body part that was injured ($p = 0.021$) (table 2). Although injuries to the upper extremities represented the largest proportion of injuries for all employees (mostly shoulder injuries), a substantially higher proportion of injuries occurred to the hand, wrist, and finger among employees in the highest obesity group. Twenty-two percent of all injuries in this very obese group were to the hand, wrist, or finger, while 15 percent had a similar body part injured in other BMI groups.

Almost 10 percent of all injuries in obesity category III were to the knee and leg, as compared with either 6 percent or 7 percent of all injuries in the other BMI categories. A larger percentage of injuries to the toe/foot/ankle was seen among workers in the obesity I and II category. A higher percentage of abrasions was seen in the obesity I and II category, and a greater percentage of contusion injuries was seen in obesity category III, as compared with the normal BMI group. Among all injured overweight or obese employees, a slightly larger percentage of injuries were sprains and strains than in the normal BMI group (33 percent vs. 28 percent).

After controlling for age, sex, education, race/ethnicity, smoking, physical demand, plant, time since hire, time on the job, and BMI \times age, there were significantly increased odds of injury for persons in the highest obesity category when compared with the reference group (odds ratio = 2.21, 95 percent confidence interval (CI): 1.34, 3.53) (table 3). Compared with the reference BMI group, the odds of injury

for the overweight and obesity I and II categories were 1.26 (95 percent CI: 1.06, 1.50) and 1.54 (95 percent CI: 1.22, 1.96), respectively. The p value for trend from the multivariable model supported an increased risk of injury as BMI increased ($p = 0.02$).

When the injuries were divided into sprains and strains ($n = 714$) and all other traumatic injuries ($n = 1,507$), the odds ratio for sprain-and-strain injuries was greatest for the heaviest employees (table 3). The odds of injury were significantly greater for the acute sprain-and-strain injuries than for all other traumatic injuries across all of the BMI categories.

DISCUSSION

It can be inferred from these results that having a BMI in the overweight or obese range is associated with an increased risk of traumatic workplace injury in comparison with having a normal BMI. Even though the 95 percent confidence interval included the null value, the odds of injury were also elevated for overweight employees when compared with employees with an ideal BMI. The odds of injury were also significantly higher for the very obese employees.

The odds of injury increased substantially when only the acute sprain-and-strain injuries were considered. This finding was expected, especially since most of these acute sprain-and-strain injuries were to the back and shoulder. We found a larger percentage of back injuries among overweight or obese employees as compared with normal-sized employees. Prior studies of workplace back injuries have shown an increased risk of injury with increasing BMI (19, 27). Our finding that knee injuries were common among obese employees was consistent with that of one prior study

TABLE 3. Odds of incurring at least one traumatic injury* in 7,690 hourly aluminum manufacturing employees from eight US plants,† by body mass index, 2002–2004‡

Model	Body mass index§ category¶						p for trend
	Overweight (25.0–29.9)		Obesity I and II (30.0–39.9)		Obesity III (≥40.0)		
	OR#	95% CI#	OR	95% CI	OR	95% CI	
Univariable model	1.08	0.94, 1.25	1.77	1.02, 1.36	1.41	1.08, 1.84	0.04
Multivariable model	1.26	1.06, 1.50	1.54	1.22, 1.96	2.21	1.34, 3.53	0.02
Multivariable model with data stratified by type of traumatic injury							
Acute sprains and strains	1.49	1.12, 1.97	2.22	1.52, 3.25	3.79	1.83, 7.87	0.02
All other injuries	1.17	0.97, 1.43	1.32	1.00, 1.72	1.74	1.02, 1.72	0.04

* Any traumatic injury (includes Occupational Safety and Health Administration-recordable injuries and first-aid injuries).

† Plants were located in Illinois, Indiana, New York, North Carolina, Ohio, Pennsylvania, Tennessee, and Texas.

‡ Estimates were derived from the full model, which included age, sex, education, race/ethnicity, smoking, job physical demand, plant, time since hire, time in the job, and an interaction term for age × body mass index.

§ Weight (kg)/height (m)².

¶ Reference category: normal (18.5–24.9).

OR, odds ratio; CI, confidence interval.

using workers' compensation claims that found the knee to be a common injury site among employees with BMIs of 40–54.9 (26). Although the knee was not the most prevalent injury site in the present study, knee injuries were more common among injured workers in the highest obesity category than among workers in the other BMI categories.

In this study, we did not specifically explore the mechanism of injury, but prior studies of this association have suggested some hypotheses. The most often suggested mechanisms have been fatigue or sleepiness, physical limitations, ergonomics, and poorer health (20, 22, 23, 28–31). Since research supports an increased risk of injury with medication use, another possibility is that medications used for illnesses associated with obesity, such as diabetes, could influence the risk of workplace injuries (32–35). Illness was not explored in the present study, but there is a high prevalence of chronic conditions in this workforce (36). Thus, it seems likely that illness or medication use could be a significant mechanism of injury in this population.

