Effect of Obesity on Falls, Injury, and Disability

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OBJECTIVES: To examine the effect of obesity on the propensity of older adults to fall, sustain a fall-related injury, and develop disability in activities of daily living (ADLs) after a fall.

DESIGN: Longitudinal population-based survey.

SETTING: Five waves of the Health and Retirement Study (HRS), 1998–2006.

PARTICIPANTS: Ten thousand seven hundred fifty-five respondents aged 65 and older in 31,602 person-intervals.

MEASUREMENTS: Falls within any 2-year interval (9,621 falls). Injuries requiring medical attention (3,130 injuries). Increased ADL disability after a fall within any 2-year interval (2,162 events). Underweight and three classes of obesity (body mass index (BMI) 30.0–34.9 kg/m^2, Class 1) 35.0–39.9 kg/m^2, Class 2; $\geq$40.0 kg/m^2, Class 3), calculated from self-reported height and weight. Self-reported presence of lower body limitation, pain, dizziness, or vision problems. Self-reported doctor's diagnosis of diabetes mellitus, stroke, or arthritis.

RESULTS: Compared with normal-weight respondents, the odds ratios (OR) for risk of falling were 1.12 (95% confidence interval (CI) = 1.01–1.24) for obesity Class 1, 1.26 (95% CI = 1.05–1.51) for obesity Class 2, and 1.50 (95% CI = 1.21–1.86) for obesity Class 3. Conditional on falling, only obesity Class 3 was related to a lower propensity for a fall-related injury (OR = 0.62, 95% CI = 0.44–0.87). Obesity Classes 1 and 2 were associated with a higher risk of greater ADL disability after a fall than normal-weight respondents (OR = 1.17, 95% CI = 1.02–1.34; OR = 1.39, 95% CI = 1.10–1.75, respectively). Being underweight was not related to risk of falling or to reported injury or greater ADL limitation after a fall. The presence of measured health problems and chronic conditions was associated with greater risk of falling and, of those who fell, greater ADL limitation but not serious injury.

CONCLUSION: Obesity appears to be associated with greater risk of falling in older adults, as well as a higher risk of greater ADL disability after a fall. Obesity (BMI $\geq$ 40 kg/m^2) may reduce the risk of injury from a fall. Further investigation of the mechanisms of obesity on falls and related health outcomes is warranted. **J Am Geriatr Soc 2011.**

Key words: chronic conditions; falling; risk factors

In the United States, more than 33% of adults aged 65 and older fall annually,[1] which resulted in nearly 16,000 deaths in 2005. Many more are injured in falls, resulting in enormous cost in hospital admissions, emergency department treatments,[2,3] and nursing home admissions,[4] in addition to the obvious trauma to older adults and their families. In addition, fall-related deaths are increasing over time,[5] a trend representing a clear threat to the physical well-being of older adults.

Simultaneously, another threat to the overall health of older adults is increasing—that of obesity. Obesity is one of the few clearly negative health trends facing older adults in the United States, particularly older men. In 2008, 37% of men and 34% of women aged 60 and older were considered obese.[6] Some subgroups of the population show significantly higher levels of obesity; for instance, 50% of non-Hispanic black women aged 60 and older are considered obese.[6] Although it is clear, for example, that obesity is no longer a major factor in old age mortality,[7,8] it plays a major role in old age disability.[7,9,10] There is also evidence that obesity plays a role in old age falls.[11,12] Potential mechanisms through which obesity may affect falls include lower levels of physical activity;[13] greater levels of pain, leading to postural balance problems;[14] high serum parathyroid hormone in individuals with diabetes mellitus;[15] and vitamin D deficiency.[16]

There is conflicting evidence on the effect of being obese on fall-related injuries.[17,18] One study found that lower body mass index (BMI) and bone mass density, along with the direction of the fall, are predictive of injury from a fall,[19] but another study found that higher

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waist circumference, hip circumference, and waist:hip ratio were positively related to fractures in men, whereas BMI was not.[18] This finding indicates that the location of obesity may be important, with the mechanism being a balance problem, a particular problem for older adults.[11,20] In addition, some researchers have found a protective effect of obesity in relation to injury from falls,[17] indicating an opposite effect for those who are underweight.

