Published in final edited form as:

Ann Intern Med. 2011 May 17; 154(10): . doi:10.7326/0003-4819-154-10-201105170-00003.

Obesity, Race, and the Risk of Mortality and Functional Decline Among Medicare Beneficiaries 65 Years and Older in the United States

Christina C. Wee, MD, MPH¹, Karen W. Huskey, MPH¹, Long H. Ngo, PhD¹, Angela Fowler-Brown, MD, MPH¹, Suzanne G. Leveille, RN, PhD^{1,3}, Murray A. Mittelman, MD, DrPH², and Ellen P. McCarthy, PhD, MPH¹

¹Division of General Medicine and Primary Care, University of Massachusetts Boston; Boston, MA

²Cardiovascular Epidemiology Research Unit, Beth Israel Deaconess Medical Center and Harvard Medical School, University of Massachusetts Boston; Boston, MA

³College of Nursing and Health Sciences, University of Massachusetts Boston; Boston, MA

Abstract

Background—The adverse impact of obesity on health outcomes may be lower in older adults and African Americans than the general US population.

Objective—To examine and compare the relationship between obesity and all-cause mortality and functional decline among older US adults.

Design—Longitudinal cohort study.

Setting—Secondary analysis of data from the 1994-2000 Medicare Current Beneficiary Survey linked to Medicare Enrollment files through 4/22/2008.

Participants—20,975 community-dwelling participants of the 1994-2000 Medicare Current Beneficiary Survey who were aged 65 and older.

Measurements—All-cause mortality through 4/22/2008; new/worsening disability in performing activities of daily living (ADL) and instrumental activities of daily living (IADL) within 2 years.

Results—Of the study sample, 37% were overweight (BMI 25-30 kg/m²), and 18% were obese (BMI>30 kg/m²); 48% died during the 14 years of follow-up; 27% had ADL and 43% had IADL disability at baseline. Of those without severe disability at baseline, 17% developed new/worsening ADL disability within 2 years; 26% developed new/worsening IADL disability. After adjustment, adults with a BMI>35 kg/m² were the only group above the normal BMI range that were at higher risk of mortality [Hazard Ratio in men, 1.49 (1.20, 1.85) and in women, 1.21 (1.06, 1.39)] when compared to the reference group (BMI=22.0-24.9 kg/m²), p=0.003 for BMI-sex interaction. In contrast, both overweight and obesity were associated with new or progressive ADL and IADL disability in a dose-dependent fashion, particularly for White men and women. We detected significant interactions between BMI and sex, but not between BMI and race for any

Corresponding Author and Requests for Reprints: Christina C. Wee, MD, MPH Division of General Medicine and Primary Care Beth Israel Deaconess Medical Center 330 Brookline Ave, Boston MA 02215 Tel: 617-754-1402; Fax: 617-754-1440
cwee@bidmc.harvard.edu.

Current Mailing Address for all authors: Beth Israel Deaconess Medical Center 330 Brookline Ave., Boston, MA 02215

The authors have no conflict of interest to disclose.

outcome although risk estimates for ADL disability appeared generally attenuated in African Americans relative to Whites.

Limitations—Observational study; baseline data are self-reported; limited power to detect differences between Whites and African Americans.

Conclusion—Among older US adults, obesity was not associated with mortality except for those with at least moderately severe obesity. However, lower levels of obesity were associated with the development of new or worsening disability within two years. Efforts to prevent disability in older adults should target those who are overweight or obese.

Introduction

Obesity is a leading health problem in the U.S. because of its rising prevalence (1) and etiologic role in many chronic health conditions (2). There is little dispute that in the general U.S. adult population, obesity is associated with a higher risk for premature mortality (3-5). The impact of obesity on mortality in the elderly and in African Americans is less certain (3, 6-8). While there is consistent evidence that obesity's adverse impact on mortality appears to diminish with increasing age, studies estimating the actual mortality risk posed by obesity in older adults have produced more conflicting results, with some suggesting that obesity confers an attenuated or no added mortality risk while others suggesting a potential protective effect (6, 9, 10). Moreover, much of these data are derived from findings in largely Caucasian populations. Given this uncertainty, weight control in the elderly has been considered controversial, especially because of early concerns about the safety of weight loss in older adults (9,11).

It is increasingly recognized, however, that outcomes other than mortality, such as functional independence and disability, are as --if not more-- salient in the elderly (12, 13). There is evidence suggesting a more consistent and stronger relationship between obesity and disability in this age group (14-18). However, much of this previous work has been cross-sectional (17, 18) or conducted in convenience samples that may or may not generalize to the broader U.S. population of older adults (14-16). Moreover, few studies have examined the influence of obesity on mortality and disability in the same cohort (14-16). Furthermore, while evidence suggests that obesity's adverse impact on mortality is attenuated in African Americans compared to White Americans in the general population (3, 7) whether obesity's effect on disability also varies between African Americans and Whites is largely unknown.

