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Bigger bodies: Long-term trends and disparities in obesity and body-mass index among U.S. adults, 1960–2008

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ABSTRACT

Increasing obesity rates and corresponding public health problems are well-known, and disparities across socioeconomic groups are frequently reported. However, the literature is less clear on whether the increasing trends are specific to certain socioeconomic groups and whether disparities in obesity are increasing or decreasing over time. This knowledge sheds light on the understanding of the driving forces to the ongoing worldwide increases in obesity and body-mass index and gives guidance to plausible interventions aiming at reverting weights back to healthy levels.

The purpose of this study is to explore long-term time trends and socioeconomic disparities in body-mass index and obesity among U.S. adults. Individual level data from ten cycles of the National Health and Nutrition Examination Survey between 1960 and 2008 are used to estimate adjusted time trends in the probabilities of obesity and severe obesity and in measured body-mass index for three racial/ethnic groups, for three educational groups, and for four levels of income, stratified by gender. Time trends in the probabilities of obesity and severe obesity are estimated by linear probability models, and trends at the 15th, 50th and 85th percentiles of the adjusted body-mass index distribution are estimated by quantile regression. Divergent time trends for the different socioeconomic groups are estimated by interaction terms between socioeconomic status and year.

The results show that, with some exceptions, increases in both obesity, severe obesity and body-mass index are similar across the different racial/ethnic, educational and income groups. We conclude that the increase in body-mass index and obesity in the United States is a true epidemic, whose signal hallmark is to have affected an entire society. Accordingly, a whole-society approach is likely to be required if the increasing trends are to be reversed.

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Introduction

Obesity is a major public health problem in the United States. Excess weight is a risk factor for many chronic diseases, including cardiovascular diseases, diabetes and certain cancers (Field, Coakley, Must et al., 2001; Mokdad, Ford, Bowman et al., 2003; Must, Spadano, Coakley et al., 1999; Visscher & Seidell, 2001). As a consequence, the increasing prevalence of obesity leads to high costs for the health care sector (Finkelstein, Fiebelkorn, & Wang, 2003; Lakdawalla, Goldman, & Shang, 2005), but obesity is also of direct individual concern; obese individuals report lower general well-being than others (Jia, 2005; Mokdad et al., 2003; Stewart, Cutler, & Rosen, 2009). Notwithstanding an awareness of obesity as a public health concern, there is no clear indication that the increase

in obesity prevalence is leveling off, much less reverting back to healthier levels. To understand the causes of the increase in obesity and to implement interventions with potential to cure the epidemic, it is essential to have a good picture of its development. By estimating time trends in body-mass index (BMI) and obesity, the purpose of this study is to provide such a picture.

Obesity prevalence and mean BMI, stratified by sex, age, race/ethnicity, and/or education are commonly reported in the literature (Flegal, Carroll, Kuczmarski, & Johnson, 1998; Flegal, Carroll, Ogden, & Curtin, 2010; Flegal, Carroll, Ogden, & Johnson, 2002; Kuczmarski, Flegal, Campell, & Johnson, 1994; Mokdad, Bowman, Ford et al., 2001, 2003; Ogden, Fryar, Carroll, & Flegal, 2004; Wang & Beydoun, 2007), and the National Health and Examination Surveys (NHANES) is a commonplace source of information. Kuczmarski et al. (1994) not only observed the dramatic increase in obesity prevalence early, but also tabulated the data for various age/sex/racial groups and noted that the increases did not seem to be limited to certain subgroups. Subsequent reports based on

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additional NHANES surveys continue to report such trends (Flegal et al., 1998, 2002, 2010; Ogden et al., 2004). It has also been frequently noted in the literature that obesity rates are higher in lower socioeconomic groups, particularly among women (Baum & Ruhm, 2009; McLaren, 2007; Sobal & Stunkard, 1989; Zhang & Wang, 2004a).

In contrast to the above mentioned studies, which all focus on period effects, Komlos and Brabec (2010) estimate trends in mean BMI by cohorts, stratified by race and gender. Controlling for age, income and education, they find that increases are larger for black females than for both white females and black and white men. A similar approach focusing on trends by deciles of the BMI distribution, reveals that the BMI distribution is becoming increasingly right-skewed (Komlos & Brabec, 2011). The focus on cohort instead of period effects also indicates that the increasing trends in BMI started already before the 1980s, which is used as a key period for the obesity accelerations in studies focusing on period effects (Komlos & Brabec, 2010, 2011).

Also using NHANES data, a few studies explore changes in socioeconomic and racial/ethnic disparities over time more directly. Grabner (2009) observes that relative increases in BMI are similar across racial/ethnic groups, but tend to be larger for medium and higher than lower socioeconomic groups, in particular when education is used as socioeconomic indicator. Wang and Beydoun (2007) assess socioeconomic disparities over time by plotting unconditional obesity prevalence for different socioeconomic groups by race/ethnicity and by calculating obesity prevalence ratios between low and high status groups across time. The low/high prevalence ratios tend to decrease over time, indicating decreased disparities. Racial/ethnic disparities are explored by estimating average annual increases in obesity and overweight by fitting unconditional linear time trends stratified by race/ethnicity. Comparing coefficients across these models indicates that the increase in obesity has been smaller for Mexican–American men and women compared to Blacks and non-Hispanic Whites, larger for black than white women, and smaller for black than white men. Zhang and Wang (2004b) compare odds ratios from logistic regressions of obesity status on socioeconomic status for four separate surveys. Odds ratios tend to converge toward one, indicating decreased disparities. Both Zhang and Wang (2004b) and Wang and Beydoun (2007) discuss that their findings of decreasing disparities suggest that social-environmental factors and not individual characteristics are important explanations to the obesity epidemic.

We extend the above referred studies by contributing with the specific aim to connect baseline disparities, changes in disparities and overall time trends to each other and to implications for our understanding of the underlying forces to the large increases in obesity.

To understand what lies behind the behavioral changes that have led to the large increases in obesity, it is valuable to link the changes in disparities to overall long-term increases in obesity or BMI. Based on data from the Behavioral Risk Factor Surveillance System for the time period 1986–2002, Truong and Sturm (2005) find that trends in adjusted mean and at the 80th percentile of the (self-reported) BMI distribution are surprisingly similar across education, race/ethnicity and gender. We complement and extend this study by exploring a longer time period and by also investigating the lower part of the adjusted BMI distribution. Even though increases in BMI among relatively lean people are not of any immediate health concern, tracking changes at these levels are important for obtaining a broader sense of the obesity epidemic. Furthermore, as disparities tend to be substantially larger among women than among men, the current analysis is carried out separately for men and women. Confirmation of the findings in Truong and Sturm (2005) is especially helpful in that BMI is based here on measured height and weight instead of self-reports. If

underreporting is positively correlated with weight, the bias in self-reported BMI is likely to have increased over time.

Insights into what, if any, subgroups of society have been disproportionately affected by the underlying societal changes behind the obesity epidemic are useful for understanding what changes have really had an impact on individuals: the proposed explanation to the obesity epidemic must be consistent with these observed changes. Food deserts, poor access to facilities for physical activity in lower socioeconomic areas, and economic and educational disparities leading to poor food choices are examples of factors brought up in the literature as important obesity determinants and explanations to the well-known socioeconomic disparities (among women). However, whereas factors like these may be important in explaining disparities at any given point in time, they may not necessarily be the driving forces to the overall increases in obesity over time.

