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The Association of BMI With Functional Status and Self-rated Health in US Adults

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Objective: To examine the association of BMI with functional status and self-rated health among US adults and how the association differs by age and sex.

Methods and Procedures: All analyses are based on the National Health Interview Survey (NHIS), 1997–2005, a yearly, representative study of the US household population. We pooled all survey years and fitted logistic regression for the two sexes and three age strata (ages 18–44, 45–64, and ≥65).

Results: Our study found that although underweight and severe obesity are consistently associated with increased disability and poorer health status, overweight and moderate obesity show associations that vary considerably by age and sex. For men, the adjusted odds ratios (ORs) for disability and poor/fair self-rated health tended to be lowest among overweight persons, especially for ages ≥45. Among men with moderate obesity, the risk of disability was elevated for ages 18–44 but lower for ages ≥65. For women, the adjusted ORs for disability and poor/fair self-rated health tended to be lowest among normal-weight persons, particularly for ages ≤45. Compared to normal-weight counterparts, overweight women aged ≥65 had a lower risk of disability but a somewhat elevated risk of poor/fair self-rated health.

Discussion: The results suggest that the association of BMI with functional status and self-rated health varies significantly across ages and sexes. The variations in the association of BMI with functional status and self-rated health suggest that a single "ideal body weight category" may not be appropriate for all persons or all health outcomes.

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INTRODUCTION

Clinical consensus panels and public health organizations have recommended weight loss in all persons with a BMI ≥ 30 kg/m^2, or with risk factors (such as obesity-associated diseases or cardiovascular risk factors) and a BMI ≥ 25 kg/m^2 (1–4). These recommendations are based on past findings showing that obesity increases the risk of several adverse health outcomes, such as hypertension, diabetes, renal disease, cardiovascular disease, some cancers, and mortality. In contrast to obesity, the health consequences associated with overweight (i.e., BMI 25 to <30 kg/m^2) are less clear. Most of the epidemiological studies examined in the National Heart, Lung, and Blood Institute report indicated a very modest increase in mortality associated with a BMI of 25–30 kg/m^2 (1,2). More recently, studies have found that overweight is unrelated to increased mortality (5–9). A focus on mortality, however, may not capture the full health impact of overweight.

Evidence is also mixed about the effect of overweight on health-related quality of life. In one of the few, large-scale, population-based studies, overweight women fared worse than normal-weight women in terms of "physically unhealthy days" and "activity limitation days," but overweight men had fewer unhealthy days than normal-weight men (10). Another study examining more commonly used measures of health-related quality of life such as the Short Form 12 and the EuroQol EQ-5D found overweight to be negatively associated with some health measures but not with others (11). Fewer studies have examined the relationship between body weight and functional status, and although some found that overweight was associated with poorer functional status, others did not (10,12,13). Functional status, when measured as the reported ability to carry out major tasks of daily living, is a significant contributor to health-related quality of life and is highly predictive of subsequent morbidity and mortality (14–16). Using the ongoing National Health Interview Survey (NHIS), a nationally representative study of the US population, we examine the relationship between relative body weight and functional status and self-rated health in US adults.

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METHODS AND PROCEDURES

Overall design and study population

The analyses are based on data from the NHIS for the years 1997–2005. The NHIS is a yearly, nationally representative study of the health of the civilian, non-institutionalized, household population of the United States (17). The study collects detailed information about participants' health, demographic characteristics, and socioeconomic information. The interviewed samples include ~43,000 households, or ~106,000 persons, each year. Although the NHIS has been conducted continuously since 1957, the study has undergone major redesign every 10–15 years (18). The last major redesign was implemented in 1997.

BMI

We calculated BMI as weight in kilograms divided by the square of height in meters. Height and weight data were self-reported. We followed the 1998 National Heart, Lung, and Blood Institute clinical guidelines (2) and classified BMI into six groups: underweight <18.5 kg/m^2; normal weight 18.5 to <25 kg/m^2; overweight 25 to <30 kg/m^2; obesity class I 30 to <35 kg/m^2; obesity class II 35 to <40 kg/m^2; and obesity class III ≥40 kg/m^2.

