Increases in Overweight and Obesity Prevalence and Changes in Disability-Free Survival in the United States

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ABSTRACT

Objectives: To estimate older-age survival differences by body mass index (BMI), and to estimate how increases in high BMI prevalence in the United States between 1990 and 2015 changed total and disability-free survival (DFS) rates to age 85.

Methods: We estimated BMI-disability and BMI-mortality associations among female and male U.S. adult populations using NHANES 1988-1994 and 1999-2006 linked mortality files through 2015. We also simulated multistate life tables - three BMI levels, two disability statuses, two mortality statuses - to estimate how changes in prevalence of overweight and obesity among the U.S. female and male populations between 1990 and 2015 affected DFS from age 45 to age 85.

Results: Compared to populations with low BMI, survival rates to age 85 are much lower among populations with overweight and obese BMI. Disability among these populations is also significantly higher. Among the U.S. male population, increases in high BMI from 1990 to 2015 are estimated to have reduced age 85 survival by 3.7% and to have reduced DFS by 4.7%. Among the U.S. female population, increases in high BMI are estimated to have reduced age 85 survival by 2.2% and to have reduced DFS by 3.4%.

Discussion: The effects of rising obesity prevalence on older-age survival have likely been underestimated. Overweight BMI and obese BMI significantly reduce the probability of DFS to older adulthood, and recent increases in overweight and obese BMI prevalence in the United States likely have reduced American men's and women's DFS rates to older adulthood.

Rates of overweight (body mass index [BMI] 25.0-30.0) and obesity (BMI 30.0 and above) among the U.S. adult population have steadily increased since the 1980s. The increases in high BMI might have affected overall U.S. life expectancy by elevating mortality risk and might have affected disability-free life expectancy (DFLE) by elevating risk of both disability and mortality. Yet existing research has produced inconsistent evidence about the BMI-disability association as well as about the BMI-mortality association, especially at older ages. Most evidence suggests that high BMI elevates risk of disability, but that mortality risk is elevated only at extreme levels of obesity. Further, both the obesity-disability and the obesity-mortality associations have been suggested to decline with age (Wang 2016). Combined, increases in high BMI in the U.S. adult population are thought to have reduced DFLE by increasing years spent with a disability, but has not affected total U.S. life expectancy (Crimmins and Zhang 2019; Diehr et al. 2007; Manton et al. 2006; Reynolds, Saito, and Crimmins 2005; Reynolds, McIlvane, and Crimmins 2009; Zhang, Saito, and Crimmins 2019). However, estimates of obesity's effect on disability-free survival (DFS) and DFLE vary across study. For example, Peeters et al. (2013) found evidence indicating that obesity elevates both disability risk and mortality risk, and, consequently, time spent with a disability was not extended because DFLE and total life expectancy were both reduced. Yet, more recently, Zhang et al. (2019) found that increases in DFLE have been greater for the U.S. adult population with obesity than the U.S. adult population without obesity.

Variation in estimates of obesity's effect on DFS and DFLE among U.S. populations likely stems from bias in estimates of both the BMI-disability association and the BMI-mortality association. Estimates of BMI-health associations in survey-based data are likely biased from negative health bias among low-BMI samples due to recent weight loss (i.e., "reverse causality" bias), positive health bias among high-BMI samples due to recent weight gain, and confounding bias from within-group heterogeneity in all BMI samples (Masters 2023). In this study, we estimate age-specific BMI-disability associations between ages 45 and 85 among US men and women and age-specific and disability-specific BMI-mortality associations between ages 45 and 85. We compare estimates using conventional measures of overweight and obesity from BMI measured at baseline survey and with estimates using measures of overweight and obesity that adjust for potential bias. We then simulate separate multistate life tables for the U.S. male and female adult populations with (1) BMI [18.5-25.0), (2) BMI [25.0-30.0), and (3) BMI 30.0+. We estimate total survival between ages 45 and 85 as well as DFS. Finally, we simulate multistate life tables for the entire U.S. male and female populations in 1990 and in 2015 to examine the extent to which changes in high-BMI prevalence likely contributed to changes in U.S. men's and women's total and DFS between ages 45 and 85.