Some risk factors for falling are well documented, including prior falls, inappropriate use of medications, gait or balance problems, and functional limitations, particularly those involving the lower limbs.[16,21–25] In addition, vision problems,[22] multiple sources of musculoskeletal pain,[26] cognitive impairment,[22] prior hip fractures and stroke,[4] and in women only, shorter sleep duration[27] have been found to be important risk factors for falls in older adults.

For older adults, the consequences of falling can be serious because of age-related changes in bone mass density among other normal physical changes. The most serious is fall-related mortality, which increased 55.3% between 1993 and 2003 in adults aged 65 and older.[5] Other physical outcomes include subsequent falls, hip and other fractures, hospitalization, persistent impaired mobility,[28] and greater likelihood of placement in skilled nursing facilities.[4] There is also evidence that falling has deleterious effects on older adults' mental well-being, primarily the fear of falling, which is both a cause and consequence of falling.[28,29] Other risks from falls include potential loss of independence, social isolation, impaired well-being and quality of life,[28] decreased self-efficacy, loss of confidence, and avoidance of activity as a coping mechanism.[29] The avoidance of activity may also have an additional deleterious effect by increasing the likelihood of persistent mobility impairment.[28]

Given these various findings, the relationship between obesity and the probability of falling, the probability of being injured in a fall, and the probability of acquiring disability in activities of daily living (ADLs) was explored. The hypotheses were that obese older adults would be more likely to fall; that underweight older adults would be more likely to be injured in a fall; and finally, that older adults who had fallen and were obese would be more likely to become disabled in ADLs.

METHODS

Data

This study used data from the 1998 to 2006 waves of the Health and Retirement Study (HRS), a longitudinal survey designed to study health, economic, and family transitions of older adults. The Institute for Social Research at the University of Michigan and the National Institute on Aging conduct the HRS every 2 years. The full description of the HRS has been published elsewhere.[30] The analysis was begun with the 1998 survey year, which is representative of the population aged 65 and older in the United States. In 1998, there were 10,755 respondents aged 65 and older. Of those, 9,589 were still alive in 2006, the last year included in the current study, although additional respondents were added in 2000, 2002, and 2004 who reached age 65 in those waves (1,135, 1,308, and 1,436, respectively).

Measures

The analysis used three dependent variables. The first was a self-report of experiencing a fall in the past 2 years, ascertained according to the question, "Have you fallen down in the last 2 years (or since our last interview)?" The second, asked of those who reported a recent fall, was whether that fall resulted in a serious injury. The question was, "In that fall (or in any of these falls if more than one fall was reported) did you injure yourself seriously enough to need medical treatment?" The third was a variable constructed to represent greater ADL disability, including bathing, dressing, eating, toileting, transferring, and walking across a room. Respondents who reported a greater number of limitations during any 2-year interval were coded as having greater ADL disability. Each dependent variable was dichotomized as a yes-or-no answer.

The primary interest was in the effects of obesity on the risk of falling and, conditional on having fallen, experiencing an injury or greater ADL disability. Because the literature suggests that the effects of body size on the risk of falling and injury may vary according to degree of obesity, five categories were created for weight: underweight (BMI < 18.5 kg/m^2), normal weight (BMI 18.5–29.9 kg/m^2; the reference category in all regression models), obese category 1 (BMI 30.0–34.9 kg/m^2), obese category 2 (BMI 35.0–39.9 kg/m^2), and obese category 3 (BMI $\geq$ 40.0).