Definitions of primary outcomes

We used self-reported disability and self-rated health status as the primary outcomes. Disability was defined as any limitation in either activities of daily living or instrumental activities of daily living. Activities of daily living limitation was defined as needing "the help of other persons with personal care needs such as eating, bathing, dressing, or getting around inside the home" and instrumental activities of daily living limitation was defined as needing "the help of other persons in handling routine needs, such as everyday household chores, doing necessary business, shopping, or getting around for other purposes."

Self-rated health status was an ordinal variable that rated general health on a 5-point rating scale ranging from "excellent" to "poor." Respondents were asked, "Would you say your health in general is excellent, very good, good, fair, or poor?" Responses were "excellent," "very good," "good," "fair," "poor," "refused," "not ascertained," or "don't know." This self-rated measure of health status has been used widely in the literature and was shown to be a significant predictor of mortality and health care utilization, even after controlling for risk factors and clinically defined health conditions (19,20). For this study, we estimated the probability that a survey participant reported that his or her overall health was either "fair" or "poor."

Auxiliary analysis

In the case of respondents with disability, we performed additional analysis to gain insights into factors underlying or mediating the relationship between their BMI group and functional limitation. Specifically, we looked at a question in the NHIS in which respondents reported having at least one functional limitation were asked, "What conditions or health problems cause you {person} limitations?" The list of the possible responses was comprehensive and included conditions that ranged from vision problem, back/neck problem, heart problem, cancer, to depression/anxiety/emotional problem and alcohol/drug/substance abuse problem. A complete list of the 36 possible responses is given in the **Supplementary Data S1** online.

Statistical analysis

All analyses were conducted using SAS for Windows version 8.2 (SAS Institute, Cary, NC), SAS-Callable SUDAAN version 9.0 (RTI International, Research Triangle Park, NC), and Stata/SE 9.2 for Windows (StataCorp LP, College Station, TX). For all survey years, sampling weights were included that took into account complex survey design, non-response, and oversampling of some population groups such as African Americans and Hispanics. We pooled all survey years and fitted logistic regression for the two sexes and three age strata (ages 18–44, 45–64, and ≥65 years). This design allowed us to assess whether the association between BMI group and the outcomes varied by sex and age. The normal-weight category (BMI 18.5 to <25 kg/m^2) was used as the reference group. All logistic models were adjusted for race, education, employment status, smoking status, and survey year. Results from the regression are presented as adjusted odds ratio (OR) and 95% confidence interval. For the auxiliary analysis, we fitted logistic regression for respondents who reported having disability and estimated by BMI group the age-adjusted prevalence of each of the 36 limitation-causing conditions or health problems. We also estimated the age-adjusted BMI group gradient for each condition/health problem and performed hypothesis testing using Zellner's seemingly unrelated regressions estimation, a method of analyzing a set of regression equations with correlated disturbances and cross-equation restrictions (21).

RESULTS

Characteristics of the study population

The characteristics of the study population are presented in **Table 1**. We found a significant association between BMI group and sex (F-test $P < 0.01$). The mean BMI was 27.08 kg/m^2 for men and 26.29 kg/m^2 for women, with a difference of 0.83 kg/m^2 (t-test $P < 0.01$). Men are 16.4 (95% confidence interval 16.0–16.8) percentage points more likely than women to be overweight, and women are 2.8 (2.5–3.2) percentage points more likely than men to be obese.

There were significant differences in the mean BMI across age groups for both men and women (adjusted Wald F-test $P < 0.01$). The prevalence of obesity among men aged 45–64 had was 6.0 (5.4–6.6) percentage points higher than those aged 18–44 and 8.0 (7.3–8.8) percentage points higher than those ≥65. Similarly, the prevalence of obesity among women aged 45–64 was 8.2 (7.7–8.8) and 7.7 (7.0–8.4) percentage points higher than those aged 18–44 and ≥65, respectively.