We analyzed the National Health and Nutrition Examination Surveys (NHANES) Linked Mortality Files (LMF), composed of NHANES respondents in the 1988-1994 and 1999-2006 waves who were linked to personal records in the National Death Index. The NHANES-LMF data contain individual survival histories of all eligibly matched respondents between survey date and December 31, 2015. The analytic sample is composed of U.S. men and women aged [35-85) at time of survey and disability status and mortality risk is estimated for ages [45-85). Measured weight (kg), measured height (cm) are provided in NHANES, which we further categorized as [18.5-25.0) ("low BMI"); [25.0-30.0) ("overweight BMI"); and 30.0+ ("obese BMI"). We created these same BMI categories using measured height (cm) and respondents' self-reported weight (lb) 10-years prior to survey date.

We coded disability status using four separate functional limitations each measured with a four-category Likert scale of difficulty (“no difficulty”, “some difficulty”, “much difficulty”, and “unable to do”): walking ¼ mile, ascending 10 steps of stairs, crouching/stooping, and carrying 10lb; and five separate activities of daily living each measured using the same Likert scale of difficulty: walking from room to room, getting up from a sitting in a chair, getting up from laying down in bed, eating, dressing. We coded respondents as having a disability if for any itemized response if they reported either “much difficulty” or “unable to do”.

We dropped respondents from the analytic sample if they had missing values on BMI, who were pregnant at time of survey, or who were assigned a sample weight of 0. We also omitted cases with missing values on anthropometric measures or other model covariates. The final analytic sample is composed of 13,196 respondents aged [45-85) at time of NHANES survey (6,749 men and 6,447 women) and 4,038 deaths between attained ages 45 and 85 (2,396 deaths among men and 1,642 deaths among women). We included sampling weights in all analyses to adjust for eligibility in the LMF files, and we accounted for the NHANES sampling design by adjusting variance estimates using Stata 17’s *svy* with 49 strata (NHANES 1988-1994), 58 strata (NHANES 1999-2006) and 117 primary sampling units.

We fitted cloglog models to disability status (1/0) separately by sex. We regressed disability status on a continuous age measure interacted with BMI level (1=BMI level 18.5-24.9, 2=BMI level 25.0-29.9, 3=BMI level 30.0+), and we estimated the age-specific probabilities of having a disability at ages 45, 50, …, 80, 85 using Stata’s “margins” command to estimate the conditional probability of disability status across age at mean values for all other model covariates. We first fitted models using indicators of “low BMI”, “overweight BMI”, and “obese BMI” measured from baseline BMI, and we refitted models using indicators measured from BMI 10-years prior to survey. We estimated age-specific BMI differences in all-cause mortality rates by fitting piecewise constant Poisson rate models across five-year age groups [45-50), …, [80-85). All models control for race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic Other, Latino/a), educational attainment (less than high school, high school, some college, bachelor’s degree or higher), smoking status (never a smoker, former smoker, current smoker), and BMI level (low BMI, overweight, obese). We fitted models separately to men and women and fitted models separately by disability status. We fitted separate models using BMI measured at baseline and models that adjusted estimates for three sources of bias in the obesity-mortality association by including principal components of body shape and size and by using BMI 10-years prior to survey for indicators of BMI level.

We estimated six separate five-year abridged multistate life tables – two disability statuses and two mortality statuses from age 45 to 85 – for U.S. men and women separately by BMI level. We used model-based estimates of five-year age-specific disability status for each BMI level separately by sex, and five-year age-specific mortality rates conditional on BMI and disability status to estimate population-level state occupancy probabilities between ages 45 and 85.
Next, we estimated five-year abridged multistate life tables – three BMI levels, two disability statuses, and two mortality statuses from age [45-49), ..., [80-85) – separately for US men and women in 1990 and 2015. We estimated population-level state occupancy probabilities using (1) CDC-provided age-specific probabilities of BMI levels in 1990 and in 2015, (2) model-based