In this context, we examined the prospective relationship between obesity and all-cause mortality and its relationship with development and progression of disability in a longitudinal cohort of Medicare beneficiaries. We hypothesized that obesity has a modest to negligible impact on mortality in this population but a substantial impact on functional decline. Our second goal was to characterize these relationships separately for men and women and for White and African Americans and explore whether obesity's adverse impact is reduced in African American relative to White older adults. Given the rapidly expanding elderly population and increasing prevalence of overweight and obesity among older adults, a better understanding of obesity's effect on mortality and disability in this population is relevant to Medicare policy and healthcare planning. These data might also inform the current debate around the appropriateness of weight control in elderly Americans.

Methods

Study sample

We used data from the Medicare Current Beneficiary Survey (MCBS), a nationally-representative survey of the health and healthcare experience of Medicare beneficiaries. Redesigned in 1994 to its current form, MCBS interviews respondents three times a year over a period of four years for a total of 12 interviews. During the first interview, baseline information including demographics, health status (including height, weight, chronic medical conditions, and functional status), smoking history, and healthcare information are gathered and assessed annually. The Year 4 interviews verify previous information; thus longitudinal data are available for up to three consecutive years for each respondent on many outcomes -- except for functional status which was assessed only in the first two follow-up years. These data are linked to Medicare claims files in the sample with fee-for-service Medicare coverage (~80% of study sample) for the entire follow-up period. With additional approval, we also linked MCBS to Medicare Enrollment files to ascertain vital status and date of death through 4/22/08.

Each Fall, about one-third of the sample is retired and replaced by 6,000 new participants to maintain three-year longitudinal data on approximately 12,000 persons at any given time. The response rate is typically 85% for new respondents, including 15% who designate a proxy respondent. In subsequent rounds, response rates usually exceed 90%. For analytical purposes, sampling weights are provided that account for the complex sampling design and for non-response, allowing results to be generalized to the U.S. Medicare population.

Our study included data from respondents interviewed at baseline between 1994 and 2000, and who were 65 years and older and community-dwelling at the time of their baseline interview (n=20,975).

All-cause mortality

We calculated time to death from dates of initial baseline interview until death through 4/22/08, providing us with up to 14 years of follow-up data on mortality. Respondents who were alive as of this follow-up date were censored.

Functional status and disability

At baseline and annually for two years thereafter, respondents were asked whether they had “any difficulty” performing six activities of daily living (ADLs) (bathing or showering; dressing; eating; getting in and out of chairs; walking; and toileting) and six instrumental activities of daily living (IADL) (using the phone; doing light housework; doing heavy housework; making meals; shopping; and managing money). We categorized respondents’ level of disability at baseline in terms of their difficulties performing ADL and IADL activities separately. We first dichotomized respondents to whether they reported any ADL or IADL difficulty, respectively; respondents reporting “bedridden” for a specific ADL, or “does not do” for a specific IADL, were categorized as having either ADL or IADL difficulty. Those with three or more missing values for the six ADL (n<15) or six IADL (n<15) questions were excluded; however, respondent reporting difficulty in at least one ADL or IADL were classified as having disability, no matter how many other responses were missing. We also categorized respondents based on the number of ADL or IADL that they reported difficulty performing: 0, 1, 2, or 3 or more. Severe difficulty was defined as difficulty in 3 or more ADL or IADL, respectively.

We characterized our outcome of functional decline in terms of ADL and IADL disability separately, based on reports of new difficulties performing ADL and IADL activities during

the follow-up annual interviews. We classified respondents as developing new ADL disability if they did not report ADL disability at baseline but reported ADL disability on at least one of the annual follow-up interviews. Among those with pre-existing ADL disabilities, we categorized those who developed difficulty performing at least one additional ADL during the follow-up as having progression in their ADL disability. Similarly, we classified respondents as having new IADL disability if they didn't report a pre-existing ADL or IADL disability at baseline but reported difficulty performing at least one IADL at follow-up. Among those with pre-existing difficulties performing IADL activities, progression in IADL disability was defined as having difficulties performing an additional IADL activity.

Body weight

We used self-reported baseline height and weight to calculate body mass index (BMI in kg/m²), which we classified into 7 categories: Underweight (<18.5), Normal Weight I (18.5 - 21.9), Normal Weight II (22.0-24.9), Overweight I (25.0-27.4); Overweight II (27.5-29.9), Obese Class I or mild obesity (30.0-34.9), and Obese Class II/III or moderate to severe obesity (>35.0). These categories were guided in part by the classification set forth by the National Institutes of Health (2). We subdivided the normal and overweight categories into 2 subcategories to allow us to explore the BMI range of lowest risk, which previous literature suggests may be higher in the elderly than in the general adult population (6, 9, 10).

Demographic factors, smoking, and comorbidities

Respondents were also asked about their age, smoking status (never, former, current), educational level, and chronic health conditions. Comorbid conditions that were systematically elicited included hypertension, coronary heart disease (including myocardial infarction and angina), other heart conditions, stroke, diabetes, arthritis, mental retardation, Parkinson's disease, chronic lung disease ("chronic obstructive pulmonary disease/emphysema/asthma"), partial paralysis, and loss of arm or leg, hip fracture and various cancers. Comorbid conditions were also available through Medicare claims in the majority of participants who had fee-for-service insurance.