Because there are no food deserts among the wealthy, because the wealthy do not need to economize by purchasing calorically dense foods, and because the well-educated can avoid the pitfalls of an adverse food environment, one would expect increasing disparities over time. Hence, most of the explanations for disparities in obesity would lead us to expect that the rise in obesity is a phenomenon that affects the poor and the poorly educated, and weight gain should not have affected the well-off and the well-educated. This study contributes to this debate by illustrating time trends for different social groups. A finding of increasing disparities would support the conventional wisdom about causes resting on individual or socially specific, group-level variables, whereas a finding of similar trends across social groups would point toward alternative, more universal, explanations.

With this background, the purpose of this study is to analyze how obesity prevalence and the adjusted distribution of BMI have changed over a long time period, including within particular subgroups of the population. Using data from 1960 to 2008 we estimate adult long-term increases for different social groups in the probability of being obese and severely obese as well as in BMI at three places of the adjusted BMI distribution. The use of quantile regression to describe trends at several places in the distribution of BMI provides an additional useful perspective beyond the previously-reported trends in mean BMI and obesity, because it examines the incidence of weight gain separately among those who are the least (or the most) preternaturally disposed toward obesity.

Data and variables

NHANES consist of repeated cross-section data, where samples of the U.S. population have been examined by health professionals every two to ten years since the 1960s. All surveys are characterized by a complex survey design, and sample weights that adjust the samples to nationally representative levels for the non-institutionalized population are provided.

This study uses information on individuals in the age range of 20–74 years from the ten available cross-sectional NHANES surveys (Table 1 includes information about when these were conducted), excluding pregnant women. We explore three outcome variables: BMI, obesity, and severe obesity, calculated from measured height and weight. Obesity is defined as $BMI \geq 30$ and severe obesity as $BMI \geq 35$.

Three dimensions of disparity and its development over time are in focus in this study: race/ethnicity, education and income. We estimate time trends for three racial/ethnic groups (Blacks, Hispanics, and non-Hispanic Whites), for three levels of education (less than high school, high-school degree or some college, and college degree), and for four levels of income. NHES I does not provide information on Hispanic origin, and for the first survey there are therefore only two racial/ethnic groups. For NHANES I and II Hispanics are classified based on reported ancestry, and for

Table 1

Sample means and standard deviations by survey-year (sample weights applied). Statistics for body measures reported for men and women separately. Demographic and socioeconomic variables reported for men and women together. No information about ethnicity available in NHES I. Educ 1: <12 years of schooling, Educ 2: 12 years or some university, Educ 3: university degree. PIR = poverty income ratio.

	NHES I		NHANES I		NHANES II		NHANES III			
	1959–62		1971–75		1976–80		1988–91 (phase I)		1991–94 (phase II)	
	mean	st. dev	mean	st. dev	mean	st. dev	mean	st. dev	mean	st. dev
BMI women	24.90	5.29	25.05	5.54	25.16	5.64	26.17	6.09	26.79	6.73
BMI men	25.14	3.87	25.56	4.14	25.48	3.96	26.36	4.85	26.91	4.87
Obesity women	0.16	0.37	0.17	0.37	0.17	0.37	0.23	0.42	0.27	0.44
Obesity men	0.10	0.30	0.12	0.32	0.12	0.33	0.18	0.39	0.21	0.41
Severe obesity women	0.05	0.22	0.06	0.23	0.06	0.25	0.09	0.29	0.12	0.33
Severe obesity men	0.01	0.12	0.02	0.15	0.02	0.15	0.05	0.21	0.06	0.24
Age	43.7	14.5	43.0	15.3	42.5	15.5	42.2	15.0	42.4	14.8
Hispanic			0.04	0.19	0.05	0.22	0.05	0.22	0.06	0.23
Black	0.10	0.30	0.10	0.30	0.10	0.30	0.11	0.31	0.11	0.32
Educ 1	0.32	0.47	0.36	0.48	0.31	0.46	0.24	0.43	0.22	0.42
Educ 2	0.56	0.50	0.50	0.50	0.52	0.50	0.51	0.50	0.51	0.50
Educ 3	0.12	0.32	0.14	0.34	0.16	0.37	0.25	0.43	0.26	0.44
PIR ≤ 1	0.18	0.38	0.11	0.31	0.11	0.31	0.11	0.32	0.12	0.33
1 < PIR ≤ 2	0.28	0.45	0.24	0.43	0.23	0.42	0.18	0.39	0.19	0.40
2 < PIR < 5	0.41	0.49	0.49	0.50	0.54	0.50	0.50	0.50	0.45	0.50
PIR ≥ 5	0.03	0.18	0.12	0.32	0.09	0.28	0.13	0.34	0.19	0.39
Unreported income	0.10	0.30	0.04	0.19	0.03	0.18	0.07	0.25	0.05	0.22
No. of obs.	5997		12,803		11,655		7083		7358	
	NHANES cont.		NHANES cont.		NHANES cont.		NHANES cont.		NHANES cont.	
	1999–00		2001–02		2003–04		2005–06		2007–08	
	mean	st. dev	mean	st. dev	mean	st. dev	mean	st. dev	mean	st. dev
BMI women	28.34	7.13	28.17	6.97	28.36	7.22	28.70	7.49	28.74	7.38
BMI men	27.75	5.57	27.99	5.71	28.22	5.46	28.66	6.08	28.53	5.99
Obesity women	0.34	0.47	0.34	0.47	0.34	0.47	0.37	0.48	0.36	0.48
Obesity men	0.27	0.44	0.28	0.45	0.31	0.46	0.33	0.47	0.32	0.47
Severe obesity women	0.17	0.38	0.15	0.36	0.16	0.37	0.19	0.39	0.19	0.39
Severe obesity men	0.10	0.30	0.09	0.29	0.10	0.30	0.12	0.33	0.11	0.31
Age	42.9	14.5	43.0	14.1	43.8	14.4	44.1	14.4	44.2	14.4
Hispanic	0.15	0.36	0.13	0.34	0.12	0.32	0.12	0.32	0.14	0.34
Black	0.11	0.31	0.11	0.31	0.11	0.32	0.12	0.32	0.12	0.32
Educ 1	0.23	0.42	0.18	0.38	0.17	0.37	0.16	0.37	0.19	0.40
Educ 2	0.54	0.50	0.55	0.50	0.59	0.49	0.57	0.50	0.55	0.50
Educ 3	0.23	0.42	0.27	0.44	0.24	0.43	0.27	0.44	0.26	0.44
PIR ≤ 1	0.14	0.35	0.12	0.33	0.12	0.33	0.11	0.31	0.13	0.34
1 < PIR ≤ 2	0.18	0.39	0.18	0.38	0.19	0.39	0.18	0.38	0.18	0.38
2 < PIR < 5	0.36	0.48	0.38	0.49	0.41	0.49	0.42	0.49	0.36	0.48
PIR ≥ 5	0.21	0.41	0.25	0.43	0.22	0.41	0.26	0.44	0.26	0.44
Unreported income	0.11	0.31	0.06	0.24	0.05	0.23	0.03	0.18	0.07	0.26
No. of obs.	3593		3914		3755		3832		4877	

the NHANES III survey and onwards, the classification is based on direct information about ethnicity.