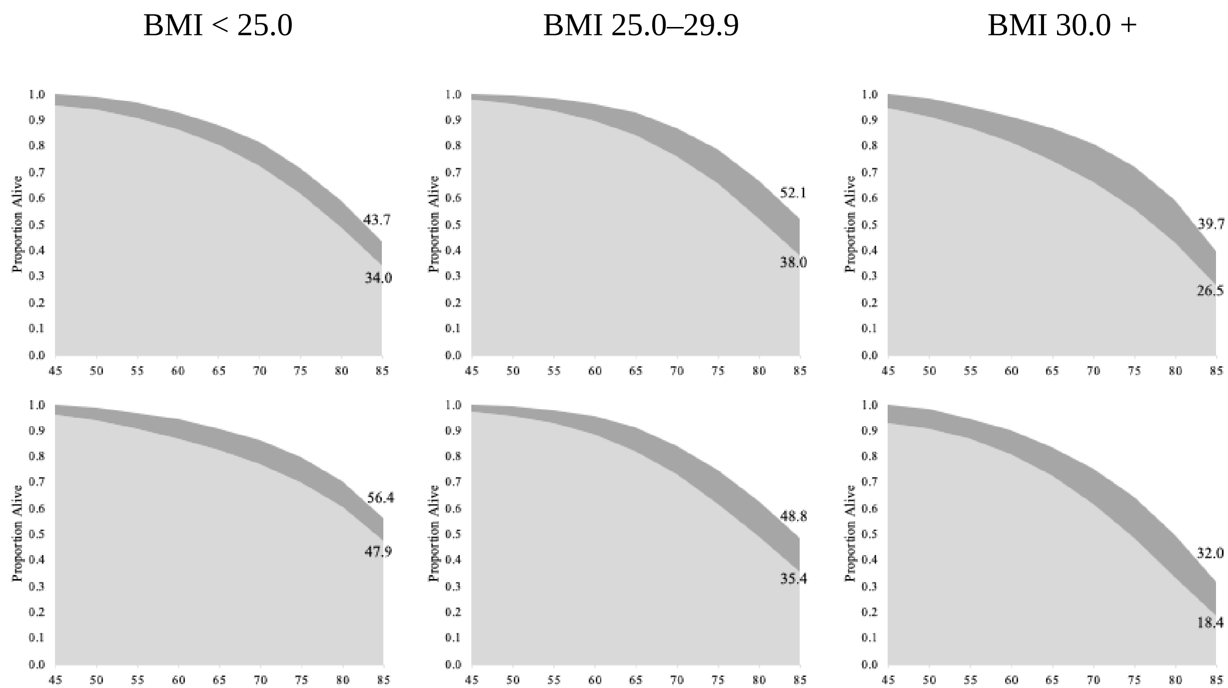
estimates of five-year age-specific disability status by BMI level, and (3) model-based estimates of five-year age-specific mortality rates by both BMI level and disability status. We estimate the 1990 and 2015 life tables using the adjusted model estimates of age-specific disability risk and adjusted model estimates of age-specific mortality rates.

We used Python (version 3.9.5) to simulate 50,000 five-year abridged multistate life tables for US men and women using (1) the age-specific estimates of low BMI, overweight BMI, and obesity BMI prevalence in 1990 and 2015 (CDC), (2) the age-specific probabilities of disability by BMI level, and (3) the age-specific mortality rates by BMI level and disability status. The age-specific probabilities of BMI level in 1990 and 2015, the age-specific probabilities of disability status, and the age-specific mortality rates are all population estimates. Therefore, we simulate Gaussian distributions of BMI status, disability status, and mortality status using the point estimates as the means and standard errors as the standard deviations. In the rare event of a negative probability value - these occurred only at young ages with low state occupancy probabilities, such as a 45-year-old with both a BMI 30.0+ and two or more disabilities - we re-simulated these cases using a uniform distribution with a lower probability bounded at 0 and an upper probability bounded at [mean - .5*SE]. We report and contrast the median (P_{50}) values of survival probability in 2015 with the values in 1990 and we provide a 90% uncertainty range composed of the P_5 and P_{95} values of simulation estimates.

