The Effect of Obesity on Disability vs Mortality in Older Americans

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Background: The association between obesity and mortality is reduced or eliminated in older subjects. In addition to mortality, disability is an important health outcome. The objectives of this study were to examine the association between body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, and subsequent disability and mortality among older Americans, as well as to estimate the effect of BMI on life expectancy and disability-free life expectancy among older Americans.

Methods: We studied 8359 non-Hispanic white Americans, 1931 African Americans, and 2435 Mexican Americans 65 years or older who were not disabled at baseline from 5 sites of the Established Populations for Epidemiologic Studies of the Elderly. Measures included BMI, medical conditions, activities of daily living, and demographic information. Cox proportional hazards regression analysis was used to estimate the hazard ratios (HRs) for subsequent disability and mortality during 7 years of follow-up. Total life expectancy and disability-free life expectancy were estimated using the interpolation of Markov chain approach.

Results: The lowest HR (1.02; 95% confidence interval [CI], 0.94-1.10) for disability was at a BMI of 25 to less than 30. Subjects with BMIs of lower than 18.5 or 30 or higher at baseline were significantly more likely to experience disability during the follow-up period. In contrast, the lowest HRs for mortality were seen among subjects with BMIs of 25 to less than 30 (HR, 0.78; 95% CI, 0.72-0.85) and 30 to less than 35 (HR, 0.80; 95% CI, 0.72-0.90), with subjects with BMIs of lower than 25 or 35 or higher experiencing higher hazards for mortality. Disability-free life expectancy is greatest among subjects with a BMI of 25 to less than 30.

Conclusion: Assessments of the effect of obesity on the health of older Americans should account for mortality and incidence of disability.

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produces lower BMIs and increased mortality. This finding has, in turn, led to calls for increasing the recommended BMI from its current range of 18.5 of less than 25 to higher values for older subjects. Other investigators have disagreed, attributing the decrease in risk of mortality associated with higher BMIs among older persons to flaws in study design and to the fact that BMI is a less accurate measure of adiposity in older subjects.

Previous research and discussions have focused on the effect of BMI on mortality. However, there are many important measures of health in addition to mortality. Diehr et al suggested that “it may be preferable to base desirable weight on other outcomes, such as disability or risk of disease.” Several studies have found an effect of obesity on health outcomes such as disability, and the magnitude of the association is comparable to or greater than the association between obesity and mortality.

We examined the association between BMI and subsequent mortality and incident disability during 7 years and estimated the effect of BMI on life expectancy and disability-free life expectancy in 12 725 initially nondisabled men and women enrolled at the 5 sites (East Boston, Mass; Iowa and Washington counties [Iowa]; New Haven, Conn; and North Central, NC) for the Established Populations for Epidemiologic Studies of the Elderly (EPESE). We hypothesized that a higher BMI would be associated with greater disability, greater mortality, and lower disability-free life expectancy across all racial/ethnic groups.

METHODS

SAMPLE AND PROCEDURES

This study is based on data from the 5 sites of the EPESE, a series of prospective cohort studies of community-dwelling persons 65 years or older in the United States. We studied 8359 non-Hispanic white Americans, 1931 African Americans, and 2435 Mexican Americans 65 years or older who were not disabled at baseline. These studies are described briefly herein and in detail elsewhere. The baseline surveys performed between 1982 and 1983 involved the entire population 65 years or older living in East Boston, Mass (1982-1989 [n = 3797]) and in 2 rural counties of Iowa (Iowa and Washington) (1982-1989 [n = 3643]) and a stratified random sample of the New Haven, Conn, population (1982-1989 [n = 2735]). In 1986, this survey was extended to a fourth site in Durham, NC (1986-1993 [n = 4133]), and in 1993 the Hispanic EPESE (H-EPESE) surveyed 3050 subjects in persons from 3 southwestern states (Texas, California, Arizona, Colorado, and New Mexico). All subjects in the H-EPESE were Mexican Americans. Follow-up data were collected annually for 7 years using in-person interviews (at baseline and the third and sixth follow-ups) and telephone interviews (at the first, second, fourth, and fifth follow-ups) for East Boston, rural Iowa, New Haven, and Durham. Subjects from the H-EPESE site were followed up for 7 years in person (at baseline and at 2, 5, and 7 years). The response rate at baseline ranged from 80% to 85% for all sites. At baseline and at each follow-up interview for all EPESE sites, interviewers gathered information on health conditions, sociodemographics, and psychosocial characteristics of the subjects or their proxies. In addition, blood pressure, anthropometric measurements, and upper and lower body physical function measures were obtained.