Data analysis

We used bivariable statistics to characterize our sample and outcome measures across BMI and other factors. We used Wald ² to test for differences in proportions and t-tests to test for differences in continuous variables.

To assess the relationship between BMI and all-cause mortality, we calculated race- and sex-specific mortality rates standardized for age and smoking through direct standardization to the sample; 95% confidence intervals were generated via bootstrapping. We then developed adjusted Cox proportional hazards regression models to examine time to death. We excluded those who died within the first 12 months (n=945) because their BMI at initial interview likely reflected a lower weight than their true baseline weight due to unintentional weight loss frequently associated with terminal illness. Because we were interested in both sex- and race- specific differences, we tested for sex-BMI and race-BMI interactions. Sex- and race- specific estimates are reported separately, derived from models that include a BMI-sex-race interaction.

To study the relationship between obesity and disability, we developed longitudinal logistic models using generalized estimating equations (GEE) to estimate the association between baseline BMI and functional decline in terms of ADL and IADL separately. We estimated adjusted risk ratios and associated standard errors and 95% confidence intervals based on the conditional marginal estimates of the outcome (ADL or IADL functional decline) for each

race/sex/BMI specific group, compared to the conditional marginal estimate of the race/sex specific BMI reference group. The confidence intervals for these estimates are calculated on the log scale, and standard errors and 95% confidence intervals are approximated via first order Taylor series approximation. We defined functional decline as the development of new or worsening ADL or IADL disability over time, specifically, from baseline to follow-up at year 1, and from year 1 to year 2. We estimated and accounted for within-subject correlation. We excluded those with severe disability at baseline to allow room for decline over time. Participants who died within the first year were excluded from these analyses and those who died between year 1 and 2 were excluded for that particular time point. In sensitivity analyses, we redefined those who died between year 1 and 2 (n=609 for ADL and n=472 for IADL analyses) as having developed new or worsening disability.

For all analyses, models were adjusted for baseline age, smoking status, education, and proxy response. We also adjusted for chronic health conditions that were systematically elicited at the baseline interview and thought to be associated with mortality (20) but were not believed to be clearly in the causal pathway between obesity and mortality. These conditions--chronic lung disease, rheumatoid arthritis, conditions associated with cognitive impairment (i.e. dementia, mental retardation, Alzheimer's and Parkinson's Disease), and cancer--are also components of the Charlson Comorbidity Index which has been validated to predict mortality in other studies (20). Our primary model included conditions assessed at the initial baseline interview. We did exclude the small number of respondents with HIV/AIDS (n<15) based on claims information.

We weighted results to reflect national estimates, and used SAS-callable (SAS Institute, Cary, NC) SUDAAN statistical software (RTI International, Research Triangle Park, NC) to account the change in standard errors as a result of the complex design (19).

Results

Sample characteristics

Of the 20,975 respondents, 11,093 (48%) died during up to 14 years of follow-up for mortality; 21% died within 5 years. The mean follow-up time for our disability outcomes was 1.8 years. Table 1 presents baseline characteristics of our sample by weight status. African Americans were disproportionately more likely to be obese. Unadjusted death rates were significantly higher in normal weight adults compared to those with higher BMI.

BMI, race, and mortality

Figure 1 presents BMI-associated mortality rates by sex and race adjusted for age and smoking. After accounting for exclusions (n=3604) and missing data (n=278), 20,008 respondents were included in our primary analysis. For all groups studied, the BMI range of lowest mortality fell in the overweight range. Figure 2 (a) shows the hazard ratio (HR) of death by BMI after adjustment. The mortality rate was highest for groups with the lowest and highest BMI. Compared to those with a BMI of 22.0-24.9, higher BMI was not associated with higher hazard of dying except for those with a BMI>35 [HR 1.49 (95% CI 1.20, 1.85) in men and 1.21 (1.06, 1.39) in women]. This pattern was true for White men and women in particular. In African American men, higher BMI did not confer higher mortality risk at any level (fig 2a); in African American women, the risk estimates were similar to that of White women but results were not statistically significant. While we detected a statistically significant interaction between BMI and sex (p=0.03), the interaction term between BMI and race was not statistically significant (p=0.17).

We conducted several additional sensitivity analyses (specified a priori) to establish the stability of our findings. Additional adjustment for census region did not alter primary

results related to mortality. Our results were also not substantially different when we excluded those who employed a proxy respondent. We additionally adjusted for conditions ascertained from diagnostic codes on Medicare claims within the first 12 months of the interview among those with linked claims information (n=15,915). This model also included additional adjustment for chronic renal failure. We then further adjusted for diagnoses from self-report or Medicare claims noted anytime during the two subsequent years of follow-up to capture pre-existing but potentially unrecognized comorbidities. Results of these analyses were largely consistent with our primary findings (data not presented). Although many cancers are shown in observational studies to be associated with obesity, we adjusted for cancer in our primary model because the causal link is often not clearly established. In sensitivity analyses, we excluded four cancers for which the link to obesity was particularly strong --breast, colon, uterine and prostate cancers; results were largely similar (data not presented). Finally, we separately tested for effect modification between BMI and smoking; the interaction was not statistically significant, $p=0.80$.

