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Short communication

Decomposing trends in adult body mass index, obesity, and morbid obesity, 1971–2012

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ABSTRACT

Trends in adult obesity have been used to motivate key public health policies in the United States. While these analyses provide important insights into the broad historical contours of the obesity epidemic in the U.S., they shed less light on the proximate mechanisms that have generated these changes and that will ultimately determine the long-term course and pace of change in obesity rates. We used data from the National Health and Nutrition Examination Survey (NHANES), Glenn Firebaugh's linear decomposition technique, and Kitagawa's algebraic decomposition method to decompose change in body mass index (BMI), obesity, and morbid obesity from 1971 through 2012 for adults aged 20+. We partitioned change into that attributable to (1) older, fitter cohorts in the population being replaced by newer, less fit cohorts (intercohort change), and (2) cohort members becoming less fit over time (intracohort change). We found that the rise in mean BMI and rates of obesity and morbid obesity was primarily a consequence of intracohort change driven by variation in the demographic and socioeconomic composition and in the diet of the population over time. Obesity and BMI in the population rose largely because of individual increases in weight status that were broadly distributed across age and cohort groups. Cohort replacement reinforced and amplified intracohort change over the study period, leading to rapid increases in mean BMI and obesity. Because intracohort change has been the central force in the increase in BMI and obesity, successful social, dietary, medical, or policy interventions have the potential to quickly slow or reverse the upward trend in weight status. Our results also imply that policy efforts and health interventions should be broadly targeted at all age groups and birth cohorts because increases in obesity have been widely distributed across all ages and generations.

1. Introduction

Over the past 40 years, key public health policies have been driven by the historically unprecedented increase in adult obesity. (Novak and Brownell, 2012; Malik et al., 1038; Gortmaker et al., 2011; Huang et al., 2015; Institute of Medicine, 2012). In 1980, the US Public Health Service used trend data to identify obesity as a major public health concern. Armed with this information, a comprehensive plan involving both federal and state agencies was developed to combat the increased prevalence of obesity. As recently as 2015, policy-makers have used trend studies to justify the implementation of programs to educate the public on dietary and fitness recommendations that minimize obesity risk (Levi et al., 2015). Despite these efforts, the prevalence of obesity in the United States continues to increase among adults (Ogden et al., 2014; Ogden et al., 2006, 2012; Flegal et al., 2010; Flegal et al., 2002). The most recent data indicate that nearly one-third of adults are obese, and another 5% are morbidly obese (Center for Disease Control, 2015).

Generally, researchers attribute the increase in obesity to changes in dietary patterns and physical activity levels (Lim et al., 2012). Overlooked in these studies is the fact that changes in diet and physical activity levels can affect the obesity rate in two different ways. On one hand, the obesity rate can rise because more recent birth cohorts have poorer diets and are less physically active than previous cohorts (intercohort change or cohort replacement). On the other hand, the obesity rate can increase because the health habits of all cohorts worsen over time (intracohort change).

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The magnitude and relative prominence of these two mechanisms of change have important implications for both the rate of growth and the prospect of the upward trend in obesity leveling off or reversing. For instance, if the increase in obesity largely reflects intercohort change (i.e., newer, less healthy cohorts replacing older, healthier cohorts), we would expect gradual increases in obesity over time, with obesity concentrated in more recent birth cohorts. Conversely, we would expect change resulting primarily from intracohort change (i.e., obesity rising over time for all cohorts) to occur more quickly and to be distributed more broadly among all birth cohorts and age groups. If cohort replacement and intracohort change reinforce one another, the obesity rate would increase rapidly over a relatively short period of time.

Disentangling the underlying mechanisms that contribute to the obesity epidemic will help researchers better understand why obesity rates continue to rise. It will also aid policy-makers to develop policies and educational campaigns aimed at reducing obesity. For example, if obesity increased largely because of intercohort change, health education campaigns should be directed primarily at younger adults. On the other hand, if the rise in obesity resulted from intracohort change such efforts should be targeted more broadly.

We use data from the National Health and Nutrition Examination Survey (NHANES) to decompose change in body mass index (BMI), obesity, and morbid obesity from 1971 through 2012 for adults aged 20 years and older. We partition change into parts attributable to (1) older, fitter cohorts in the population being replaced by newer, less fit cohorts (between-cohort change), and (2) cohort members becoming less fit over time (within-cohort change).