We use the poverty to income ratio (PIR), based on self-reported income, as income measure. The PIR takes inflation and household composition into account but does not adjust for, for example, regional variation in prices. A household with a PIR value of one or less is considered poor, and a value of for example three means that the household income is three times the federal poverty line. We categorize individuals into four income groups (plus unreported income): PIR ≤ 1; 1 < PIR ≤ 2; 2 < PIR < 5; PIR ≥ 5. All surveys except the first conducted in 1959–62 report PIR directly. For the first survey, PIR is constructed by dividing the reported household income level by the average of the federal poverty lines for 1959 and 1962.

Methods

Sample weights

For surveys with complex designs, like NHANES, sample weights are crucial in order to get accurate nationally representative estimates of sample statistics. However, the correct use of sampling

weights in a multi-year analysis of repeated cross-sectional survey data is a difficult and unsettled matter in the literature. The complexity is conceptual, not technical.

To begin with, the use of sampling weights may or may not affect the estimated coefficients. When there is effect modification (that is, moderation or an interaction effect) of the main effect under study by one of the variables upon which the sampling was unbalanced, then the use of sample weights is required to generate results that are valid for the population as a whole. On the other hand, if there is no such effect modification, then the use of sampling weights will not affect the point estimates, and unweighted coefficient estimates will be unbiased and more efficient (Deaton, 1997 pp. 67–73).

The use of sampling weights is nonetheless frequently recommended. However, there are situations in which the danger of sampling weights to efficiency or consistency may outweigh their usefulness, and the analysis of successive waves of cross-sectional data can be such an example. Within each wave, each respondent is assigned a sample weight that, when used in a single wave, produces results that are appropriate to the composition of the population at that moment in time. However, over a period of many

years the composition of the population changes. When this happens, it is not possible to use any set of weights that will make the overall sample representative. In extreme cases, the use of weights can introduce bias, if the population is evolving in ways that are correlated with moderating variables. For example, if the population is becoming more Latino over time, and if a given effect is different for Latinos and non-Latinos, then the use of within-wave sampling weights will cause a Latino-specific effect to be wrongly attributed to a change in the effect over time, when it is instead a compositional effect. In this situation, it would reduce estimation bias to specify a model that strips out interaction effects, so that the weighted and unweighted estimates are statistically the same. This is the approach recommended for a similar data set (CHRR, 1999 p. 36).

Because of these complications around the use of sample weights, in what follows, estimations from both weighted and unweighted estimates are reported. We estimate *weighted* probability models of obesity and severe obesity, and *unweighted* quantile regressions of the development in adjusted BMI. In this way, if the same conclusions can be drawn from both analyses, it is unlikely that the results are driven by the fact that sample weights are used or not. Although not reported here for space constraints, unweighted models of the probability of obesity and severe obesity, and weighted quantile regressions, were also estimated, with similar results.

Probability models of obesity and severe obesity

In each of the three disparity dimensions (race/ethnicity, education, and income), we estimate time trends in the probability of being obese and severely obese by linear probability models, stratified by gender. For the race/ethnicity dimension the model specification is:

$\Pr(\text{obese}_i) \text{ or } \Pr(\text{severely obese}_i)$

$$= \alpha + \varphi_1 b_i + \varphi_2 h_i + \gamma_t \mathbf{y}_t + \delta_t (\mathbf{y}_t^* b_i) + \rho_t (\mathbf{y}_t^* h_i) + \beta_k \mathbf{x}_{i,k} + \varepsilon_i$$

where b and h are race/ethnicity variables indicating whether individual i is black or Hispanic, respectively, keeping non-Hispanic Whites as reference group. \mathbf{y} is a vector of nine survey-year dummies, where the first survey conducted in 1959–1962 is reference year. $\mathbf{y}^* b$ and $\mathbf{y}^* h$ refer to interaction terms between survey-year and the black and Hispanic groups, respectively. Hence, γ , δ and ρ give potential different survey-year estimates for non-Hispanic Whites, Blacks and Hispanics. \mathbf{x} is a vector of k control variables, including age, age-squared, education (three groups as defined above), and income (five groups specified as described above). The error term ε is assumed to be independent of all regressors and have a zero mean. The parameter standard errors are adjusted for the complex survey design with clusters and strata, are calculated with the Taylor series (linearization) method, and are robust to heteroskedasticity.

Divergent trends in obesity and severe obesity across education groups are estimated by the following model:

$$\Pr(\text{obese}_i) \text{ or } \Pr(\text{severely obese}_i) = \alpha + \varphi_1 \text{educ}2_i + \varphi_2 \text{educ}3_i + \gamma_t \mathbf{y}_t + \delta_t (\mathbf{y}_t^* \text{educ}2_i) + \rho_t (\mathbf{y}_t^* \text{educ}3_i) + \beta_k \mathbf{x}_{i,k} + \varepsilon_i$$

where $\text{educ}2$ refers to high-school degree or some college and $\text{educ}3$ to university degree, keeping individuals with less than 12 years of schooling as reference group. i denotes individual, \mathbf{y} refers to nine survey-year dummies, and $\mathbf{y}^* \text{educ}2$ and $\mathbf{y}^* \text{educ}3$ to interaction terms between survey and educational level. γ , δ and ρ give potentially different time trends for the three educational groups. The \mathbf{x} vector

includes age, age-squared, income, and race/ethnicity. The error term ε has the same properties as in the race/ethnicity model.

Finally, the time trends in the probabilities of obesity and severe obesity across income groups are estimated by the following model:

$$\Pr(\text{obese}_i) \text{ or } \Pr(\text{severely obese}_i) = \alpha + \varphi_1 \text{pir}2_i + \varphi_2 \text{pir}3_i + \varphi_3 \text{pir}4_i + \varphi_4 \text{pir}5_i + \gamma_t \mathbf{y}_t + \delta_t (\mathbf{y}_t^* \text{pir}2) + \rho_t (\mathbf{y}_t^* \text{pir}3_i) + \theta_t (\mathbf{y}_t^* \text{pir}4_i) + \beta_k \mathbf{x}_{i,k} + \varepsilon_i$$

where $\text{pir}2$ refers to $1 < \text{PIR} \leq 2$, $\text{pir}3$ to $2 < \text{PIR} < 5$, $\text{pir}4$ to $\text{PIR} \geq 5$, and $\text{pir}5$ represents individuals with unreported income, keeping the poorest group as reference. i refers to individual, \mathbf{y} to nine survey-year dummies, and $\mathbf{y}^* \text{pir}2$, $\mathbf{y}^* \text{pir}3$ and $\mathbf{y}^* \text{pir}4$ to interaction terms between year and income group. γ , δ , ρ and θ indicate whether increases in obesity and severe obesity over time differ across income groups. The \mathbf{x} vector includes age, age-squared, education, and race/ethnicity. ε has the same properties as in the race/ethnicity model.