Because it is well-known that the association between BMI and mortality takes the form of a U-shaped relationship, we developed models to examine the BMI-mortality association for those with a BMI>25.0. For these analyses, our reference group was the group with the lowest observed risk of mortality from our primary analyses (i.e. BMI 25.0-27.4). Test for trend for the relationship between BMI and mortality was significant for White men ($p=0.001$) and women ($p<0.001$); this trend was driven largely by the higher risk associated with a BMI>35. In men, the HRs were 0.98 (0.87, 1.10) for BMI 27.5-29.9; 1.07 (0.95, 1.21) for BMI 30.0 – 34.9 and 1.81 (1.41, 2.32) for BMI>35.0. In women the respective HR were 0.93 (0.83, 1.03), 1.12 (1.00, 1.26), and 1.38 (1.16, 1.61). The test for trend was not significant for African American men and women; however, the interaction between BMI and race was not statistically significant ($p=0.23$).

BMI, race, and disability

Tables 2 and 3 present the unadjusted relationship between BMI and disability at baseline and follow-up. BMI was significantly associated with presence of ADL and IADL disability at baseline. Moreover, the baseline prevalence of ADL and IADL disability were substantially higher in African Americans relative to Whites at almost every BMI level ($p=0.02$ in men and $p<0.001$ in women for racial difference in proportions in ADL prevalence; $p=0.0004$ in men and $p<0.001$ in women for racial differences in IADL prevalence). BMI, however, was not always consistently associated with developing new or progressive ADL and IADL disability at follow-up before adjustment.

Figure 2 (b,c) also presents the adjusted relative risk (RR) of new or worsening ADL (n=16,861) and IADL disability during the 2-year follow-up (n=12,345); we excluded 2% of the eligible sample for each of these analyses due to missing data. In contrast to its relationship with mortality, above-normal BMI was associated with new or progressive ADL and IADL disability in a dose-dependent fashion in both men and women, $p=0.009$ for the interaction between BMI and sex. The relationship between obesity and new/progressive ADL disability appeared generally attenuated in African Americans relative to Whites, although the BMI-race interaction was not significant, $p=0.23$ (fig 2b). In contrast, the relationship between obesity and IADL disability was more consistent between men and women and between Whites and African Americans; the interaction between BMI and sex ($p=0.86$) and BMI and race ($p=0.84$) were not statistically significant. As with our mortality analyses, we found that additional adjustment for census region and proxy response did not alter our primary findings nor did additional adjustment for conditions abstracted from claims data within the first 12 months of the baseline interview. Our results were largely consistent when we reclassified those who died between Year 1 and 2 as having new or worsening disability.

Among those with a BMI >25, the test for trend for the outcome of new or progressive ADL disability was significant for White men ($p<0.001$) and women ($p<0.001$) and African American women ($p=0.01$) in a dose-dependent fashion but not for African American men ($p=0.4$); however, the interaction between BMI and race ($p=0.46$) was not significant. Tests for trend in the relationship between higher BMI and IADL disability were also significant for both White men ($p=0.01$) and women ($p=0.001$) but not for either African American men ($p=0.4$) nor African American women ($p=0.2$); racial differences were, nevertheless, not statistically significant.

Discussion

Among Medicare recipients age 65 years and older, we found that after up to 14 years of follow-up, BMI above “normal” was associated with all-cause mortality only among those with a BMI of 35 and higher. This was particularly the case for White men and women; among African American men and women, no level of obesity was significantly associated with premature mortality, although these differences between White and African Americans were not statistically significant. In contrast, even modestly elevated levels of BMI above the normal range were associated with the development of new or worsening disability. The association was particularly pronounced for disability related to activities of daily living (ADL). The estimates for obesity's relationship with ADL disability appeared weaker in African Americans relative to Whites; however, these racial differences were also not statistically significant.

To our knowledge, our study is the largest longitudinal study to date to examine the association between obesity and both mortality and disability in a nationally representative cohort of community-dwelling Medicare beneficiaries aged 65 and older. Previous studies on the influence of age on the obesity-mortality relationship have shown that the adverse effect of obesity appears to diminish with advancing age (6, 9, 10). However, estimates of the actual mortality risk posed by obesity have been variable across studies (6). A recent systematic review and metaanalysis by Janssen (6) of 32 studies found that obesity as defined by BMI was associated with higher mortality in 13 subgroups of subjects aged 65 and older; in another 13 groups, obesity was associated with lower mortality, and in the remaining groups, no association was detected. These studies were methodologically diverse with most consisting of convenience samples of predominantly Caucasian participants, with varying sample sizes ranging from a few hundred to a few thousand elders. As with our study, most studies relied on self-reported height and weight. In their metaanalysis, Janssen estimated the associated mortality risk was 1.00 (95% CI 0.97-1.03) for overweight and 1.10 (1.06-1.13) for obesity. They concluded that overweight was not associated with mortality and that moderate obesity was associated with a modest increase in mortality. Our findings are consistent with Janssen's conclusions although our estimates are not directly comparable because Janssen did not estimate the risk associated with mild and moderate obesity separately.