MEASUREMENTS

For East Boston, rural Iowa, New Haven, and Durham, height and weight were obtained by self-report at baseline. Height and weight were measured at baseline in the H-EPESE. Body mass index was grouped according to the National Institutes of Health obesity standards (<18.5, underweight; 18.5-24.9, normal weight; 25.0-29.9, overweight; 30.0-34.9, obesity category I; 35.0-39.9, obesity category II; and ≥40.0, extreme obesity). Functional disability was assessed by self-report using 7 items from a modified version of an ADL scale by Branch et al. Activities of daily living included bathing, grooming, dressing, eating, using the toilet, walking across a small room, and transferring from a bed to a chair. Activity of daily living disability was dichotomized as needing no help vs needing help with performing or being unable to perform 1 or more of the 7 ADL activities.

COVARIATES

Sociodemographic variables included age, sex, and years of formal education. Race/ethnicity was determined by self-report. Smoking status was assessed by asking subjects whether they were current smokers, former smokers, or never smokers. The presence of medical conditions was assessed by asking if subjects had ever been told by a physician that they had cancer, hypertension, diabetes mellitus, or a hip fracture, or had ever had a heart attack or stroke.

STATISTICAL ANALYSIS

Cox proportional hazards regression analysis was used to estimate the hazard ratio of incidence of ADL disability and the hazard ratio of mortality at each follow-up as a function of BMI category at baseline among 12 725 subjects who reported no limitation in ADLs at baseline. Those subjects who died or were unable to be located were censored at the date of last follow-up (last interview date for the 7-year follow-up). Analyses for disability and mortality were stratified by sex, EPESE site, race/ethnicity, and age (65-74 vs ≥75 years). All analyses were controlled for age, sex, marital status, smoking status, years of formal education, and selected medical conditions.

Body mass index was also analyzed as a continuous variable on disability and mortality using Martingale residuals from Cox proportional hazards models adjusted for relevant covariates. Applying the locally weighted scatterplot smooth
method\(^2\) to the Martingale residuals, we found a J-shaped or U-shaped association between BMI and disability or mortality. The location knot (inflection point) on the curves was estimated by nonlinear least squares regression analysis\(^2\) and then was used to fit piecewise Cox proportional hazards models to estimate the hazard ratios from BMIs of 15 to 40. Three models were estimated. Model 1 was adjusted for baseline comorbidity, model 2 was not adjusted for comorbidity, and model 3 excluded current smokers and those who died during the first 2 years of follow-up and was controlled for comorbidity.

We also estimated total life expectancy and disability-free life expectancy jointly for the sample of EPESE subjects who were not disabled at baseline. We used the interpolation of Markov chain method and software developed by Lièvre et al.\(^24\) This method estimates life expectancy by health status (disability free vs disabled) from longitudinal investigations that track functional disability and vital status during a follow-up period. The life and health expectancies are calculated from multinomial logistic estimates of age-adjusted transition probabilities between health statuses during follow-up (ie, from nondisabled to disabled, nondisabled to dead, disabled to nondisabled, and disabled to dead). This analysis was stratified by sex. We estimated 5 models for each sex, using in each an indicator variable for 1 of 5 BMI categories (<18.5, 18.5 to <25, 25 to <30, 30 to <35, and ≥35). For this analysis, we put all subjects with BMI of at least 35 into a single group because the small number of these subjects did not permit separate estimates for each BMI category using this method.

Data were managed and Cox proportional hazards models were estimated using SAS software version 9.1.3 (SAS Institute, Cary, NC). Health life expectancies were calculated using the interpolation of Markov chain approach (IMACH version; Institut National d’Etudes Demographiques/Euro-REVES, Paris, France).

### RESULTS

Table 1 gives the baseline characteristics of the sample by status at the end of the 7-year follow-up period. Subjects who became disabled or who died during the follow-up period were older and reported more comorbid diseases than those without disability and those who were lost to follow-up. The mean ± SD BMI was 26.4 ± 4.5 for nondisabled subjects, 26.4 ± 5.3 for disabled subjects, 25.7 ± 4.8 for those who died, and 26.7 ± 4.8 for those who were lost to follow-up.