It is also likely that obese workers are less able to tolerate hazardous mechanical energy exposure. Biologic factors are known to influence the ability of the body to tolerate impact forces (37, 38). Excess body fat could affect the ability of the body to resist such forces. Additionally, it is possible that personal protective equipment, such as gloves and eye goggles, are less likely to be used by obese workers because of lack of comfort, fit, or availability. The availability and use of personal protective equipment for obese employees should be the focus of more research, especially since one strategy for preventing injury is to separate the body from hazardous injury-causing energy (39).

Since the prevalence of overweight and obesity in these employees was high, interventions should aim to improve this estimate. Most workplace obesity interventions with effectiveness data have focused on employees working in an office environment or civil servants (40–42). Few studies have explored whether such interventions can be applicable

to blue-collar workers (43). Future research is needed to design and test the effectiveness of interventions for reducing weight among blue-collar employees, who often have limited access to work-site health promotion programs, must remove protective clothing to accommodate midday exercise regimens, or do not participate in after-work programs because of additional employment or competing responsibilities at home (44).

This study had some limitations that should be considered when interpreting its findings. First, 84 percent of employees in the study were either overweight or obese. This prevalence was substantially greater than the current estimated prevalence of overweight and obesity in the general US adult population. It is possible that the high prevalence of overweight and obesity in our study resulted from the geographic locations of the plants represented in the sample. It is widely known that the prevalence of obesity varies by geography (45). Despite this possible concern, we feel that our sample was representative of the general US adult population, because differences in the distribution of BMIs by race/ethnicity, sex, age, and smoking in the present analysis were similar to prior estimates (1, 46–50).

Arguably, BMI is not the best measure of obesity. There is particular misclassification for adults with BMIs less than 30 (51, 52). Furthermore, misclassification is possible for adults with lean muscle mass. In one recently published study, Craig et al. (53) reported that a higher BMI was associated with a reduced risk of workplace injury. The authors hypothesized that their finding was contrary to some prior work because employees may have been misclassified as obese due to their lean muscle mass. We believe that this misclassification was minimal in the present study, especially after direct observation in the plants by the study team, which revealed that the presence of large numbers of employees with especially large lean muscle mass was unlikely.

The height and weight measures used to calculate BMI were only recorded at baseline. Thus, there may have been

potential misclassification of BMI in 2003 and 2004 by the use of BMI measured at baseline. If this was the case, the potential impact of misclassification by BMI was probably minimized, since the follow-up time was relatively short. Additionally, during the study period there was no concerted weight loss effort targeted at these employees, thereby reducing the likelihood of significant variation in weight over the study period. However, if misclassification by BMI was present, it was most likely nondifferential and would have attenuated the strength of the associations seen.

While missing data are always a concern with studies using administrative and surveillance data, we found that employees with missing BMI values were similar to those with BMI values for age, race/ethnicity, sex, etc. There was little evidence to suggest that our results were biased on the basis of missing data. Missing values related to attrition could also have affected our results. However, since the average annual attrition in this workforce is less than 3 percent, the departure of a small number of employees during the study period is unlikely to have biased our results. We were also missing measures for some key risk factors for injury, including alcohol drinking. The lack of data on alcohol use was not deemed problematic, since alcohol drinking on the job is not tolerated by the employer. Alcohol use at work is punishable by immediate discharge; thus, it is unlikely that it played a significant or confounding role.

An employee's injury experience began in 2002, and we did not include information on history of injury in this analysis. We considered examining only the newly hired employees, which would have allowed for an analysis of complete injury history beginning in 2002. However, statistical power was a concern, since only 164 employees were newly hired. Future studies of this association should attempt to prospectively examine newly hired employees to capture all injury information beginning when BMI is measured. Although costly, follow-up should also occur for a long enough time period to determine differences in days of work lost or restricted; such information was not included in this study because of a small number of such cases.

We analyzed all employees with one or more injuries together, and potential differences in recurrence of injury by BMI were not explored. Results from a study by Stoohs et al. (21) showed a significant association between BMI and work-related recurrent injuries. We are planning future analyses using these data that will focus on exploring whether overweight and obese employees are at higher risk of recurrent injury.

Despite these research limitations, there are many strengths of this study. First, we took advantage of the availability of multiple administrative databases, which permitted the inclusion of data on known and potential confounders. For this reason, unlike investigators in prior studies, we did not have to rely on self-reported information on height and weight. Second, unlike most studies that have examined BMI and injury, this study was able to explore differences in the primary body part injured and the nature of injury. Lastly, we were able to explore the most prevalent type of workplace injuries, first-aid only, in addition to OSHA-recordable injuries. Many studies of occupational injury exclude injuries that result in first-aid attention only, mainly

because of the lack of reporting of these events on the job. Recent analyses of these more minor injuries have shown that their inclusion increases the power to conduct subanalysis of employees without biasing risk estimates.

While employees with BMIs of 40 or higher are at greatest risk of injury, there are other known risk factors for occupational injury, both distal and proximate to the time of the injury. Efforts to reduce injury in the workplace should *still* focus on controlling hazardous energy exposures and modifying the work environment. More epidemiologic and intervention/evaluation studies are needed to determine whether obesity prevention efforts in the workplace will have the added benefit of improving injury rates.

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