The probability models are estimated with sample weights. In order to avoid that the increasing population size over time affect the results, the sample weights for the nine first surveys are rescaled to sum up to the same total population size as in the 2007–08 survey.

Quantile regression models

In each of the three disparity dimensions, we also estimate time trends at the 15th, 50th and 85th percentile of the adjusted BMI distribution by quantile regressions (Koenker & Hallock, 2001). In a general form, the linear quantile regression can be written

$$\text{BMI}_i = \alpha_\tau + \sum_k \mathbf{z}_{k,i} \beta_{k,\tau} + \mu_{i,\tau}, \text{Quant}_\tau(\text{BMI}_i | \mathbf{z}_i) = \alpha_\tau + \sum_k \mathbf{z}_{k,i} \beta_{k,\tau}$$

where τ is the 15th, 50th or 85th percentile, \mathbf{z} represents the k explanatory variables included in the model for individual i , α is a constant, and β is a vector of parameters. $\text{Quant}_\tau(\text{BMI}_i | \mathbf{z}_i)$ is the τ th conditional quantile of BMI given \mathbf{z} . $\beta_{k,\tau}$ is found by solving $\min_\beta \sum_i \rho_\tau(\mu_{i,\tau})$, where $\rho_\tau = \tau\mu$ if $\mu \geq 0$ and $\rho_\tau = (\tau - 1)\mu$ if $\mu < 0$, by linear programming.

Similar to the probability models, \mathbf{z} consists of the following variables for each of the three dimensions:

Race/ethnicity:

$$\mathbf{z}_i = (b_i, h_i, \mathbf{y}_t, \mathbf{y}_t \times b_i, \mathbf{y}_t \times h_i, \text{educ}2_i, \text{educ}3_i, \text{pir}2_i, \text{pir}3_i, \text{pir}4_i, \text{pir}5_i, \text{age}_i, \text{age}_i^2)$$

Education:

$$\mathbf{z}_i = (\text{educ}2_i, \text{educ}3_i, \mathbf{y}_t, \mathbf{y}_t \times \text{educ}2_i, \mathbf{y}_t \times \text{educ}3_i, b_i, h_i, \text{pir}2_i, \text{pir}3_i, \text{pir}4_i, \text{pir}5_i, \text{age}_i, \text{age}_i^2)$$

Income:

$$\mathbf{z}_i = (\text{pir}2_i, \text{pir}3_i, \text{pir}4_i, \text{pir}5_i, \mathbf{y}_t, \mathbf{y}_t \times \text{pir}2_i, \mathbf{y}_t \times \text{pir}3_i, \mathbf{y}_t \times \text{pir}4_i, b_i, h_i, \text{educ}2_i, \text{educ}3_i, \text{age}_i, \text{age}_i^2)$$

where, as before, i indexes individual, b and h are race/ethnicity variables indicating whether the individual is black or Hispanic, respectively, $\text{educ}2$ and $\text{educ}3$ are education level indicator variables defined as before, and $\text{pir}2$, $\text{pir}3$, $\text{pir}4$ and $\text{pir}5$ indicate which income group the individual belongs to. \mathbf{y} is a vector of nine survey-

year dummies. y^*b and y^*h refer to interaction terms between survey-year and the black and Hispanic groups, respectively. Similarly, y^*educ2 and y^*educ3 are interaction terms between survey-year and educational group, and y^*pir2 , y^*pir3 and y^*pir4 are interaction terms between time and income group. The parameter estimates for these interaction terms give potentially different survey-year estimates for the different race/ethnicity, education and income groups.

The quantile regressions are estimated without sample weights. μ is assumed to be uncorrelated with z . Parameter standard errors are estimated by bootstrapping (500 replications), assuming that the sample distribution is the same as the population distribution. Probability values are based on the standard errors and the assumption of an approximately normal sample distribution. The complex survey design with cluster and strata is taken into account in the re-sampling. Because of the small number of sampling units per strata, the bootstrapped standard errors will be downwardly biased (Korn & Graubard, 1999 pp. 32–33). This bias is conservative here. The main interest is in whether there are any divergent trends across socioeconomic groups, i.e. whether the interaction terms between socioeconomic group and survey-year are significant. If the null hypothesis of equal increase for a certain socioeconomic group and the reference group is not rejected based on the downwardly biased standard errors, it would also not be rejected with the correct standard errors. Hence, potential evidence of equal trends will not be due to incorrect standard errors.

Period effects

Because age, birth-year and time are linearly dependent (birth-year = time – age), all three variables cannot be included in the same model. Both age, period and cohort effects arguably exist. Period effects are time-specific factors that affect all individuals, irrespective of age and birth cohort. In the obesity epidemic context we believe that such period effects are important – it is likely that obesity-related societal changes impact individuals from a broad set of cohorts. Komlos and Brabec (2010, 2011) note that the period can be considered as the upper bound for the time when the weight gain occurred, whereas the year of birth can be viewed as the lower bound. Although we recognize that there may be cohort effects, the current study follows the large literature that focuses on period effects.

Diverging time trends

Both the probability models of obesity and severe obesity and the quantile regression models allow for fully flexible time trends in the sense that all time estimates are estimated with dummy variables. In this way the time trends are not forced to behave in a certain way such as following a linear, squared or cubic development over time, which is an important advantage. To evaluate whether the overall increase for a certain group differs from the reference group, the size, sign and statistical significance of the interaction term between the last survey-year and socioeconomic group is used. However, because sample sizes are quite small toward the end of the period, the point estimates for at least some of these terms are estimated with imprecision. This is important to keep in mind when evaluating the results. Further, the purpose of this study is to give an overview of the overall time trends rather than focusing on temporary, shorter sub-period deviations. For such an analysis, other methods, and a more detailed analysis would be needed.

In all models, the potentially divergent time trends for different social groups in the three dimensions are estimated in separate models, i.e. the year dummies are interacted with the social groups

in only one dimension per model. An alternative would be to estimate only one model, with interaction terms between survey-year and all three socioeconomic variables. However, as this would be an even more saturated model with about three times as many parameters being estimated, and with the likely result of even more imprecise and insignificant estimates, we decide to keep the model less complex by estimating divergent time trends for one dimension at a time.

The estimated time trends are presented graphically by plotting the time trends for each group while keeping population characteristics (that we control for) constant across time. This gives an easy-to-grasp overview and visual picture of long-term trends in BMI and obesity.

Results

Table 1 shows final sample sizes and descriptive statistics broken down by year. Body-mass measures are reported for men and women separately whereas demographic and socioeconomic variables are reported for men and women jointly. In 1999, NHANES moved to a continuous survey format, and sample sizes for these years are smaller than in previous surveys.

Estimated time trends in obesity and severe obesity, broken down by race/ethnicity (Panel A), education (Panel B) and income (Panel C), are presented in Figs. 1 and 2 for women and men, respectively. Fig. 3 (for women) and Fig. 4 (for men) illustrate the results from the quantile regression analysis. The slopes of the curves in Figs. 1–4 illustrate the estimated survey-year coefficients (plus interaction terms for the non-reference groups), and vertical differences between the curves correspond to the estimated disparities. Because information on Hispanic origin is missing for the first survey, the increases between the first and second survey are assumed to be the same for Hispanics and other Whites. The Supplemental Appendix provides full regression results for all models.