We also found significant differences in the mean BMI across race and education groups as well as by smoking and working status (adjusted Wald F-test all $P < 0.01$ for both men and women). African Americans had a higher mean BMI than white counterparts. African-American men were 4.8 (3.9–5.7) percentage points more likely than white men to be obese, and African-American women were 14.2 (13.4–15.1) percentage points more likely than white women to be obese. The prevalence of obesity declined with the level of education at the rate of 3.1 (2.9–3.3) percentage points per education group, and it declined faster for women than for men (t-test for interaction with education and sex $P < 0.01$). For men, smokers were 4.7 (4.1–5.3) percentage points more likely than non-smokers to be obese, whereas for women, the difference between the two groups was 4.3 (3.7–4.9) percentage points. Although among women, employed persons had slightly lower prevalence of obesity than those who were not (with a difference of 1.9 (1.4–2.5) percentage points), among men, there was minimal difference in the prevalence of obesity between employed and unemployed persons (with a difference of 0.7 (0.1–1.2) percentage points).

Adjusted ORs by age and sex

Adjusted ORs for disability and self-rated health are shown in **Table 2** for each BMI group. The reference group is the

Table 1 Characteristics of the study population

	All	Underweight	Normal weight	Overweight	Obese I	Obese II	Obese III	Obese I, II, III	Mean BMI (s.d.)	ANOVA
Men										
BMI distribution, no. (%)	123,356 (100)	1,086 (0.9)	40,656 (33.6)	52,926 (42.7)	19,062 (15.3)	5,241 (4.2)	4,385 (3.4)	28,688 (22.8)		
Age in years (%)										
18–44	64,621	1	37.2	40.5	13.9	4	3.4	21.3	26.8 (5.7)	
45–64	38,357	0.6	26.3	45.8	18.3	5.2	3.8	27.3	27.9 (4.7)	*
65+	20,378	1.3	35.6	43.7	14	3	2.3	19.3	26.6 (3.9)	
Race (%)										
White	100,611	0.9	33.1	43.4	15.3	4.2	3.1	22.6	27.1 (4.5)	*
African American	14,984	0.9	31.5	40.2	17.3	5.3	4.8	27.4	27.6 (5.6)	
Education (%)										
Less than HS	21,688	1.5	34.7	39	16.0	4.3	4.5	24.8	27.0 (5.4)	*
HS	37,773	1.1	31.8	41.8	16.7	4.8	3.8	25.3	27.3 (5.2)	
Some college	33,630	0.8	32.7	42.6	16.0	4.7	3.2	23.9	27.3 (5.1)	
College	30,265	0.5	35.9	45.8	12.5	2.9	2.4	17.8	26.6 (3.9)	
Employment status (%)										
Working	87,536	0.7	32.4	43.9	15.6	4.3	3.2	23	27.2 (4.6)	*
Not working	35,811	1.6	36.6	39.5	14.5	4.1	3.8	22.4	26.8 (5.6)	
Smoking status (%)										
Smoke	32,054	1.4	40.1	39.2	13.1	3.6	2.6	19.4	26.4 (4.7)	*
Do not smoke	91,302	0.7	31.3	43.9	16	4.4	3.6	24	27.3 (4.1)	
Women										
BMI distribution, no. (%)	160,708 (100)	4,651 (3.1)	69,323 (45.0)	43,396 (26.3)	21,615 (12.7)	8,450 (5.0)	13,273 (8.0)	28,688 (25.7)		
Age in years (%)										
18–44	79,855	3.7	50.9	22.5	11.1	4.5	7.5	23.1	25.7 (5.7)	*
45–64	47,225	1.7	37.9	29.1	14.9	6.3	10.2	31.3	27.4 (7.1)	
65+	33,628	3.6	41.7	31.0	13.3	4.2	6.2	23.7	26.1 (5.8)	
Race (%)										
White	126,508	3.2	46.8	25.9	12.0	4.4	7.7	24.1	26.0 (7.2)	*
African American	24,763	1.6	29.9	30.2	18.4	8.9	11.1	38.3	28.8 (7.0)	
Education (%)										
Less than HS	29,495	3.1	34.9	30.1	16.4	6.6	8.9	32.0	27.5 (7.1)	*
HS	51,261	2.9	41.3	28.1	13.8	5.2	8.7	27.7	26.9 (5.7)	
Some college	46,186	3.1	45.5	25.6	12.5	5.2	8.0	25.8	26.3 (5.9)	
College	33,766	3.3	56.0	22.3	9.0	3.1	6.4	18.5	24.9 (6.0)	
Employment status (%)										
Working	89,808	2.8	47.2	25.3	12.2	4.8	7.8	24.8	26.1 (6.0)	*
Not working	70,889	3.5	42.1	27.7	13.4	5.1	8.3	26.8	26.5 (5.9)	
Smoking status (%)										
Smoke	32,781	4.6	48.2	24.9	11.3	4.4	6.5	22.3	25.7 (6.3)	*
Do not smoke	127,927	2.7	44.1	26.7	13.0	5.1	8.4	26.6	26.5 (6.7)	