PRELIMINARY RESULTS

Older-age male survival (total and DFS) rates by BMI level are shown in **Figure 1**. The top row shows estimates from models fitted using baseline BMI level and the bottom row shows estimates from models adjusted for bias. Compared to baseline models, the adjusted models indicate higher survival for low BMI population (e.g., male total survival: 56.4% baseline vs. 43.7% adjusted; male DFS: 47.9% baseline vs. 34.0% adjusted) and lower survival for high BMI (e.g., male total survival among obese BMI: 39.7% baseline vs. 32.0% adjusted; male DFS among obese BMI: 26.5% baseline vs. 18.4%). In **Figure 2**, we plot BMI differences in age-85 survival (overweight vs. low BMI, obesity vs. low BMI). Baseline model estimates indicate a survival advantage (overweight, male) or no significant differences (obesity, male) for high BMI populations compared to low BMI samples. In contrast, we see substantively large and significant differences estimated from models that adjust for bias. Finally, **Figure 3** shows distributions of older-age survival estimates (total and DFS) for the U.S. male and female populations in 1990 and 2015 from 50,000 multistate life tables. The only difference between the life tables in 2015 and 1990 are the higher prevalence rates of overweight BMI and obese BMI in 2015. Thus, the reduction in survival rates in 2015 reflect the increases in overweight and obese BMI prevalence in the male and female U.S. adult populations. The median total survival rate between age 45 and 85 for U.S. men in 1990 is estimated to have been 47.4% (IQR = 47.1–48.4%) and the median disability-free survival rate is estimated to have been 36.1% (IQR = 35.2–37.1%). In 2015, the median estimate of total survival between age 45 and 85 for U.S. men had decreased by over three percentage points to 43.9% (IQR = 43.1–44.7%) and disability-free survival had decreased by almost five percentage points to 31.3% (IQR = 30.3– 32.3%).

Figure 1. Survival Curves between Ages 45 and 85 for U.S. Men by BMI Status Estimated from Baseline Model (top) and Adjusted Model (bottom).



Note: light-gray shade is DFS and dark-gray shade is survival with disability. Women results not presented here due to space limitation but are consistent with the findings among U.S. men.

Figure 2. Age 85 Survival among Overweight and Obese BMI Populations (Relative to Low BMI Populations), Total and Without Disability, Baseline vs. Adjusted