The curves in Figs. 1–4 are rather non-smooth, particularly toward the end of the period. The probable reason for this is the small sample sizes. The imprecision of the point estimates toward the end of the period makes it difficult to evaluate the most recent trends, and the results presented below focus on longer-term trends rather than the most recent changes in disparities.

Trends in the risk of obesity and severe obesity (Figs. 1 and 2)

Among women, there are racial disparities as illustrated by the vertical space between the Blacks' and the others' curves in Panel A of Fig. 1. At baseline, the probability of obesity among Blacks is about ten percentage points higher compared to non-Hispanic Whites, and the corresponding number for severe obesity is 3.5 percentage points. For Whites, the total increases over time in obesity and severe obesity are about 22 and 14 percentage points, respectively. Increases are larger for Black women: another 5–10 percentage points for obesity, and another 8–10 percentage points for severe obesity. Regarding Hispanic women, the baseline disparity is smaller (and statistically insignificant), and there is no evidence of any diverging trends in obesity or severe obesity.

In the education dimension (Fig. 1, Panel B), women with less than 12 years of education are more likely than women with higher education to be obese and severely obese. However, over time, there is no evidence of larger increases for the lowest educated group. If anything, there is a tendency of larger increases for women with high-school degree or some college. Increases among the highest and lowest educated women are very similar in size.

Also in the income dimension (Panel C) there are initial disparities where women with a PIR of two and higher are

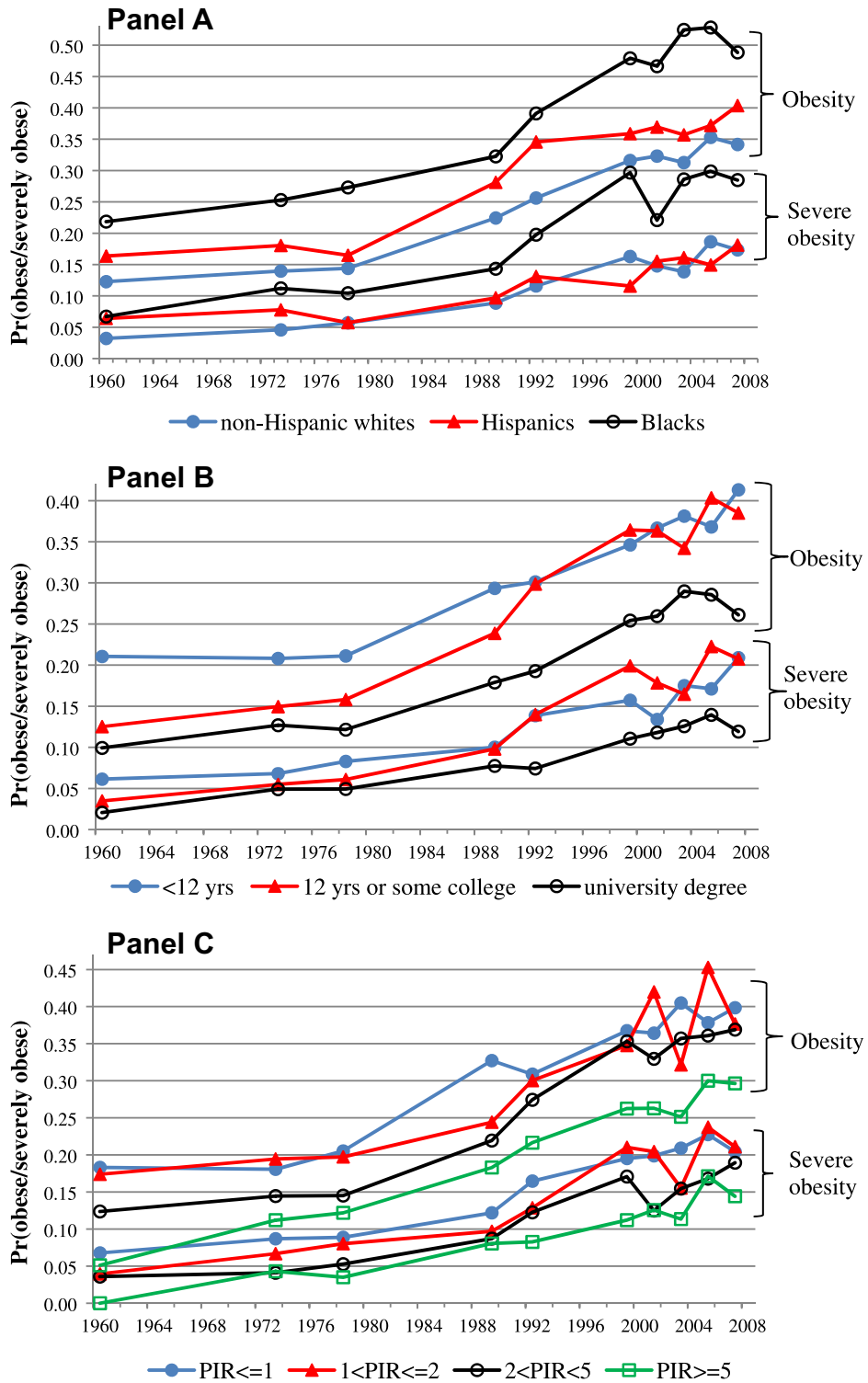


Fig. 1. Female adjusted time trends and disparities in obesity and severe obesity by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on linear probability models controlling for age, race/ethnicity, education, and income, taking the complex survey into account when calculating standard errors, and using sample weights.

significantly less likely to be obese and severely obese. However, over time there is no evidence for diverging trends across income groups. Hence, increases in obesity and severe obesity have not been smaller among women with a PIR of five or more than among the poorest women.

Among men, racial or ethnic baseline disparities in obesity and severe obesity are smaller and not statistically significant (Fig. 2,

Panel A). Increases in the probabilities of obesity and severe obesity over time are very similar for all three racial/ethnic groups. The increases among black men are somewhat larger, although insignificantly so, than among Whites. The insignificance may be due to small sample sizes of black men. However, the estimated additional increase is nevertheless not more than three percentage points compared to white men, corresponding to about 15 and 35 percent