BMI distribution is in no. (%). Mean BMI (standard deviation) is in kg/m^2. The rest of the data is in %. BMI group is defined as: underweight <18.5 kg/m^2; normal weight 18.5 to <25 kg/m^2; overweight 25 to <30 kg/m^2; obesity class I 30 to <35 kg/m^2; obesity class II 35 to <40 kg/m^2; and obesity class III ≥40 kg/m^2.
*Adjusted Wald *F*-test for the mean differences in the BMI $P < 0.01$.

Table 2 Adjusted odds ratio for the association between BMI and disability and self-rated health among US adults, 1997–2005, by age and sex

	Men			Women		
	18–44 OR (95% CI)	45–64 OR (95% CI)	65+ OR (95% CI)	18–44 OR (95% CI)	45–64 OR (95% CI)	65+ OR (95% CI)
Disability						
Underweight	1.92 (1.09–3.40)	2.76 (1.75–4.35)	3.67 (2.64–5.09)	1.97 (1.42–2.75)	3.35 (2.53–4.44)	2.43 (2.09–2.82)
Normal weight	1.00	1.00	1.00	1.00	1.00	1.00
Overweight	0.98 (0.78–1.23)	0.71 (0.61–0.83)	0.60 (0.53–0.68)	1.41 (1.16–1.72)	1.10 (0.95–1.28)	0.87 (0.80–0.95)
Obese I	1.60 (1.23–2.09)	0.86 (0.71–1.05)	0.63 (0.53–0.75)	1.91 (1.53–2.39)	1.49 (1.28–1.74)	1.14 (1.03–1.26)
Obese II	1.70 (1.17–2.49)	1.47 (1.14–1.89)	0.98 (0.73–1.33)	2.51 (1.92–3.29)	2.49 (2.07–2.98)	1.54 (1.31–1.80)
Obese III	2.88 (2.12–3.90)	2.38 (1.87–3.03)	1.83 (1.39–2.41)	3.04 (2.46–3.77)	2.58 (2.18–3.06)	1.83 (1.61–2.07)
Poor/fair self-rated health						
Underweight	2.29 (1.69–3.12)	3.07 (2.05–4.59)	2.71 (2.05–3.59)	1.47 (1.23–1.77)	2.57 (2.08–3.17)	1.74 (1.50–2.02)
Normal weight	1.00	1.00	1.00	1.00	1.00	1.00
Overweight	1.12 (1.01–1.23)	0.86 (0.78–0.94)	0.88 (0.81–0.96)	1.47 (1.34–1.61)	1.39 (1.27–1.52)	1.11 (1.03–1.20)
Obese I	1.89 (1.67–2.14)	1.34 (1.21–1.49)	1.10 (0.99–1.22)	2.20 (1.99–2.44)	2.12 (1.94–2.33)	1.46 (1.34–1.60)
Obese II	3.08 (2.57–3.69)	2.16 (1.87–2.50)	1.71 (1.37–2.12)	2.95 (2.62–3.34)	2.99 (2.65–3.38)	2.05 (1.79–2.36)
Obese III	2.91 (2.49–3.42)	2.62 (2.20–3.11)	1.76 (1.43–2.18)	3.54 (3.18–3.94)	2.75 (2.47–3.06)	1.97 (1.76–2.21)

Data are ORs (95% confidence intervals (CIs)). ORs are adjusted for age, race, education, survey year, employment status, and smoking status. BMI group is defined as: Underweight <18.5 kg/m^2; normal weight 18.5 to <25 kg/m^2; overweight 25 to <30 kg/m^2; obesity class I 30 to <35 kg/m^2; obesity class II 35 to <40 kg/m^2; and obesity class III ≥40 kg/m^2.