Based on the studies cited earlier, several other conditions related to falling were controlled for. Controls were limited to factors it was felt might be particularly related to obesity and for which consistent, reliable measures were available across waves of the HRS. Lower limb disability was operationalized according to reports of difficulty in climbing stairs or walking outside the home. Three health problems indicated in falls were also controlled for: frequent dizziness, chronic pain, and poor eyesight. In addition, self-reported doctor's diagnoses of three disease conditions associated with falls were controlled for: arthritis, diabetes mellitus, and stroke. Because the risk of falls varied according to age, sex, and race (white vs all other), all three were included in the analyses.

Statistical Analysis

Each interval between 1998 and 2006 was examined, measuring baseline characteristics at Time 1 and the experience of a fall, a fall-related injury, or ADL disability at Time 2. Combining the four 2-year intervals yielded 31,602 periods of observation, 9,621 falls, 3,130 injuries from falls, and 4,324 instances of greater ADL disability after a fall. All explanatory variables were measured at the beginning of the wave. A random effects sequential logistic regression model was used, examining the effect of obesity and underweight and then adding in health problems and chronic conditions. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Interaction terms for age and sex were included to determine whether

the effects of body size varied across these dimensions. In addition, in some models, linear and quadratic terms for BMI, rather than obesity category, were included. Model fit was assessed using the Wald chi-square and −2 log likelihood (−2LL) statistics.

RESULTS

Descriptive analyses (not shown) indicated that individuals who had experienced a fall in the previous 2 years were approximately 2 years older than those who had not (75.2 vs 73.3, $P < .001$). Recent fallers were more likely to be female (64.2% vs 58.2%, $P < .001$) and white (88.1% vs 85.7%, $P < .001$). The relationship between weight and experiencing a recent fall appeared to be nonlinear, with obesity and underweight more common than normal weight in those with falls. Of those who experienced a fall, 23.1% were categorized as obese and 4.7% as underweight, compared with 19.7% ($P < .001$) and 4.2% ($P = .03$) of those who did not fall. All of the health problems and chronic conditions examined were more common in those who had fallen. More than one-third of those reporting a fall had a lower body limitation, compared with approximately one-fifth of those who had not fallen ($P < .001$). Pain (37.0% vs 23.6%, $P < .001$), dizziness (9.4% vs 5.6%, $P < .001$), and vision problems (27.2% vs 20.0%, $P < .001$) were more prevalent in those with falls. A small percentage of respondents reported having had a stroke, and those who had fallen were twice as likely as nonfallers to have had a stroke (9.9% vs 5.3%, $P < .001$). Arthritis and diabetes mellitus were also more prevalent in those who had fallen recently (73.7% vs 61.5%, $P < .001$; 21.2% vs 15.3%, $P < .001$, respectively). Differences between the surviving study sample and those who died between 1998 and 2006 were analyzed, and it was found that those who died were more likely to have fallen, to have sustained an injury, and to have developed an ADL disability. Those who died were also less likely to be obese, in any of the three categories, but more likely to have been underweight.

Multivariate regression revealed that age, female sex, and white background were associated with higher risk of falling in any 2-year period (Table 1, Model 1). Greater BMI category was associated with a higher risk of falling. Being underweight was not associated with a higher risk of falls (Model 2), but successive categories of obesity were associated with higher risk of falling. For example, the OR associated with experiencing a fall for people with a BMI of 40.0 kg/m^2 or greater, obesity Class 3, was 2.20 (95% CI = 1.78–2.74), compared with 1.73 (95% CI = 1.44–2.08) for a BMI of 35.0 to 39.9 kg/m^2 and 1.34 (95% CI = 1.21–1.49) for a BMI of 30.0 to 34.9 kg/m^2.