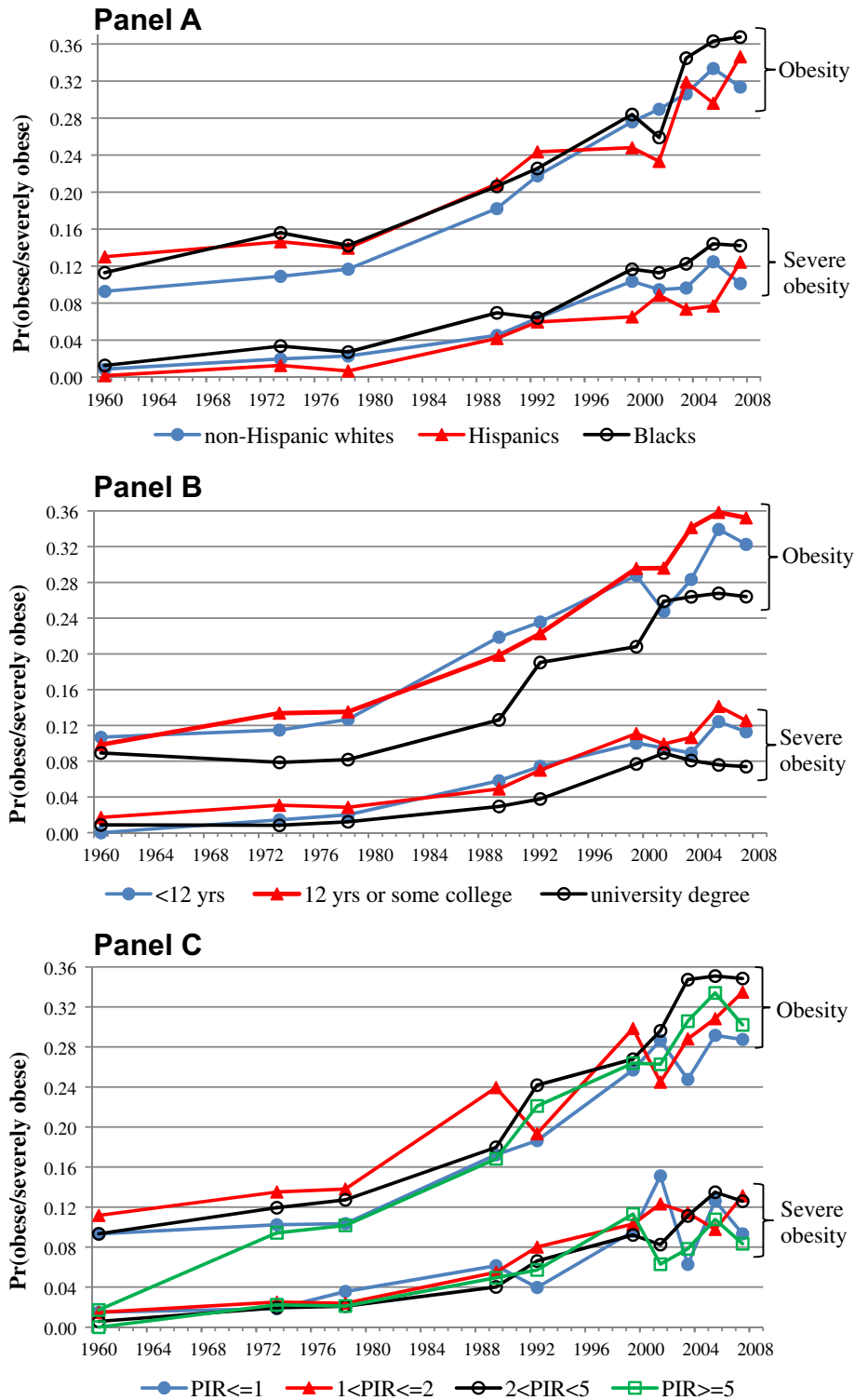


Fig. 2. Male adjusted time trends and disparities in obesity and severe obesity by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on linear probability models controlling for age, race/ethnicity, education, and income, taking the complex survey into account when calculating standard errors, and using sample weights.

more for obesity and severe obesity, respectively. Hence, irrespective of significance level, the sizes of the increases are rather similar.

Also in the education dimension (Panel B), there are no particular initial disparities among men, and there is no evidence of smaller (nor larger) increases for the higher educated compared to the lowest educated over time. Men with a university degree appear to have followed a somewhat slower development in both

obesity and severe obesity. Yet, over the full period, around 80 percent of the increase in obesity among the lowest educated is shared also by the university educated men. In severe obesity, just over 50 percent of the increase among the lowest educated is shared also among the highest educated.

Regarding the income dimension, in the first survey, obesity among the richest men was rare, as illustrated by the outlying

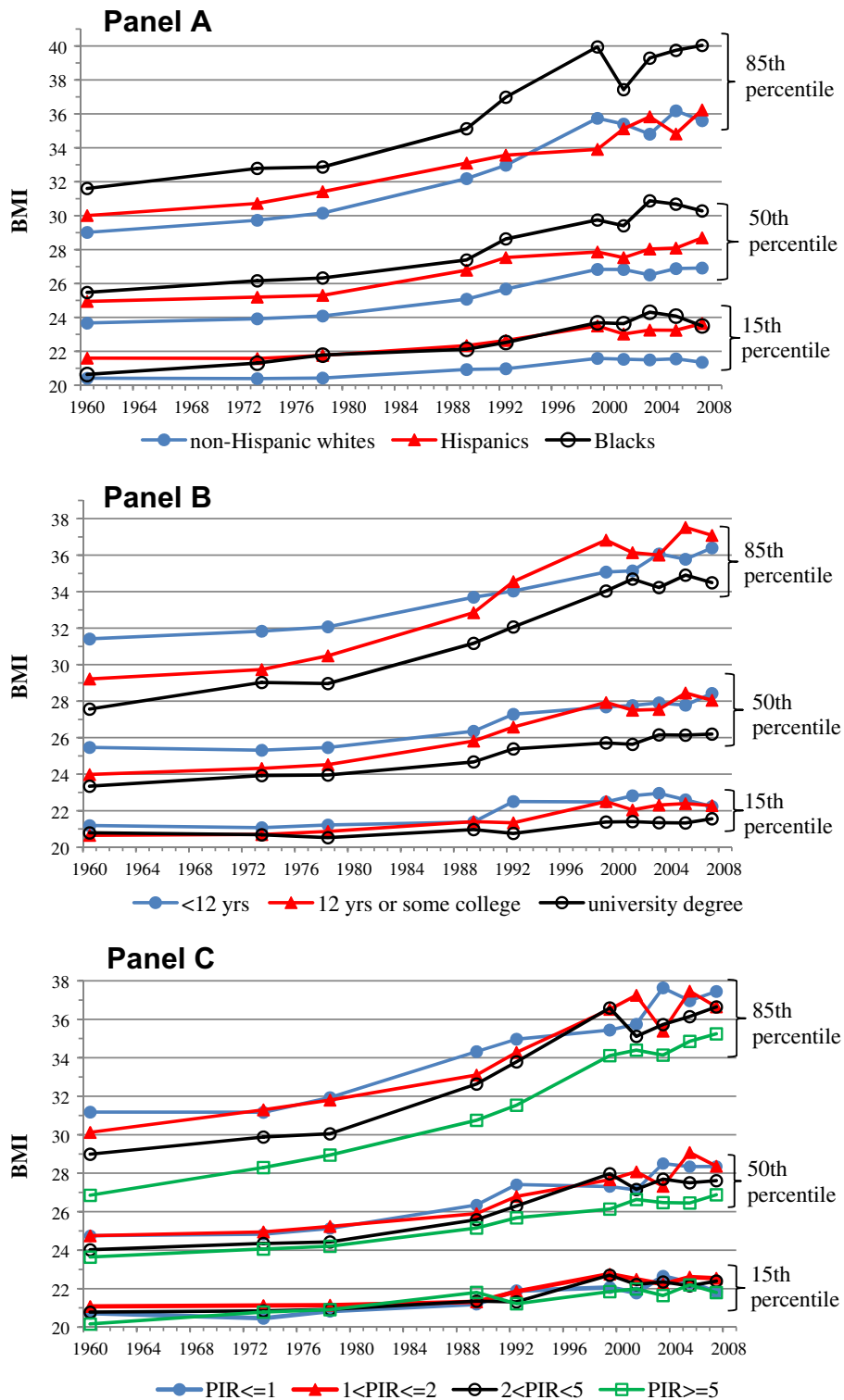


Fig. 3. Female adjusted BMI time trends and disparities at the 15th, 50th, and 85th percentile of the conditional BMI distribution, broken down by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on quantile regressions controlling for age, race/ethnicity, education, and income without use of sample weights. Bootstrapped standard errors adjusting for strata and clusters.