normal-weight category. The estimated ORs for both disability showed significant variation by age and sex (adjusted Wald *F*-tests for interactions with each age and sex $P < 0.01$). Among men, the estimates for disability tended to be significantly elevated for underweight persons, lowest among overweight persons, and then increasing across the obese categories. We also found several age-related differences: for ages 18–44, the risk of overweight was not statistically different from that of normal weight (OR 0.98 (95% confidence interval 0.78–1.23)). Among men with class I obesity, the risk of disability was significantly elevated for ages 18–44 only (1.60 (1.23–2.09)), but for ages ≥65, the risk was significantly lower (0.63 (0.53–0.75)). Class II obesity was associated with a higher risk of disability among men aged <65 (1.70 (1.17–2.49) for ages 18–44; 1.47 (1.14–1.89) for ages 45–64) but not among those aged ≥65 (0.98 (0.73–1.33)).

We also found a J-shaped relationship between BMI group and disability among women: the adjusted ORs for disability tended to be higher for underweight persons, lowest among normal weight or overweight persons, and again increasing across the obese categories. The estimate for disability was lowest among normal-weight persons if they were aged 18–44, and among overweight persons if they were aged ≥65 (0.87 (0.80–0.95)). For ages 45–64, the OR for overweight persons was not statistically different from that for normal-weight persons (1.10 (0.95–1.28)).

The patterns of results for self-rated health were largely similar to those for disability. The adjusted ORs for poor/fair self-rated health tended to be higher for underweight persons, lowest for overweight (for men) and normal-weight (for women) persons, and then increasing across the obese categories. There were also some differential results: unlike the case of disability, overweight was associated with an elevated risk of poor/fair self-rated health for ages 18–44 (1.12 (1.01–1.23)). Also, obese I men aged 45–64 and obese II men aged ≥65 had a higher risk of poor/fair self-rated health: (1.34 (1.21–1.49) for obese I men aged 45–64 and 1.71 (1.37–2.12) for obese II men aged ≥65), respectively. Overweight women aged ≥65 had a lower risk of disability compared to normal-weight counterparts, but had a somewhat elevated risk of poor/fair self-rated health (1.11 (1.03–1.20)). For both men and women, the adjusted ORs for disability and poor/fair self-rated health associated with underweight tended to increase across the age groups (adjusted Wald *F*-test $P = 0.09$ for men, $P = 0.10$ for women), whereas the ORs associated with obesity declined across the age groups ($P < 0.01$ for both men and women).

Auxiliary analysis

The age-adjusted prevalence of the most important conditions/health problems for adults with disability is shown by BMI group in **Figure 1** for men (a) and women (b). Among men with disability, arthritis/musculoskeletal problem had a significantly higher age-adjusted BMI group gradient than any other conditions (adjusted Wald *F*-test $P < 0.01$). The estimated gradient of 3.22 (95% confidence interval 2.72–3.71) percentage points per BMI group means that moving from underweight to class III obesity was associated with a 19 percentage points increase in the likelihood that the respondent ascribed the cause of the functional limitation to arthritis/musculoskeletal problem. Arthritis/musculoskeletal problem also had a significantly higher BMI group gradient than other conditions for women ($P < 0.01$). Women had a BMI group gradient of 4.19 (3.85–4.53), and this estimate was significantly higher than

