The Body Mass-Mortality Association in the United States: A Reassessment of Secular Trends

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Abstract

Three recent studies, all using the National Health and Nutrition Examination Surveys (NHANES), reached three different conclusions regarding the changing association between body mass index (BMI) and mortality in the US. This paper used the NHANES I and NHANES III data to examine mortality differences across BMI categories. The purpose is 1) to replicate previous analyses and reconcile discrepant findings in existing research and 2) to focus attention on variations across time periods and birth cohorts as well as variations across socio-demographic sub-populations. Preliminary results show that male and female BMI-related mortality differences are fairly similar in 1971-87, but diverge substantially afterwards. Relative to the normal-weight, mortality for almost all overweight and obese categories increases from 1971-87 to 1988-2006 among women. Relative mortality decreases over time among older men, but the decrease is substantial and significant for the class I obese only. These results caution against sweeping statements about BMI and mortality, and deserve the attention of those interested in the underlying mechanisms of the association and its implications for mortality trends.
Introduction

Life expectancy at birth in the United States increased from 40 years at the turn of the 20th century to 78 years in 2007. The longevity march is expected to continue (Wilmoth 1998; Oeppen and Vaupel 2002). In tandem with the secular trend in survival has been an increase in body size. About two thirds of the American health improvement in the first seven or eight decades of the last century could be attributed to factors associated with changes in physiology (Fogel 1994). An excess of body fat, however, could lead to a host of metabolic complications and fatal illnesses such as cardiovascular disease, diabetes, stroke and cancer (WHO 2000; Hu 2008). It has been suggested that if the current trend continues, excess body fat would wipe out the recent gains in health and longevity (Sturm et al. 2004; Olshansky et al. 2005).

The impact of excess fat on national mortality levels depends not only on its prevalence but also on its associated mortality differences. Thanks to the series of nationally representative National Health and Nutrition Examination Surveys (NHANES) that have consistently collected anthropometric data since the 1970s, there is little dispute regarding levels and trends of overweight (commonly defined as having a body mass index or BMI between 25 and 30) and obesity (BMI 30 and greater). Currently, 69 per cent of the American adults are overweight or obese (Flegal et al. 2012), increasing from less than 50 per cent in the early 1970s (Ogden et al. 2007).

Less certain and more controversial are the relative mortality levels associated with BMI and their temporal patterns. A tremendous body of research, including studies using the NHANES data, found that compared with the normal-weight (BMI between 18.5 and 25), mortality is lower for the overweight, not higher for the moderate obese (BMI between 30 and 35), but highest for the underweight (BMI less than 18.5) (Flegal et al. 2005; McGee
On the other hand, substantial excess mortality for the overweight or moderately obese was reported, for example, in analyses of the Framingham Heart Study (Peeters et al. 2003) and Nurses’ Health Study (van Dam et al. 2006). Body weight is not a fixed trait but interwoven with behaviours and health conditions. This dynamic process varies across study populations, and analytic strategies that are employed to handle the inter-relationships (e.g., sample exclusion and statistical adjustment) may also vary, leading to empirical inconsistencies.

The number of studies on trends in the BMI-mortality association is limited. In fact, it is a common practice for mortality projections to assume no change in BMI-related mortality differences, while entertaining various scenarios of change in the prevalence of overweight and obesity (e.g., Costa 2004; Stewart et al. 2009). Despite being small in number, empirical findings are no less conflicting. Using the samples of men aged 40-50 in the Union Army Records and the 1971-75 National Health and Nutrition Examination Survey (NHANES I), both with 18 years’ mortality follow-up, Su (2005) found an increase in overweight and obese mortality relative to the normal-weight from the end of the 19th century to the early 1970s. Using data from the NHANES I and 1988-94 NHANES (NHANES III), Mehta and Chang (2011) found a decrease in excess mortality due to moderate obesity from 1971-87 to 1988-2006 and declared “secular declines in the obesity-mortality association in the United States.” Their analysis provided an update of some earlier NHANES-based results (Flegal et al. 2005; Flegal et al. 2007), firming up the suggestion that advances in medical technology and health care may have eliminated the negative health consequences of excess body fat (Flegal et al. 2005; Gregg et al. 2005). Also using the NHANES I and NHANES III data, Cutler et al. (2011) found an increase in excess mortality due to severe obesity (BMI 35 and greater) among women and concluded that mortality returns to obesity (and smoking) have
grown over time. Using the NHANES III data only, Yu (2011) found excess overweight and obese mortality to be greater for women than for men, increasing from earlier to later cohorts, but not changing over the study period between 1988 and 2006.

Unlike Mehta and Chang (2011) that adjusted for sex in a combined analysis of men and women, Cutler et al. (2011) and Yu (2011) analysed men and women separately. In addition, the three studies differed in the treatment of the age, period and cohort dimensions of the association. To analyse period trends, Mehta and Chang (2011) restricted the sample to those aged 50-74 years at survey baseline, whereas Cutler et al. (2011) included and adjusted for a broader range of baseline ages (25-74 year olds). Yu (2011) estimated age-period-cohort models to examine age patterns of the BMI-mortality association and found evidence that the declining age pattern claimed in prior research (Stevens et al. 1998; Bender et al. 1999; Calle et al. 1999; Park et al. 2006) was largely an artefact of cohort patterns.