Including health problems reduced the effects of obesity, although all levels of obesity remained statistically significant (Table 1, Model 3). All of the health problems considered were related to significantly higher risks of falling—lower body limitations, pain, dizziness, and poor eyesight—and all three chronic conditions—diabetes mellitus, stroke, and arthritis—also significantly increased the odds of having fallen. In Models 3 and 4, inclusion of the health problems and the three conditions partially explained the effects of all three obesity categories. However, even in the full model, obesity Classes 1, 2, and 3 were still associated with 12%, 26%, and 50% greater risk of having fallen, respectively (OR = 1.12, 95% CI = 1.01–1.24; OR = 1.26, 95% CI = 1.05–1.51; OR = 1.50, 95% CI = 1.21–1.86, respectively). The effect of the interactions between age and sex and body size on the risk of falling was also examined. None of the interaction terms were significant, indicating that the effects of body size do not vary across age or sex (results not shown).

The results for a fall-related injury were slightly different. Age, female sex, and white race remained significantly related to the risk of experiencing a fall-related injury (Table 2, Model 1). Being underweight was not related to

Table 1. Logistic Regression on the Probability of Falling Since the Prior Wave

	Odds Ratio (95% Confidence Interval)			
Characteristic	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Age	1.06 (1.07–1.07)***	1.07 (1.06–1.07)***	1.05 (1.05–1.06)***	1.05 (1.05–1.06)***
Female	1.35 (1.24–1.47)***	1.32 (1.21–1.43)***	1.18 (1.09–1.28)***	1.18 (1.09–1.28)***
White	1.28 (1.13–1.44)***	1.34 (1.19–1.51)***	1.41 (1.25–1.58)***	1.47 (1.31–1.65)***
Obese 1		1.34 (1.21–1.49)***	1.20 (1.08–1.33)***	1.12 (1.01–1.24)*
Obese 2		1.73 (1.44–2.08)***	1.40 (1.17–1.67)***	1.26 (1.05–1.51)*
Obese 3		2.20 (1.78–2.74)***	1.66 (1.34–2.05)***	1.50 (1.21–1.86)***
Underweight		1.14 (0.95–1.36)	1.08 (0.91–1.29)	1.10 (0.93–1.31)
Lower body limitation			1.67 (1.54–1.82)***	1.54 (1.42–1.67)***
Pain			1.57 (1.46–1.70)***	1.45 (1.35–1.57)***
Dizziness			1.28 (1.14–1.45)***	1.23 (1.09–1.39)***
Vision problem			1.17 (1.08–1.27)***	1.12 (1.03–1.21)**
Diabetes mellitus				1.47 (1.34–1.62)***
Stroke				1.73 (1.50–1.98)***
Arthritis				1.48 (1.37–1.61)***
Wald chi-square	502.63	586.35	1,043.00	1,227.57
−2 log likelihood	−18,199.53	−18,154.62	−17,903.26	−17,791.21

* $P < .05$, ** $P < .01$, *** $P < 001$.

Table 2. Logistic Regression on the Probability of Serious Injury Conditional on Falling Since the Prior Wave

	Odds Ratio (95% Confidence Interval)			
Characteristic	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Age	1.04 (1.03–1.04)***	1.03 (1.02–1.04)***	1.03 (1.02–1.04)***	1.03 (1.02–1.04)***
Female	2.02 (1.77–2.30)***	2.03 (1.78–2.32)***	1.98 (1.73–2.26)***	1.98 (1.74–2.27)***
White	1.29 (1.07–1.56)**	1.25 (1.04–1.51)*	1.28 (1.06–1.54)*	1.28 (1.06–1.55)*
Obese 1		0.88 (0.74–1.04)	0.85 (0.72–1.01)	0.85 (0.71–1.00)
Obese 2		0.92 (0.69–1.22)	0.87 (0.66–1.16)	0.86 (0.65–1.15)
Obese 3		0.67 (0.48–0.93)*	0.63 (0.45–0.88)**	0.62 (0.44–0.87)**
Underweight		1.19 (0.91–1.56)	1.18 (0.90–1.54)	1.18 (0.91–1.55)
Lower body limitation			1.14 (1.00–1.29)	1.13 (0.99–1.28)
Pain			1.09 (0.97–1.24)	1.09 (0.96–1.23)
Dizziness			1.03 (0.86–1.24)	1.03 (0.85–1.24)
Vision problem			1.04 (0.92–1.19)	1.04 (0.91–1.18)
Diabetes mellitus				1.06 (0.91–1.23)
Stroke				1.04 (0.86–1.27)
Arthritis				1.04 (0.90–1.19)
Wald chi square	182.07	191.54	200.52	201.45
−2 log likelihood	−5,847.52	−5,842.60	−5,828.28	−5,827.78