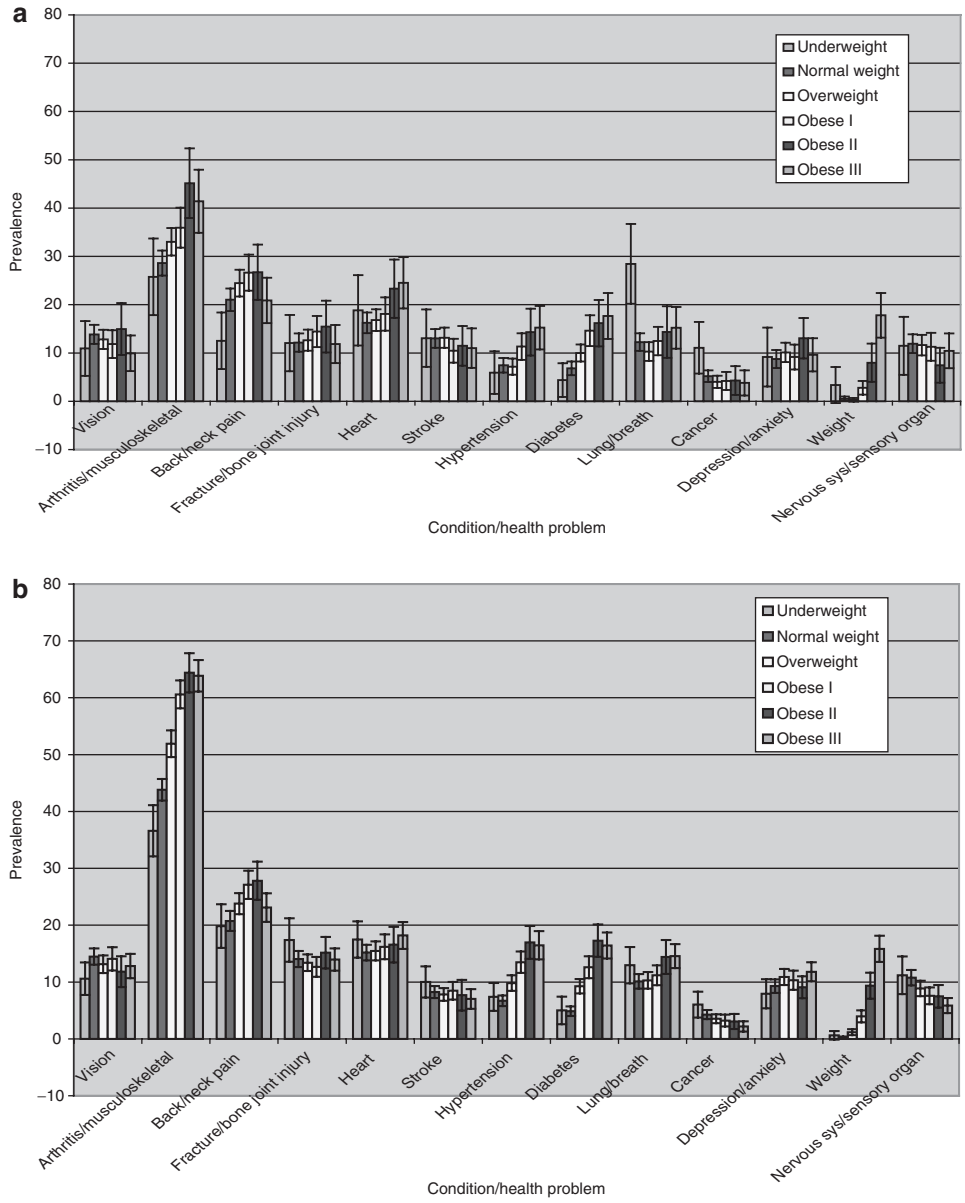

Figure 1 BMI group is defined as: Underweight <18.5 kg/m^2; normal weight 18.5 to <25 kg/m^2; overweight 25 to <30 kg/m^2; obesity class I 30 to <35 kg/m^2; obesity class II 35 to <40 kg/m^2; and obesity class III ≥40 kg/m^2. (**a**) Men; (**b**) women.

that of men ($P = 0.024$). Weight problem *per se* was also found to be an important cause of disability in men (2.14 (2.00–2.28)) and women (2.40 (2.30–2.50)), and again, it was more so for women than for men ($P < 0.01$).

Other conditions/health problems with a significant BMI group gradient among men included diabetes (1.35 (1.18–1.52)); heart problem (1.01 (0.74–1.27)); hypertension (0.94 (0.77–1.12)); and fracture/bone joint injury (0.38 (0.03–0.72)). For women, they were: hypertension (1.19 (1.09–1.29)); diabetes (1.14 (1.06–1.22)); lung/breathing problem (0.64 (0.48–0.80)); and heart problem (0.42 (0.29–0.54)). Heart problem had a bigger BMI group gradient for men than for women ($P = 0.01$), while diabetes and hypertension were equally important for men and women ($P = 0.47$ for diabetes; $P = 0.15$ for hypertension).