squared point estimate in 1960 in Panel C of Fig. 2. This initial disparity disappears with time, and this initial increase among the richest put aside, there are no sizeable or statistically significant differences in the increases between any of the groups. Also for severe obesity there are few differences in increases over time.

Trends at the 15th, 50th and 85th percentiles of the adjusted BMI distribution (Figs. 3 and 4)

The results from the quantile regressions are similar to the results from the probability models, but add the perspective of the lower part of the distribution. Increases are clearly larger as one

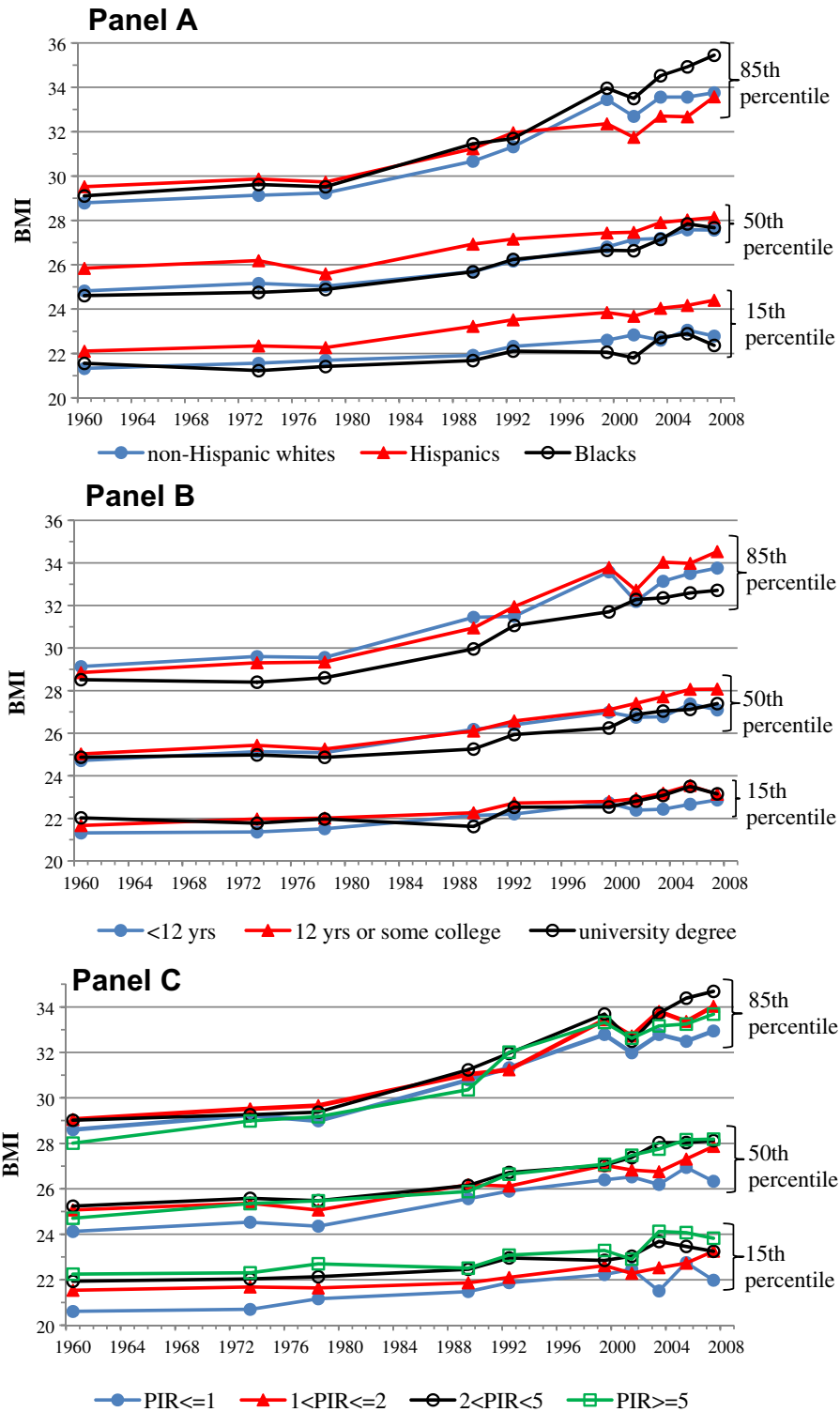


Fig. 4. Male adjusted BMI time trends and disparities at the 15th, 50th, and 85th percentile of the conditional BMI distribution, broken down by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on quantile regressions controlling for age, race/ethnicity, education, and income without use of sample weights. Bootstrapped standard errors adjusting for strata and clusters.

moves up in the distribution, but even at the 15th percentiles total increases are significant. The average total increase at the 15th percentile is 1.4 BMI for both men and women, and around seven BMI points for women and five for men at the 85th percentile.

Regarding the racial disparities among women, these are evident at the 50th and 85th percentiles, which is in accordance

with the probability models results. At the 15th percentile the initial racial disparity is small and not statistically significant, but the additional increase among Blacks is substantial – the increase among Blacks is about three times as large compared to non-Hispanic Whites. Among men, the quantile regressions do not suggest any racial disparities. Increases over time are rather similar

for Blacks and Whites, but with a tendency of somewhat larger (but insignificant) increases among Blacks at the 85th percentile. The evidence of substantial increases in the racial disparities at the 15th percentile among women does not appear for men.

For both men and women, the quantile regressions suggest that BMI is higher among Hispanics at both the 15th, 50th and 85th percentile. As for obesity and severe obesity, there is no evidence of larger trends for Hispanics at the 50th and 85th percentiles, but rather a slight tendency of smaller increases among Hispanic men compared to other white men. At the 15th percentile, there is evidence of increasing disparities among women, but not as substantial as for Blacks. The Hispanic (absolute) female disparity doubles over the full period at this lower part of the distribution. Also among men there is a tendency toward increasing Hispanic disparity at the 15th percentile.

Regarding education, the quantile regressions for the 50th and 85th percentile confirm the results of existing initial disparities among women, no baseline disparities among men, and no evidence of larger increases among the lowest educated women or men. At baseline at the 15th percentile, BMI among university educated men is larger than among the lowest educated. Over time, among men there is no evidence of diverging trends at the lower part of the distribution when evaluating the full period. The increase among the university educated women is somewhat smaller compared to the lowest educated.