* $P < .05$, ** $P < .01$, *** $P < 001$.

the odds of being injured. Only obese people in the most extreme BMI category, Class 3 (≥ 40.0 kg/m^2) were significantly less likely to be injured in a fall (OR = 0.67, 95% CI = 0.48–0.93). None of the health problems (Model 3) or chronic conditions (Model 4) considered were associated with a difference in the odds of experiencing a fall-related injury. Controlling for the health factors somewhat decreased the probability of injury for those in obesity Class 3 (OR = 0.62, 95% CI = 0.44–0.87).

To explore this relationship further, two alternative models were run: one that included a linear and quadratic function of BMI and one with underweight and a dichotomous obesity category (BMI $\geq$ 30.0 kg/m^2). None of the findings changed substantively; for example, Model 4 in Table 2 resulted in obesity being negative and significant, with underweight being positive and nonsignificant. Similarly, the linear function of BMI was significant and negative, and the quadratic function was significant and positive.

Finally, the effect of obesity on ADL disability was examined, conditional on having fallen (Table 3). Model 1 indicated that age and being female were associated with a higher risk of greater ADL disability; subsequent models did not substantively alter the effect of age, but the addition of the obesity measures explained the sex effect. Being white was associated with lower risk of greater ADL disability. In Model 2, all three classes of obesity were associated with higher risk of greater ADL disability after a fall (OR = 1.43, 95% CI = 1.23–1.65; OR = 2.02, 95% CI = 1.60–2.55; OR = 1.94, 95% CI = 1.49–2.53, for obesity Classes 1, 2, and 3, respectively). Being underweight was unrelated to greater ADL disability after a fall.

In Models 3 and 4, it was found that adding health problems and chronic conditions explained some but not all of the effects of obesity. Obesity was significantly associated with a 17% higher risk of greater ADL disability for Class 1 (OR = 1.17, 95% CI = 1.02–1.36) and a 39% higher risk for Class 2 (OR = 1.39, 95% CI = 1.10–1.75).

DISCUSSION

The first hypothesis was that obese older adults would be more likely to fall than others. The results indicated this was true, although chronic conditions and health problems somewhat explained the relationship between obesity and propensity to fall. The second hypothesis was that underweight older adults would be more at risk of sustaining injury in a fall. The direction of the relationship between being underweight and being injured in a fall was the one that was anticipated, but it did not reach the level of significance, although a protective effect in obesity Class 3 (BMI $\geq$ 40.0 kg/m^2) was found, with these people significantly less likely to be injured in a fall than normal-weight individuals. The third hypothesis was that people who were obese would be more likely to develop greater ADL disability after a fall. The results partially supported this hypothesis, with Class 1 and 2 obesity related to greater likelihood of greater ADL disability after a fall. The fact that Class 3 obesity was not related to greater ADL disability after a fall may be related to selective mortality. These relationships did not appear to vary according to age or sex.

Evidence was found that the effect of weight on the risk of falling appeared to be linear; greater obesity was related to greater risk of falling, although this linearity was not seen with respect to fall-related injury or ADL disability. For example, only individuals in obesity Class 3 were significantly less likely than normal-weight individuals to report a serious fall-related injury, possibly because of the presence of excess soft tissue over the areas most vulnerable to breaking.[19] Alternative modeling strategies, one using linear and quadratic functions of BMI and one with underweight and a dichotomous obesity category (BMI $\geq$ 30.0 kg/m^2), did not substantively change the results. The findings indicated, then, that the effect of weight on falls, injury, and greater ADL disability was important but not strictly linear. It was less clear that the three categories of obesity were truly meaningful.