Several factors may contribute to the apparent attenuation in obesity-related mortality risk relative to younger adults (21). This lower risk may reflect a “survivor effect” where susceptible individuals have already died, and the remaining surviving samples of obese persons included in studies of elderly populations are more “resistant” to the adverse consequences of obesity. Competing mortality risks and shortened life-expectancy in the elderly can effectively shorten a study's “follow-up time” and its ability to establish the obesity-mortality relationship. Confounding is also a greater problem among older adults; the exposure BMI measured in the study may be different from the individual's true lifetime exposure because of weight loss associated with illness or chronic disease and unhealthy behaviors. While we addressed this in our study, there is likely residual confounding.

Another possible explanation may be that BMI is a poorer measure for adiposity as people age, lose muscle mass, and gain adipose tissue (22, 23). Some studies suggest that waist circumference and waist-hip ratio may be a better measure than BMI alone (23); however, when waist circumference is studied independently of BMI, it predicts mortality to a similar extent and its predictive ability also diminishes with age (10). Interestingly, despite its problems as a measure of obesity and adiposity, our results confirm the findings of prior work suggesting a strong and consistent adverse effect of obesity on disability and functional independence in the elderly (14-16). Previous studies have been methodologically variable. Many were cross-sectional (17, 18) while longitudinal studies were often comprised of convenience samples and focused on outcomes in the longer-term (14, 15, 24). A few studies have examined the influence of obesity on both mortality and disability in the elderly using the same cohort. Snih and colleagues (15) analyzed data from 5 US communities in the EPESE study and found that the BMI for the lowest hazard for mortality was 27 kg/m² whereas a BMI of 24 kg/m² was the lowest hazard for disability after 7 years of follow-up. A longitudinal study (16) of 3793 English participants followed for 5 years found the RR of ADL disability was 1.99 (95% CI 1.42-2.78) for obesity and 5.26 (2.21-9.97) for severe obesity among men; among women, the respective RRs were 1.66 (1.25-2.19) and 2.69 (1.81-4.01). Our findings are striking in demonstrating that obesity's effect on disability can manifest itself over even in a short follow-up period of only 2 years, and point to the large adverse impact that obesity can still have on the lives of older adults even when we acknowledge all the limitations of using an imperfect surrogate measure.

Taken together, our findings suggest that greater attention needs to be paid to addressing the morbidity and disability posed by obesity in the elderly. The role of weight loss in this population has been controversial. Weight loss can lead to loss of bone mineral density and concerns for malnutrition (11), although a recent systematic review of weight loss interventions in the elderly suggests that this effect may be small (9). Several studies and the systematic review suggest that weight loss interventions can improve muscle strength, pain symptoms, and overall physical functioning particularly when exercise is a component in the intervention (9, 11, 24, 25). Whether advising weight loss is warranted and would reduce the risk of new or progressive disability in obese older adults requires further study. Other weight neutral interventions focused on improving mobility and physical functioning such as interventions to improve muscle strength, balance and flexibility could be targeted at obese elders who are at higher risk, although there is some evidence that such interventions may be less effective in obese elders compared to nonobese elders (26).

Our results must be interpreted in the context of the study's limitations. Much of the data are self- or proxy-reported and are subject to recall bias and misclassification (27). Height and weight may be particularly inaccurate for those who have not seen a health provider or been weighed recently; there may also be variation in reporting according to age and race (28). As mentioned, BMI is a suboptimal proxy for adiposity in older adults (21, 22); nevertheless, it is more easily and commonly assessed clinically and our findings suggest that it is still useful in the context of identifying elders most at risk for functional decline. Finally, the sample size of African Americans and other race groups was relatively modest and may have limited our ability to detect small but meaningful differences between Whites and African Americans. Whether our primary findings apply uniformly across different racial and ethnic groups is also unknown.

In summary, obesity as measured by BMI appears to confer added mortality risks in the elderly only among those with a BMI in excess of 35; however, more modest elevations in BMI above the normal range appear to predict functional decline within a two year period in community dwelling elders in the U.S. We did not detect statistically significant differences between Whites and African Americans, although risk estimates associated with obesity

generally appeared lower for the development of ADL disability in African American relative to White adults. Future studies are needed to develop and test interventions aimed at reducing disability in older adults with obesity.

Acknowledgments

The study was supported by a research grant from the National Institute of Diabetes, Digestive and Kidney Diseases (R01 DK071083). We thank the Centers for Medicare and Medicaid Services (CMS) for providing the initial data. The results, findings, and interpretation presented in this paper are those of the authors and do not represent the views of CMS or the National Institutes of Health. Ms. Huskey had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis

References

1. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA*. Apr; 2006 295(13):1549–1555. [PubMed: 16595758]
2. National Heart, Lung, and Blood Institute, Obesity Education Initiative. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. National Institutes of Health; Bethesda, MD: 1998.
3. Calle EE, Thun MJ, Petrelli JM, Rodriguez C, Heath CW Jr. Body-mass index and mortality in a prospective cohort of U.S. adults. *N Engl J Med*. Oct 7; 1999 341(15):1097–1105. [PubMed: 10511607]
4. Adams KF, Schatzkin A, Harris TB, et al. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *N Engl J Med*. Aug 24; 2006 355(8):763–778. [PubMed: 16926275]
5. Lenz M, Richter T, Muhlhauser I. The morbidity and mortality associated with overweight and obesity in adulthood: a systematic review. *Dtsch Arztebl Int*. Oct; 2009 106(40):641–648. [PubMed: 19890430]
6. Janssen I, Mark AE. Elevated body mass index and mortality risk in the elderly. *Obes Rev*. Jan; 2007 8(1):41–59. [PubMed: 17212795]
7. Stevens J. Obesity and mortality in Africans-Americans. *Nutr Rev*. Nov; 2000 58(11):346–353. [PubMed: 11140906]
8. McTigue K, Larson JC, Valoski A, et al. Mortality and cardiac and vascular outcomes in extremely obese women. *JAMA*. Jul 5; 2006 296(1):79–86. [PubMed: 16820550]
9. McTigue KM, Hess R, Ziouras J. Obesity in older adults: a systematic review of the evidence for diagnosis and treatment. *Obesity (Silver Spring)*. Sep; 2006 14(9):1485–1497. [PubMed: 17030958]
10. Kuk JL, Ardern CI. Influence of Age on the Association Between Various Measures of Obesity and All-Cause Mortality. *J Am Geriatr Soc*. Sep 15.2009
11. Jensen GL, Hsiao PY. Obesity in older adults: relationship to functional limitation. *Curr Opin Clin Nutr Metab Care*. 2010; 13(1):46–51. [PubMed: 19841579]
12. Doshi JA, Polsky D, Chang VW. Prevalence and trends in obesity among aged and disabled U.S. Medicare beneficiaries, 1997-2002. *Health Aff (Millwood)*. Jul-Aug;2007 26(4):1111–1117. [PubMed: 17630454]
13. Peeters A, Bonneux L, Nusselder WJ, De Laet C, Barendregt JJ. Adult obesity and the burden of disability throughout life. *Obes Res*. Jul; 2004 12(7):1145–1151. [PubMed: 15292479]
14. Lang IA, Llewellyn DJ, Alexander K, Melzer D. Obesity, physical function, and mortality in older adults. *J Am Geriatr Soc*. Aug; 2008 56(8):1474–1478. [PubMed: 18662211]
15. Al Snih S, Ottenbacher KJ, Markides KS, Kuo YF, Eschbach K, Goodwin JS. The effect of obesity on disability vs mortality in older Americans. *Arch Intern Med*. Apr 23; 2007 167(8):774–780. [PubMed: 17452539]
16. Walter S, Kunst A, Mackenbach J, Hofman A, Tiemeier H. Mortality and disability: the effect of overweight and obesity. *Int J Obes (Lond)*. Dec; 2009 33(12):1410–1418. [PubMed: 19786964]

17. Chen H, Guo X. Obesity and functional disability in elderly Americans. *J Am Geriatr Soc.* Apr; 2008 56(4):689–694. [PubMed: 18266843]
18. Liou TH, Pi-Sunyer FX, Laferrere B. Physical disability and obesity. *Nutr Rev.* Oct; 2005 63(10): 321–331. [PubMed: 16295145]
19. SUDAAN Language Manual, Release 10.0. 2008.
20. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987; 40(5):373–383. [PubMed: 3558716]
21. Zamboni M, Mazzali G, Zoico E, et al. Health consequences of obesity in the elderly: a review of four unresolved questions. *Int J Obes (Lond).* Sep; 2005 29(9):1011–1029. [PubMed: 15925957]
22. Zamboni M, Zoico E, Scartezzini T, et al. Body composition changes in stable-weight elderly subjects: the effect of sex. *Aging Clin Exp Res.* Aug; 2003 15(4):321–327. [PubMed: 14661824]
23. Moore SC. Waist versus weight: which matters more for mortality? *Am J Clin Nutr.* Apr; 2009 89(4):1003–1004. [PubMed: 19244373]
24. Jensen GL, Friedmann JM. Obesity is associated with functional decline in community-dwelling rural older persons. *J Am Geriatr Soc.* May; 2002 50(5):918–923. [PubMed: 12028181]
25. Messier SPLR, Miller GD, et al. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the Arthritis, Diet, and Activity Promotion Trial. *Arthritis Rheum.* 2004; 50:1501–1510. [PubMed: 15146420]
26. Shea MK HD, Nicklas BJ, Messier SP, Davis CC, Miller ME, Harris TB, Kitzman DW, Kennedy K, Kritchevsky SB. The Effect of Randomization to Weight Loss on Total Mortality in Older Overweight and Obese Adults: The ADAPT Study. *J Gerontol A Biol Sci Med Sci.* 2010
27. Manini TM, Newman AB, Fielding R, et al. Effects of Exercise on Mobility in Obese and Nonobese Older Adults. *Obesity (Silver Spring).* Oct 15.2009
28. Rothman KJ. BMI-related errors in the measurement of obesity. *Int J Obes (Lond).* Aug; 2008 32(Suppl 3):S56–59. [PubMed: 18695655]
29. Villanueva EV. The validity of self-reported weight in US adults: a population based cross-sectional study. *BMC Public Health.* 2001; 1:11. [PubMed: 11716792]

a.