DISCUSSION

Using large, cross-sectional, representative surveys of the US population repeated annually over the past 9 years, we examined the association of BMI with functional status and with self-rated health. Our study found that although underweight and severe obesity are consistently associated with increased disability and poorer health status, overweight and moderate obesity show associations that vary considerably by age and sex. For men, the adjusted ORs for disability and poor/fair self-rated health tended to be lowest among overweight persons, especially for ages ≥45. Among men with class I obesity, the risk of disability was elevated for ages 18–44 but lower for ages ≥65. Class II obesity was associated with a higher risk of disability and self-rated health, in particular for age ≤45. For women, the adjusted ORs for disability and poor/fair self-rated health

tended to be lowest among normal-weight persons, especially if they are aged ≤45. Compared to normal-weight counterparts, overweight women aged ≥65 had a lower risk of disability but a somewhat elevated risk of poor/fair self-rated health. The differences in these associations by age and sex seen in this study may explain why previous studies found inconsistent relationships between overweight and health status (10,11).

Additional analyses showed that three factors are particularly important in explaining the association of BMI with functional status: (i) arthritis/musculoskeletal problems; (ii) weight problem *per se*; and (iii) vascular conditions such as diabetes, hypertension, and heart problem. These findings are consistent with previous literature claiming that obesity influences disability through its association with osteoarthritis and vascular diseases (2,22–30). The results also show that disability risk associated with overweight and obesity is greater for women than for men. There are other studies that found that overweight and obesity elevate the risk of developing osteoarthritis to a great extent in women than in men (2,22).

Our study reinforces findings from several epidemiological studies that found variations in the associations between relative body weight and health status across different subgroups (10,31–34). Prospective studies have also supported the finding that overweight and obesity have a greater effect on younger adults than on older ones (27–28). The findings are also consistent with population-based studies showing sex differences in the association of overweight and obesity with health-related quality-of-life measures. Most of these observational studies found that overweight and obesity were associated with a higher excess health risk among women than among men (10,31,33–34). Population-based surveys of mental health likewise have suggested that overweight and obesity have a larger psychological effect among women than among men (10,35). In a recent study of older British men, overweight men fared worse than normal-weight men in terms of cardiovascular disease and its risk factors but not in terms of disability and general health (36).

Several hypotheses have also been proposed to explain the age-related differences in the BMI–morbidity relationship. One hypothesis is that older adults have larger waist circumferences than younger adults, contributing to a higher risk of mortality for the same level of BMI (37). Some investigators have emphasized the "selection" factor: adults most sensitive to the adverse health consequences of obesity are more likely to have died before reaching old age, leaving only those who are more resilient to the health effects of obesity (2).

This study had a large sample size, which enabled us to estimate both age- and sex-stratified models with a single data source. This is also one of the few existing studies that used nationally representative surveys of the health of the US population to examine the association between BMI and functional limitation.

The study also has a number of limitations. First, these data are observational, and residual confounding by unmeasured covariates may have biased our results. For example, we did not control for coexisting medical conditions, so that if underweight persons were systematically in poorer health, their high rate of disability may be a result of their poorer health rather than their BMI. Changes in BMI may also be a marker of decreased physical activity (38), negatively affecting self-rated health. Second, these data are cross-sectional in nature, making it difficult to ensure that the outcome, disability, was not a cause of the exposure, BMI. For example, disabled persons may be less physically active and more prone to gaining weight than able-bodied persons. However, there is little evidence to indicate that disability leads to the subsequent onset of obesity (39). Third, our study used self-reported, rather than measured, height and weight (in some cases proxy-reported). It is well established that heavier persons underreport their weight more than leaner persons, and that women underreport more than men (40,41). If the overweight category included some persons who were actually obese, then we may have overestimated the deleterious impact of overweight on disability and health status. In addition, our finding that overweight was associated with increased disability among women, but not among men, may be in part an artifact of greater underreporting of body weight in women.

Our study has some important implications. First, the results suggest that for men, the risk of developing disability may begin to rise at a BMI of 30 kg/m^2. This general result does not apply to women. Second, the observed heterogeneity in the association of BMI with functional status and self-rated health suggests that using a single "ideal body weight category" may not be appropriate for all persons or for all health outcomes (6,42). Future research is needed to understand better why age- and sex-related differences exist in the association between BMI and disability.

SUPPLEMENTARY MATERIAL

Supplementary material is linked to the online version of the paper at http://www.nature.com/oby.

DISCLOSURE

The authors declared no conflict of interest.

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