<table>
<thead>
<tr>
<th>Table 1. Baseline Characteristics by Status at the End of the 7-Year Follow-up Period Among 12 725 Subjects*</th>
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<tbody>
<tr>
<td><strong>Explanatory Variable†</strong></td>
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<tr>
<td><strong>Age, y</strong></td>
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<tr>
<td><strong>Body mass index‡</strong></td>
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<tr>
<td>&lt;18.5</td>
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<tr>
<td>18.5 to &lt;25</td>
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<td>≥35</td>
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<tr>
<td><strong>Mean</strong></td>
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<tr>
<td><strong>Female sex</strong></td>
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<tr>
<td><strong>Married</strong></td>
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<td><strong>Years of formal education</strong></td>
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<tr>
<td><strong>Race/ethnicity</strong></td>
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<td><strong>White</strong></td>
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<td><strong>African American</strong></td>
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<td><strong>Mexican American</strong></td>
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<tr>
<td><strong>EPESE site</strong></td>
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<td><strong>East Boston, Mass</strong></td>
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<td><strong>Rural Iowa</strong></td>
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<td><strong>New Haven, Conn</strong></td>
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<td><strong>Durham, NC</strong></td>
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<td><strong>Hispanic EPESE</strong></td>
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<tr>
<td><strong>Smoking status</strong></td>
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<td><strong>Never</strong></td>
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<tr>
<td><strong>Former</strong></td>
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<td><strong>Current</strong></td>
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<tr>
<td><strong>Comorbidity</strong></td>
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<td><strong>Heart attack</strong></td>
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<td><strong>Stroke</strong></td>
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<td><strong>Hypertension</strong></td>
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<td><strong>Cancer</strong></td>
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<td><strong>Hip fracture</strong></td>
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<td><strong>Diabetes mellitus</strong></td>
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</tbody>
</table>

Abbreviation: EPESE, Established Populations for Epidemiologic Studies of the Elderly.

*Data are given as mean ± SD or number (percentage) and are from unweighted analyses.

†P ≤ .001 for all explanatory variables.

‡Calculated as weight in kilograms divided by height in meters squared.
Table 2 gives the results of Cox proportional hazards models predicting the hazards for ADL disability and mortality as a function of BMI category, controlling for age, sex, race/ethnicity, marital status, level of formal education, smoking status, comorbidity, and EPESE site. The hazard for ADL disability was lowest among subjects in BMI categories of 18.5 to less than 25 and 25 to less than 30. Subjects with BMIs of lower than 18.5 or 30 or higher at baseline were significantly more likely to experience disability during follow-up than subjects with BMIs of 18.5 to less than 25. Similar findings were obtained when the disability thresholds were set at least 2 and 3 limitations in ADLs. In contrast, the lowest hazards for mortality were seen among subjects in BMI categories of 25 to less than 30 and 30 to less than 35, with subjects with BMIs of lower than 25 or 35 or higher experiencing higher hazards for mortality. Similar results were obtained when the analyses for mortality included disabled and nondisabled subjects at baseline.

The Figure shows the results of a model examining the hazards of disability and mortality with BMI treated as a continuous variable, the lowest hazard for disability was experienced by subjects with BMIs of 18.5 to less than 25 or 25 to less than 30 (Table 2). The associations between BMI and subsequent disability or mortality were similar in all subgroups. This question was assessed formally by testing for interactions between BMI and sex, age, EPESE site, and race/ethnicity in the model shown in the Figure for each of the 2 outcomes. The only significant interaction (P = .04) was between BMI and age on the hazard of disability. The BMI associated with the lowest hazard of disability (approximately 24) was the same in both age groups, but the curves for older subjects rose more steeply for BMIs of lower than 24 and rose more gradually for BMIs of higher than 24. We repeated the analysis, redefining disability using thresholds of at least 2 and 3 reported limitations in ADLs to define the disabled state. Patterns were similar to those given in Table 2.

Finally, we calculated the total life expectancy and the disability-free life expectancy as a function of BMI category, stratified by age and sex (Table 3). For men, the total life expectancy and the disability-free life expectancy were greatest in subjects with BMIs of 25 to less than 30. For women, the total life expectancy was higher among those with BMIs of 30 to less than 35, while the disability-free life expectancy was higher among those with BMIs of 25 to less than 30, although the differences were generally not statistically significant. Also given in Table 3 are the estimated percentages of total life expectancy that will be disability free. In general, these percentages fall sharply for subjects with BMIs of 30 of higher.

We examined whether the patterns in Table 2 and the Figure were similar in various subgroups of subjects in several ways. We repeated the analyses in Table 2, stratifying by sex, age, EPESE site, and race/ethnicity (65-74 vs ≥75 years). The associations between BMI and subsequent disability or mortality were similar in all subgroups. This question was assessed formally by testing for interactions between BMI and sex, age, EPESE site, and race/ethnicity in the model shown in the Figure for each of the 2 outcomes. The only significant interaction (P = .04) was between BMI and age on the hazard of disability. The BMI associated with the lowest hazard of disability (approximately 24) was the same in both age groups, but the curves for older subjects rose more steeply for BMIs of lower than 24 and rose more gradually for BMIs of higher than 24. We repeated the analysis, redefining disability using thresholds of at least 2 and 3 reported limitations in ADLs to define the disabled state. Patterns were similar to those given in Table 2.
tion between BMI and subsequent mortality was differ-
ent, with somewhat higher BMIs associated with the low-
est hazard for mortality in continuous and categorical
analyses. The increasing risk of disability and mortality asso-
ciated with BMI was similar in men and women and
among African Americans, Mexican Americans, and non-
Hispanic white Americans. Estimates of disability-free life expectancy or active life expectancy account for mortality and incidence of disability. In these analyses, the disability-free life expectancy was greatest for subjects with BMIs of 23 to less than 30.