Overall and by sex

b.

Among White and African American (AA) men and women

Figure 1.

a. Age and smoking-adjusted mortality rate (number of deaths per 100,000 person years)*

b. Age and smoking-adjusted mortality rate (number of deaths per 100,000 person years)*

* Rates derived through direct standardization with applied survey weights.

Figure 2. Relationship between BMI and mortality and disability[‡]

a. Adjusted hazard ratios for death

b. Adjusted risk ratios for developing new / progressive ADL disability

c. Adjusted risk ratios for developing new / progressive IADL disability**

[‡] Mortality was assessed at up to 14 years from baseline interview. Disability was assessed at one and two years after baseline interview. All models were adjusted for baseline age, smoking status, highest education, proxy response and individual non-obesity related comorbidities (chronic lung disease, rheumatoid arthritis, conditions associated with cognitive impairment, and cancer); a small number of persons with HIV/AIDS were

excluded ($n < 15$). Models include a BMI/ race/ sex interaction term, with BMI 22.0-24.9 kg/m² as the reference category within each race/gender specific model.

* African Americans in this BMI category have a sample size < 30 .

** Analyses excluded those with any ADL at baseline, as well as those in the underweight BMI category due to zero cell sizes.

Table 1Sample characteristics at baseline^{*}

	Overall n=20,975	Underweight (<18.5 kg/m²) n=842	Normal (18.5 –24.9 kg/m²) n=9,006	Overweight (25.0 –29.9 kg/m²) n=7,661	Obese (≥ 30.0 kg/m²) n=3,466
Mean age	74.7	79.0	75.9	74.0	72.8
Sex					
Women, n (%)	12,053 (57)	639 (76)	5,473 (61)	3,758 (49)	2,183 (62)
Race, n (%)					
White	17,458 (84)	708 (85)	7,621 (85)	6,395 (84)	2,734 (81)
AA	1,798 (8)	63 (6)	629 (6)	624 (7)	482 (12)
Hispanic	1,248 (6)	45 (5)	510 (5)	497 (6)	196 (6)
Other	471 (2)	26 (3)	246 (3)	145 (2)	54 (2)
Smoking, n (%)					
Current	2,292 (12)	169 (23)	1,204 (15)	662 (9)	257 (8)
Former	9,858 (48)	309 (37)	3,926 (44)	3,968 (53)	1,655 (49)
Never	8,825 (40)	364 (40)	3,876 (41)	3,031 (38)	1,554 (43)
Education, n (%)					
< HS	8,019 (38)	369 (44)	3,251 (36)	2,865 (37)	1,534 (44)
HS Diploma	6,245 (30)	233 (28)	2,695 (30)	2,295 (30)	1,022 (29)
Some College, College Degree, or Professional/Advanced Degree	6,711 (32)	240 (29)	3,060 (34)	2,501 (33)	910 (26)
Response					
Proxy, n (%)	1,806 (8)	159 (8)	836 (8)	574 (7)	237 (6)
Mortality, n (%)					
2 years	1,935 (8)	230 (26)	970 (9)	501 (6)	234 (6)
5 years	5,194 (21)	451 (51)	2,578 (25)	1,484 (17)	681 (18)
8 years	8,466 (35)	596 (67)	4,098 (40)	2,590 (30)	1,182 (31)

^{*} All sample characteristics presented differed significantly across BMI levels at a level of $p < 0.001$. Percentages are weighted to reflect population estimates.

Table 2Prevalence of baseline and development of new or worsening ADL disability, by race and BMI ^{*}