2. Methods

2.1. Data sources

Analyses are based on ten waves (1971/75, 1976/80, 1988/94, 1999/00, 2001/02, 2003/04, 2005/06, 2007/08, 2009/10, 2011/12) of the NHANES, a cross-sectional survey of the civilian, non-institutionalized U.S. population (CDC, 2011). NHANES uses a complex multistage probability sampling design, with oversampling of smaller racial/ethnic subgroups. Analyses were estimated weighted to account for differences in the chances of selection and non-response.

2.2. Study population

Models were restricted to adults 20 years and older with a completed body measurement component. Pregnant females were excluded. The total sample size for all years is 59,627 participants.

2.3. Outcome variables

We analyzed three independent outcome measures: BMI, obesity, and morbid obesity. BMI was calculated as weight (kg)/height (m) (Malik et al., 1038). We logged BMI to adjust for the non-linearity (positive skew) of BMI. Obesity was defined as a BMI $\geq$30 and $\leq$ 39.9 kg m^{-2}, and dichotomized to indicate whether or not the individual is obese. Morbid obesity was defined as a BMI at or above 40.0 kg m^{-2}, and treated as a binary variable to indicate whether or not the individual is morbidly obese.

2.4. Covariates

We included covariates to represent demographic, socioeconomic, nutritional, and physical activity factors known to be associated with weight-related outcomes. Demographic and socioeconomic characteristics include survey year, birth year, gender (1 = female), race (1 = non-Hispanic white), marital status (1 = not married), household income, and educational attainment (1 = less than high school). Nutrition characteristics include total intake of energy (1 = > 2000 kcal), fat (1 = > 78 g), carbohydrates (1 = <100 g), protein (1 = > 56 g), and sodium (1 = >1500 mg) during a 24-h period. Physical activity was classified by rate of energy expenditure (1 = < 3 metabolic equivalents (MET) defined as 3.5 ml $O_2 \cdot kg^{-1}$ min^{-1}) pursuant to a particular activity.

2.5. Statistical analysis

We used Glenn Firebaugh's (1989) linear decomposition technique to decompose aggregate (i.e., total) change in weight-related outcomes from 1971 through 2012. With this approach, cohort differences were estimated by regressing obesity on birth year and survey year. This approach assumed linearity. Because change may not be linear, we also collapsed birth year into cohort subgroups (Firebaugh, 1989), and used Kitagawa's algebraic decomposition method that does not assume linearity (Kitagawa, 1955). Both methods allowed us to partition total change (TC) in weight-related outcomes into two components of aggregate change: intracohort change (IC) and cohort replacement (CR). Intracohort change is computed by multiplying the regression coefficient for the survey year variable by the length of the study period (i.e., last survey year - first survey year). Cohort replacement is computed by multiplying the regression coefficient for the birth year variable by the difference between the mean birth years for the final and initial survey years. IC indicates how much of the aggregated change in weight status is attributable to individual change in body weight (i.e., period changes), and CR tell us how much of the total change in weight status is attributable to population turnover (i.e., the death of old cohorts with lower BMIs and the birth of new cohorts with higher BMIs). We assigned the midpoint mean for each survey wave (e.g., if 1971/73 we used 1972) and used linear interpolation methods to account for the multi-year data collection design in the NHANES data.

3. Results

BMI, Obesity, and Morbid Obesity increased significantly between 1971 and 2012 (Table 1). In 1971, the average BMI for adults aged 20 years and older was 25.66 (logged = 3.23). By 2012, the mean BMI increased to 28.71 (logged = 3.33). Obesity increased by nearly 15 percentage points from 1971 to 2012, whereas morbid obesity rose by 5 percentage points during this period.

Figs. 1–3 display historical trends in BMI, obesity, and morbid obesity, overall and for men and women, between the early 1970s and the early 2010s. Between the early and the late 1970s, mean BMI and obesity rates were remarkably stable. Beginning in the early 1980s, both average BMI and obesity rates rose sharply. Average BMI rose by 9% between the early 1980s and the late 1990s, with mean BMI increasing from 25.23 in the 1976/80 wave to 27.52 in the 1999/2000 wave. Over this period, the obesity rate nearly doubled, rising from 13% to 22%, and the morbid obesity rate quadrupled, from 1% to 4%. Increases in BMI and obesity have moderated considerably since the late 1990s.

Obesity and morbid obesity rates (but not mean BMIs) are somewhat higher for women than for men from the early 1970s into the 1990s. For example, the obesity rate for women in the 1971/74, 1976/80, and 1988/90 waves average about 18% and the morbid obesity rate averaged about 3%, whereas the obesity rate for men averaged about 14% and the morbid obesity rate averaged about 1%. While trends in BMI and obesity for men and women