Also in the income dimension the quantile regression results for the 50th and 85th percentiles are similar to the results based on the probability models with no diverging trends across income groups over time. At the 15th percentile there are no initial income disparities or any particular diverging trends among women. Among men, conditional BMI increases with income at the 15th and 50th percentiles at baseline, but there is no evidence of diverging trends over time.

Sensitivity analysis

The results presented in the previous sections are robust to various alternative specifications. First, excluding income from the regression and thereby interpret the education variable as a more comprehensive socioeconomic status variable, does not affect the overall results. The level of initial disparities changes somewhat (the education variable now captures also part of the previous income effect), but the patterns regarding increases over time remain the same as in the main analysis.

Second, the main analysis shows that unweighted quantile regressions and weighted linear probability models give very similar pictures about the development of the obesity epidemic. Moreover, estimating the quantile regressions from the main analysis with sample weights and the linear probability models without sample weights does not change the overall picture. Exact point estimates differ somewhat, and in some cases the significance level is affected considerably. For example, when removing the sample weights from the linear probability models, the estimated Hispanic baseline disparity in obesity reaches statistical significance for both men and women, although the size remains rather equal in size as before. When adding sample weights to the quantile regressions the most noticeable difference also regards the Hispanics. At the 85th percentile, the baseline disparity loses its statistical significance for both men and women. Also for both genders, at the 15th percentile the baseline disparity increases, and there is no evidence of any additional increases among Hispanic women over time. Finally, at the 15th percentile the baseline disparity among the highest and lowest educated women increases and reaches statistical significance when adding the sample weights. At the same time the tendency toward a somewhat

smaller increase for the highest educated disappears. In short, despite some differences, results are not particularly sensitive to the use of sample weights in this case, and the results of similar trends across socioeconomic groups are not driven by the handling of sample weights.

Third, in addition to the race/ethnicity, education and income time trends breakdowns, potentially divergent time trends by region of residence (West, Midwest, South and Northeast) are estimated. Because data on region are publicly available for the first five surveys only, this complementary analysis covers only the period between 1960 and 1994. Regarding obesity, increases between 1960 and 1994 do not differ significantly across Census regions for men, whereas the increase among women in the Midwest region is about 60 percent of the increase in other regions. For severe obesity there are no differences in time trends among women, whereas the increase among men in the South region is larger (6.6 percentage points as compared to 2.5 percentage points in the West region). The quantile regressions suggest that increases are smaller among women in the Northeast and Midwest regions. Among men, the increase in BMI is somewhat larger in the South region at the 50th percentile. Overall, though observed on a shorter time frame, these results support the primary conclusion that the obesity epidemic has affected individuals in all parts of the society.

Discussion

The overall most striking result from Figs. 1–4 is how similar the time trends are for the different racial/ethnic, educational and income groups. By the end of the period, obesity and BMI are significantly worse for the best-off group than they had been in the beginning for the worst-off group. The principal dimension of disparity is accordingly not income, education, or race/ethnicity, but rather time. Baseline disparities exist, particularly among women, but generally, the greatest part of the *increases* in BMI and obesity over time is shared by individuals in all subgroups of society. Although there are some differences in time trends by race/ethnicity, education and income, and even though in a couple of cases these differences are of a clinically meaningful magnitude and warrant further investigation, the primary result is that changes in disparities are uneven and small relative to the overall upward trends over time. Hence, the obesity epidemic is far from limited to low socioeconomic and minority groups. The additional increases among Blacks are worth noting and merit further investigation.

We do not find any evidence of diverging time trends across income groups. Although baseline disparities exist among women, increases over time are not smaller among the richest than among the poorest men or women. Further, we do not find any evidence of smaller increases among the highest compared to the lowest educated. These results are in line with findings of decreased disparities over time (Grabner, 2009; Wang & Beydoun, 2007; Zhang & Wang, 2004b). Without control for income, Truong and Sturm (2005) find very similar time trends for four levels of education. Our results confirm also these findings. However, we find substantially larger increases for all groups – a result that may be explained by the fact that our results are based on measured BMI instead of self-reports and occur over a longer time period.

The perhaps most important limitations with the method used in this study regard the modeling of the time trend, the rule of what a difference in time trend is, and the inherent problem with the small sample size toward the end of the period – aspects that are discussed in the [Methods section](#). Further, while this study gives an overview of the obesity epidemic development over time, it may well miss out on, and not highlight, some relevant aspects. For example, although trends are overall and generally similar, there

are exceptions. Likewise, in the present study we do not investigate socioeconomic disparities and trends *within*, for example, different racial/ethnic groups. Hence, the current study should not be taken as giving the full picture of the very complex ongoing obesity epidemic, but rather as a broad picture. Despite this limitation, we believe that the findings are relevant for the current debate and provide a useful overview.

An additional limitation regards omitted variable bias. Clearly, the time trends estimated in this study are conditional on included control variables only, and not on unobserved characteristics. If the assumption of no correlation between the regressors and the error term fails to hold, the resulting estimates are biased, and omitted variables may potentially drive the changes over time that are identified here. The primary purpose of this paper is descriptive, and no argument on behalf of any particular causal pathway can be made.

If increases in obesity and BMI are similar for most societal groups, this phenomenon has significant implications for our understanding of the kind of societal changes that have caused the behavioral change leading to large increases in obesity over time. The important point made in the current study is that whereas there exist baseline disparities between socioeconomic groups, minority and groups with lower socioeconomic status are generally not overrepresented in the increases of obesity. This is an important distinction. Although the nature of the analysis is descriptive and excludes controls for, for example, ability, genes and smoking behavior, the similar trends over time across income levels point toward that money, or not being able to afford a healthy lifestyle, is unlikely to be an important factor behind the obesity epidemic. Similarly, the parallel rise in obesity across educational groups suggests that it is unlikely that lack of knowledge would be an important driver to the observed increases. A convincing explanation of the increases in obesity must therefore involve a change that pervades the whole society, and not only minority and low socioeconomic groups. One possible explanation that is consistent with our results is that over time the marketing of obesogenic foods has become more pervasive or more powerful (Zimmerman, 2011).

In short, the obesity epidemic has reached all corners of society. The increasing trends are broadly speaking universal across the three racial/ethnic groups as well as across the educational and income groups that are analyzed in this study. Moreover, the results show that increases in obesity, severe obesity and BMI have occurred not only in all socioeconomic groups, but also at the lower end of the BMI distribution. In order to reverse this universal weight gain phenomenon it is clear that individuals in *all* socioeconomic groups would need to acquire healthier lifestyles, including new (or perhaps long-discarded) habits regarding food, drink and physical activity. Successful and sustainable interventions have to manage the complex relationships between preferences, surrounding framework, environment, macro-level factors and individual behavior. The urgent challenge is to figure out what societal-level interventions, or combination of interventions, will really make a change. Irrespective of socioeconomic status, race/ethnicity, and body size, individuals have shown a common tendency to add weight. The widespread weight gain suggests that obesity can be addressed only with a whole-society approach (Rose, Khaw, & Marmot, 2008).

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Appendix A. Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.socscimed.2012.03.003.

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