	Men			Women		
	All n = 8 918	White n = 7 419	African American n = 711	All n = 12 052	White n = 10 033	African American n = 1 088
Disability at baseline among the entire sample						
Overall, n (%)	2 270 (23) [*]	1 857 (22) [*]	204 (27) [*]	4 046 (30) [*]	3 274 (29) [*]	461 (40) [*]
BMI, n (%)						
< 18.5 kg / m ²	115 (55) [*]	93 (55) [*]	15 (66) [*]	300 (44) [*]	257 (44) [*]	18 (47) [*]
18.5-21.9 kg / m ²	319 (28) [*]	248 (28) [*]	36 (39) [*]	747 (27) [*]	644 (27) [*]	56 (34) [*]
22.0-24.9 kg / m ²	556 (19) [*]	453 (19) [*]	52 (23) [*]	849 (23) [*]	708 (23) [*]	68 (32) [*]
25.0-27.4 kg / m ²	557 (20) [*]	465 (19) [*]	39 (22) [*]	698 (25) [*]	560 (24) [*]	72 (33) [*]
27.5-29.9 kg / m ²	341 (23) [*]	290 (23) [*]	21 (20) [*]	472 (31) [*]	371 (30) [*]	72 (43) [*]
30.0-34.9 kg / m ²	271 (22) [*]	220 (22) [*]	29 (28) [*]	618 (37) [*]	479 (36) [*]	98 (44) [*]
35.0 kg / m ²	111 (43) [*]	88 (42) [*]	12 (46) [*]	362 (53) [*]	255 (52) [*]	77 (54) [*]
New or worsening disability at during follow-up						
Overall, n (%)	1 778 (18) [*]	1 480 (18) [*]	160 (21)	2 993 (23) [*]	2 464 (23) [*]	300 (26) [*]
BMI, n (%)						
< 18.5 kg / m ²	49 (22) [*]	40 (22) [*]	**(<25)	133 (20) [*]	119 (21) [*]	-
18.5-21.9 kg / m ²	204 (19) [*]	147 (17) [*]	27 (30)	530 (20) [*]	458 (20) [*]	39 (19) ^{*§}
22.0-24.9 kg / m ²	457 (17) [*]	377 (17) [*]	46 (21)	679 (20) [*]	571 (20) [*]	47 (25) [*]
25.0-27.4 kg / m ²	500 (18) [*]	424 (18) [*]	39 (22)	573 (22) [*]	484 (22) [*]	46 (22) [*]
27.5-29.9 kg / m ²	266 (18) [*]	228 (18) [*]	18 (16)	393 (27) [*]	314 (27) [*]	47 (27) [*]
30.0-34.9 kg / m ²	227 (21) [*]	202 (22) [*]	17 (18)	474 (30) [*]	362 (29) [*]	78 (36) [*]
35.0 kg / m ²	75 (29) [*]	62 (30) [*]	**(<25)	211 (32) [*]	156 (33) [*]	43 (28) [*]

^{*} Statistically significant at a level of P<0.05 according to a Wald chi-square test for difference in proportions across the range of BMIs. All percentages are weighted to reflect population estimates.

^{**} Cell sizes were <11; precise estimates cannot be presented in accordance with CMS policies.

[§] Estimate is for the combined categories of BMI < 18.5 and 18.5-21.9

Table 3Prevalence of baseline and development of new or worsening IADL disability, by race and BMI ^{*}

	Men			Women		
	All n = 8 918	White n = 7 419	African American n = 711	All n = 12 052	White n = 10 033	African American n = 1 088
Disability at baseline among the entire sample						
Overall, n (%)	3 922 (40) [*]	3 177 (39) [*]	356 (46) [*]	5 964 (45) [*]	4 857 (44) [*]	620 (54) [*]
BMI, n (%)						
< 18.5 kg / m ²	148 (70) [*]	119 (70) [*]	18 (83) [*]	436 (65) [*]	367 (64) [*]	30 (74) [*]
18.5-21.9 kg / m ²	572 (51) [*]	436 (49) [*]	61 (63) [*]	1 215 (45) [*]	1 042 (45) [*]	78 (49) [*]
22.0-24.9 kg / m ²	1 084 (40) [*]	885 (39) [*]	99 (42) [*]	1 366 (39) [*]	1 137 (38) [*]	109 (51) [*]
25.0-27.4 kg / m ²	994 (36) [*]	818 (35) [*]	77 (43) [*]	1 050 (40) [*]	848 (38) [*]	102 (48) [*]
27.5-29.9 kg / m ²	533 (36) [*]	444 (36) [*]	36 (35) [*]	650 (44) [*]	511 (43) [*]	91 (53) [*]
30.0-34.9 kg / m ²	454 (40) [*]	364 (39) [*]	51 (48) [*]	826 (50) [*]	646 (50) [*]	122 (56) [*]
35.0 kg / m ²	137 (54) [*]	111 (55) [*]	14 (53) [*]	421 (62) [*]	306 (63) [*]	88 (63) [*]
New / worsening impairment at year 1 or year 2 follow-up						
Overall, n (%)	2 702 (29) [*]	2 246 (30) [*]	210 (29)	3 785 (30) [*]	3 107 (30)	361 (31)
BMI, n (%)						
< 18.5 kg / m ²	44 (21) [*]	35 (20) [*]	** (<20)	160 (25) [*]	139 (26)	12 (28)
18.5-21.9 kg / m ²	297 (28) [*]	230 (27) [*]	28 (31)	765 (30) [*]	654 (30)	52 (35)
22.0-24.9 kg / m ²	721 (28) [*]	591 (27) [*]	62 (29)	954 (29) [*]	809 (29)	58 (29)
25.0-27.4 kg / m ²	790 (30) [*]	670 (30) [*]	49 (29)	733 (29) [*]	623 (29)	52 (27)
27.5-29.9 kg / m ²	420 (30) [*]	352 (31) [*]	29 (28)	424 (30) [*]	332 (30)	57 (31)
30.0-34.9 kg / m ²	336 (32) [*]	292 (33) [*]	28 (27)	516 (33) [*]	389 (32)	84 (37)
35.0 kg / m ²	94 (38) [*]	76 (38) [*]	** (<30)	233 (34) [*]	161 (33)	46 (30)

^{*} Statistically significant at a level of P<0.05 according to a Wald chi-square test for difference in proportions across the range of BMIs. All percentages are weighted to reflect population estimates.

^{**} Cell sizes were <11; precise estimates cannot be presented in accordance with CMS policies.