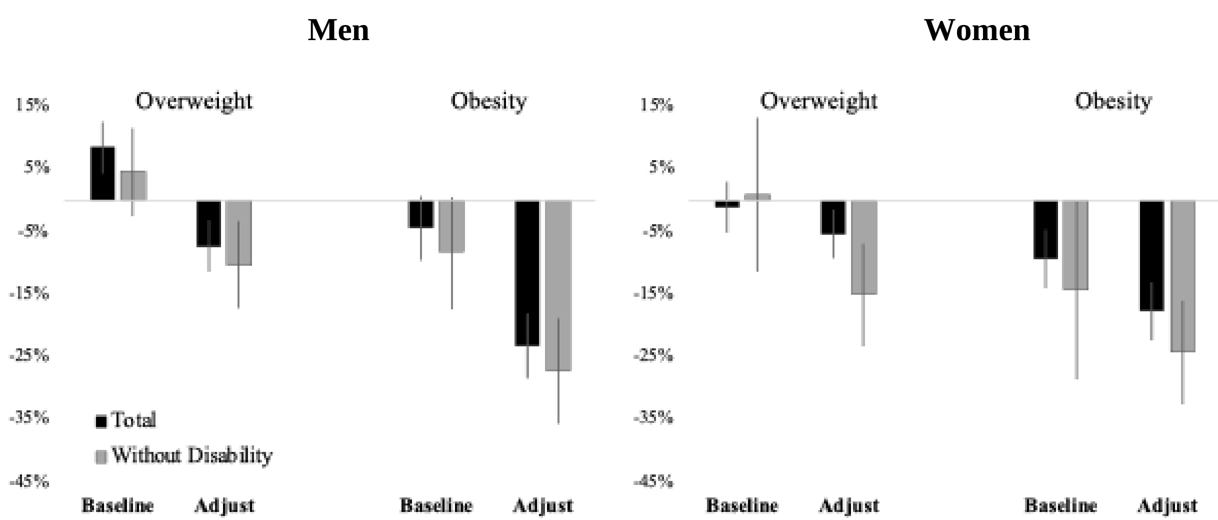
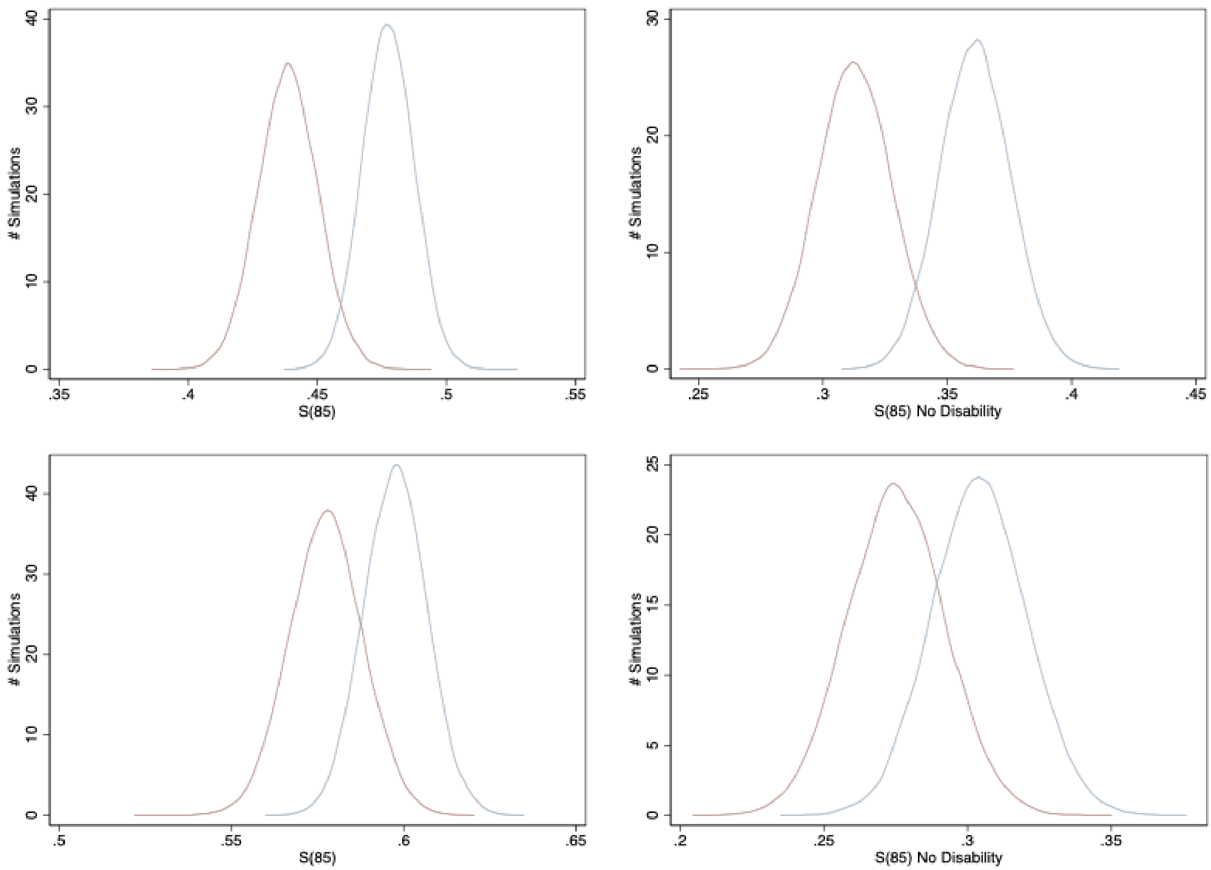


Figure 3. Total Survival and DFS Rates from Age 45 to 85 in 2015 and in 1990 among U.S. Men (top) and Women (bottom)



Note: blue line indicates distribution of 1990 estimates and pink line indicates distribution of 2015 estimates.