This study has some limitations. First, self-reported heights and weights were used to compute BMI at 4 of 5 sites of the EPESE, which tends to produce somewhat lower BMIs than when directly measured. Second, assessments of ADL tasks were obtained by self-report. However, investigations have demonstrated a high concordance between self-reported data and direct observations of ADL performance. Third, the assessments of comorbidity were also made through self-reports. Research findings show good agreement between self-reported data and direct observations of medical events and comorbid diseases or conditions. Fourth, information on physical activities was not consistently available at baseline interviews for all EPESE sites. Physical activity is related to disability and mobility. Fifth, the list of self-reported comorbid conditions did not include arthritis, a major cause of disability, because information about this was not available for all EPESE sites. We analyzed the data of those sites that included information about arthritis at baseline, and the results did not change. More generally, there was insufficient information from all EPESE sites to construct a Charlson comorbidity index or similar summary measure of comorbidity. Sixth, inference to the national population of the United States is strictly speculative because the pooled EPESE data set is a composite of 5 discrete regional samples. However, the EPESE sites constitute a broad range of population subgroups, including rural and urban non-Hispanic white subjects and non-Hispanic black subjects, as well as a Hispanic sample representative of Mexican Americans living in the southwestern United States. Subgroup analysis by race/ethnicity and by EPESE site demonstrated patterns similar to those we report across these distinct groups (data available on request from the author).

In general, the findings reported herein are consistent with prior studies examining the association between BMI and subsequent disability or mortality in older populations. In this discussion, we address the following 2 issues: first, the possible explanations for the effect of obesity on disability vs mortality in older subjects and, second, the implications of these findings for ideal body weight in older persons.

The link between obesity and subsequent disability is probably established through multiple pathways. Obesity is associated with several conditions that, in turn, are risk factors for subsequent disability, including osteoarthritis of the weight-bearing joints, diabetes mellitus, and cardiovascular disease. In addition, while muscle mass increases along with fat mass in obese individuals, muscle strength per gram of muscle tissue actually declines with increasing adiposity.

There are 4 potential explanations for the weak association between elevated BMI and subsequent mortality in older subjects. The first explanation is that comorbidity, smoking status, and other risks obscure the association between obesity and mortality. However, we addressed this concern by adjusting for comorbidity, by excluding current smokers, and by excluding subjects who died during the first 2 years of follow-up (Figure) and found little effect on the association between BMI and mortality. A second explanation is that methodological limitations obscure the association between BMI and mortality. A suggestion is that BMI is a poor marker for adiposity in older persons. Another suggestion is that the absolute increase in mortality rates should be assessed rather than the relative rates that are produced by Cox proportional hazards models. Our results provide indirect evidence against these methodological arguments because the same methods that found little association between elevated BMI and subsequent mortality found a strong association between elevated BMI and disability. A third explanation for the weak association between elevated BMI and mortality is that the relationship is attenuated by selective survival. Elevated BMI is clearly associated with increased mortality at younger ages. It is possible that persons susceptible to increased...
early mortality associated with elevated BMI die at younger ages, weakening the observed relationship at older ages. A fourth explanation for the weak association between elevated BMI and mortality in older persons is that obesity might have a protective effect at older ages that is less important at younger ages. This protective effect might counterbalance the known adverse consequences of obesity on survival. Examples of protective effects include decreased risk of hip fractures and increased ability to tolerate periods of low caloric intake associated with acute illness.

The controversy over the association between BMI and mortality in older adults is important because various interpretations may lead to different or conflicting recommendations regarding the ideal BMI in older persons. Our results suggest that the association between BMI and mortality is only 1 factor in determining optimal BMI values for older adults. Loss of independence is one of the most feared outcomes experienced by older individuals and is a major contributor to poor quality of life. The association between elevated BMI and subsequent disability provides evidence that obesity in older populations is associated with a substantial increase in risk for poor health outcomes. If this risk is confirmed, values for BMI in older adults should be interpreted accordingly and appropriate prevention and intervention programs developed.

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