Table 3. Logistic Regression on the Probability of Greater Activity of Daily Living Disability Conditional on Falling Since the Prior Wave

	Odds Ratio (95% Confidence Interval)			
Characteristic	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Age	1.06 (1.05–1.07)***	1.06 (1.06–1.07)***	1.05 (1.04–1.06)***	1.05 (1.04–1.06)***
Female	1.12 (1.00–1.25)*	1.09 (0.98–1.22)	0.93 (0.83–1.03)	0.94 (0.84–1.04)
White	0.64 (0.55–0.74)***	0.68 (0.58–0.79)***	0.79 (0.68–0.92)**	0.80 (0.69–0.93)**
Obese 1		1.43 (1.23–1.65)***	1.21 (1.05–1.40)**	1.17 (1.02–1.36)*
Obese 2		2.02 (1.60–2.55)***	1.44 (1.15–1.82)**	1.39 (1.10–1.75)**
Obese 3		1.94 (1.49–2.53)***	1.36 (1.05–1.76)*	1.29 (1.00–1.68)
Underweight		1.11 (0.88–1.41)	1.02 (0.81–1.29)	1.05 (0.83–1.33)
Lower body limitation			2.41 (2.16–2.69)***	2.26 (2.02–2.53)***
Pain			1.42 (1.27–1.58)***	1.36 (1.21–1.52)***
Dizziness			1.25 (1.07–1.47)**	1.21 (1.04–1.42)*
Vision problem			1.42 (1.27–1.58)***	1.38 (1.23–1.54)***
Diabetes mellitus				1.21 (1.07–1.37)**
Stroke				1.51 (1.30–1.76)***
Arthritis				1.26 (1.10–1.43)**
Wald chi square	240.05	295.05	785.32	821.56
−2 log likelihood	−4,983.88	−4,952.07	−4,691.11	−4,665.85

* $P < .05$, ** $P < .01$, *** $P < 001$.

Limitations of this study include reliance on self-report of functioning, disease presence, and health conditions, which are subject to bias, albeit probably not systematically. The exception is the propensity of adults to overestimate height and underestimate weight, which tends to minimize BMI and thus underestimate those who would be classified as obese. In addition, BMI is an imperfect measure of obesity but the only consistent measure available in the HRS. These findings provide the impetus for further examination of the relationship in data sets with more-detailed measure of adiposity and weight distribution. Detailed information was lacking on hospitalizations related to falls, fractures, and other health services usage related to a fall that would be helpful in further analyzing the effects of body size on the type and extent of any injury suffered in a fall. Another concern that must be addressed in any longitudinal analysis is attrition. The likely result of these differences is a slight underestimation of the findings. Those who died were less likely to be obese, in any of the three categories, but more likely to have been underweight.

Finally, the HRS data offer a unique opportunity to examine the question of falls, fall-related injuries, and disability in a late middle-aged and older population, but the study did not include measures of several important risk factors, including frequently prescribed medications, serum parathyroid hormone, vitamin D, postural balance measures, and more-detailed measures of adiposity, such as waist circumference, waist-to-hip ratio, dual-energy X-ray absorptiometry measures of body composition, and many others.[14–17] Other factors to be considered in future research are the roles of cognitive status, depression, and fear of falling. Nevertheless, these results demonstrate a complex relationship between weight and the propensity to fall, be injured, or develop ADL disability due to a fall, a relationship that deserves much more rigorous examination. Considering the problems that can be anticipated with future cohorts of obese older adults, further study on the health effect of gradations of low and high weight are critical for an understanding of how to manage potentially disabled individuals.

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