This paper used the NHANES I and NHANES III data to examine mortality differences across BMI categories in the United States, focusing on variations across time periods and birth cohorts as well as variations across socio-demographic sub-populations. Specifically, two sets of analyses were conducted. First, I replicated Mehta and Chang (2011) and analysed changes in the BMI-mortality association from 1971-87 to 1988-2006 separately for two baseline age groups. The difference from the sex-adjusted analysis of Mehta and Chang (2011) was in analysing men and women separately, to be compared with a combined analysis. Similar to Cutler et al. (2011), I included all subjects aged 25-74, but divided them into two baseline age groups: the 25-49 year olds and the group of 50-74 year olds as examined by Mehta and Chang (2011). The purpose of this period only comparison within baseline age groups was to explore sex and age group variations in the changing association between BMI and mortality and reconcile discrepancies in existing research.
Second, I pooled the two baseline age groups in the two NHANES samples and applied an age-period-cohort framework to examine period and cohort trends in the BMI-mortality association. The purpose was to replicate and extend the study period of the age-period-cohort analysis in Yu (2011), and place the focus on comparing period vs. cohort contributions to secular trends in how mortality differs by BMI.

**Data and Methods**

Conducted by the National Center for Health Statistics, the NHANES consists of a series of cross-sectional multistage stratified probability samples that represent the U.S. non-institutionalized population. This study used two samples with baselines in 1971-74 and 1988-94, respectively referred to as NHANES I and NHANES III (National Center for Health Statistics 1973; National Center for Health Statistics 1994). Mortality follow-up data are based on linkage with the National Death Index, through 1992 for the NHANES I sample and through 2006 for the NHANES III sample. Following Mehta and Chang (2011), the analysis used the NHANE I mortality data through 1987 only to make the two comparison periods (1971-87 vs. 1988-2006) non-overlapping.

BMI was calculated as weight in kilograms divided by the square of height in meters. Both weight and height were physically measured by health professionals at survey baseline. Based on the guidelines of the World Health Organization (2000), BMI was classified into five categories: underweight (BMI <25 kg/m\(^2\)), normal-weight (BMI 18.5-<25 kg/m\(^2\), as reference), overweight (BMI 25-<30 kg/m\(^2\)), class I obese (or moderately obese, BMI 30-<35 kg/m\(^2\)) and class II/III obese (or severely obese, BMI >=35 kg/m\(^2\)).
The analysis selected subjects aged 25-74 at baseline, totalling 19,468 cases after the sequential deletion of 251 cases missing for mortality status and 178 cases missing for anthropometric information or pregnant at baseline. Table 1 presents the break-down of the final sample by baseline age (25-49 vs. 50-74 years) and sex. Noteworthy is the substantially smaller number of deaths in the younger age group, due to low overall mortality levels among younger adults.

Mortality follow-up data, indexed by age in months, were analyzed by using the parametric Gompertz function. The model, characterized by an exponential increase of mortality over age $a$, can be written as:

$$\log h(a) = \beta + \gamma \cdot a,$$

where $h(a)$ denotes age-specific mortality rates in the NHANES sample, and $\beta$ and $\gamma$, the scale and shape parameter of the mortality curve. Previous analysis showed that the NHANES age-specific mortality rates appear to be linear on the log scale (Yu 2008), suggesting that the parametric model is robust as well as statistically more efficient than the semi-parametric Cox hazard model.

To analyze period changes ($T$, 1971-87 vs. 1988-2006) in how mortality differs by BMI ($W$), I estimated the following model separately for each of the two baseline age groups:

$$\log h(a) = \beta_0 + \beta_1 \cdot W + \beta_2 \cdot T + \beta_3 \cdot Z + \beta_4 \cdot W \times T + \gamma_0 \cdot a,$$  \hspace{1cm} (1)

where $Z$ denotes covariates other than age, period and BMI (see below for the full list), and “$\times$” indicates interactions. The coefficients are vectors when the variables are of more than two levels. $\beta_1$ estimates mortality differences in the reference 1971-87 period, and $\beta_4$, changes after 1988 in these differences.
The sex-specific analysis included seven additional covariates constructed from information collected at baseline. Education had four levels based on highest completed grade or degree: less than high school (grade less than 12), high school degree (grade 12 or GED), some college (13-15 years of school, or associates degree), and college graduates (at least 16 years of school or bachelor degree). Race/ethnicity had three groups: non-Hispanic whites, non-Hispanic blacks, and other. Marital status had six categories: married, widowed, never married, separated/divorced, and cohabiting (for the NHANES III sample only). Poverty income ratio, computed as a ratio of the observed family income to the poverty threshold, was divided into three levels: <1, between 1 and 3, and >=3. Geographic region was divided into four categories: the northeast, mid-west, south and west. Smoking status, created from two questions about whether having smoked more than 100 cigarettes, and whether smoking now, had three groups: current, former and never smoking. Smoking intensity was defined as: 0-9, 10- and >=20 cigarettes smoked per day. Missing data for each covariate were coded into a separate category. The combined analysis of men and women adjusted for sex. The analysis stratified by education adjusted for education for the high-school graduated sample only. These socio-demographic, economic and behavioural factors are all associated with both BMI and mortality. The statistical adjustment ensures that compositional differences with respect to these factors would not be responsible for the BMI differences in mortality.
REFERENCES


Table 1: Sample size at baseline and during mortality follow-up

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