Original Article

BMI Trends, Socioeconomic Status, and the Choice of Dataset

Michael Grabner

HealthCore, Inc., Wilmington, DE, USA

Key Words

Body mass index • BMI • Obesity • Socioeconomic status • Health surveys • Ethnic differences

Abstract

Objective: This study is a descriptive investigation of trends in BMI in the USA over time, across race/ethnicity, gender, and socioeconomic status (SES) groups, and across different datasets. **Methods:** The study analyzes micro-level data from three widely used cross-sectional US health datasets: the National Health and Nutrition Examination Survey (NHANES), the National Health Interview Survey (NHIS), and the Behavioral Risk Factor Surveillance System (BRFSS), from the 1970s to 2008. Consistent race/ethnicity and SES groups are constructed for all datasets. SES is measured by education and income. Focusing on adults aged 20–74 years, the study estimates BMI time trends, distributional shifts, and incremental associations (gradients) with SES. **Results:** SES-BMI gradients are consistently larger for women than for men, differ across race/ethnicity groups, and are similar across datasets. Trends in mean BMI are comparable across White, Black and Hispanic males, while Hispanic females range between White and Black females. Self-reported BMI in the NHANES differs markedly from self-reports in the NHIS and BRFSS. **Conclusion:** The NHANES, NHIS, and BRFSS provide similar evidence regarding BMI trends over time and across race/ethnicity, gender, and SES groups. Racial disparities in BMI remain after adjusting for SES and should be studied further.

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Introduction

Obesity remains a major public health concern. Obesity levels among US adults have increased dramatically over the past 30 years, from about 14% in 1970 to 34% in 2008 [1, 2]. By 2020, over 70% of the population is expected to be overweight or obese [3, 4]. Although the USA is an outlier, other developed countries are experiencing similar changes [5]. Obesity

Dr. Michael Grabner
HealthCore, Inc.
800 Delaware Avenue, Fifth Floor
Wilmington, DE 19801, USA
Tel. +1 302 230 2121, E-Mail mjgrabner@gmail.com

increases the risk of coronary heart disease, diabetes, hypertension, and other diseases, and is a significant preventable cause of death with more than 200,000 associated deaths per year [6, 7]. The direct medical costs of obesity were projected at USD 115–151 billion for 2010 [4].

Obesity levels vary considerably by gender, race/ethnicity, age, and socioeconomic status (SES) [2, 8–10]. SES is usually captured by income, education, or occupation, or a combination of these. In developed countries there typically is a strong negative relationship (a negative gradient) between SES and obesity for women, while the relationship for men and children is inconsistent. Furthermore, in the USA the prevalence of obesity is much more pronounced in African-Americans and Mexican-Americans than non-Hispanic Whites [10]. It has also been documented [3, 10] that severe obesity has grown even faster – the prevalence of obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) doubled from 1986 to 2000, while class 3 obesity rates ($\text{BMI} \geq 40 \text{ kg/m}^2$) have quadrupled.

Much of prior analysis of US obesity trends has been focused on either single years of observation, single population groups, or a single dataset (most commonly the National Health and Nutrition Examination Survey, NHANES). The NHANES is regarded as a reliable source of prevalence estimates since it contains exam-based measurements in addition to self-reported measurements, which are known to be biased [11]. However, the NHANES works with relatively small sample sizes and has been conducted annually only since 1999. This presents challenges for subgroup analysis and the examination of long-run time trends. The National Health Interview Survey (NHIS) and the Behavioral Risk Factor Surveillance System (BRFSS), two other national health datasets, offer much larger sample sizes and have been conducted annually since 1957 and 1984, respectively, but are constrained to self-reported measurements.

This study has two main objectives: First, it explores similarities and differences in BMI trends among US adults across the NHANES, NHIS, and BRFSS over a long time horizon (1971–2008). This provides a more detailed picture of recent BMI trends as well as evidence regarding the comparability of these datasets. Second, the study investigates and quantifies the incremental association between SES, as measured by education and income, and BMI across all three datasets. These gradients provide rough estimates of the health returns (measured as BMI improvements) to education and income. To account for potential heterogeneity across subgroups, all analysis is stratified by gender (male/female) and/or race/ethnicity (White/Black/Hispanic). Taken together, this study provides new information on health disparities in BMI across all major sociodemographic subgroups in the USA, using several independent data sources and a long-run perspective.

Material and Methods

Variables

The outcome of interest in this study is the patient's BMI level (calculated as height/weight^2 ; kg/m^2), the most common measure of obesity. BMI is less accurate than laboratory measures because it ignores variations in the distribution of body fat and muscle mass [12]. It remains the most preferred measure in obesity research since it is easy and inexpensive to calculate, and the only readily available measure in most population-based datasets. Most analyses in this study focus on (mean) BMI in order to examine trends across the height/weight spectrum.

SES is determined using completed years of education and personal real income. Education and income were usually reported in brackets and transformed into continuous variables. Complete and consistent race/ethnicity recodes were created across the three datasets (non-Hispanic Whites, non-Hispanic Blacks, Hispanics). More information on data preparation is contained in the online supplementary material (available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=337018>).

Description of Datasets

Data are drawn from repeated cross-sections of the NHANES, NHIS, and BRFSS. All observations are from the public-release files.

The NHANES is a nationally representative cross-sectional survey of the US civilian non-institutionalized population conducted by the National Center for Health Statistics (NCHS) [13]. The first series of interviews and measurements took place from 1971 to 1975 (NHANES1), the second from 1976 to 1980 (NHANES2), and a third from 1988 to 1994. Since 1999, the NHANES has been carried out continuously, with new data being released every 2 years. At the writing of this study the last available dataset was from 2005 to 2006, bringing the total number of available series to 7. Unique among similar national datasets, the NHANES combines interviews with physical examinations in mobile examination centers that travel to different counties every year. The NHANES over-samples persons 60 years of age and older, Blacks, and Hispanics. Starting with the NHANES2 there are two sources of body measurements – self-reports and clinical examinations (NHANES1 only includes clinical measurements). Clinically measured height and weight are reported in metric units, while self-reports use imperial units and were converted by the author to metric standards.

The NHIS is also a nationally representative cross-sectional survey of the US civilian non-institutionalized population conducted by the NCHS, in conjunction with the US Bureau of the Census [14]. It has been conducted continuously since 1957, with major design revisions every 10–15 years, the last one in 1997. Like the NHANES it over-samples Blacks and Hispanics. The NHIS is based on in-person household interviews and samples up to 87,500 people per year.

The Minnesota Population Center has released a harmonized set of data and documentation based on the public release files of the NHIS, starting in 1969, called the ‘Integrated Health Interview Series’ or IHIS [15]. Information on height, weight, and Hispanic ethnicity is available starting in 1976, and this was chosen as the base year for this study’s use of the IHIS. The NHIS only provides self-reports of height and weight; before 1997, these self-reports also included proxy reports from other members of the household. The analysis used the BMI variable calculated by the IHIS, which is based on the publicly released height and weight files.

The BRFSS is another cross-sectional survey of civilian non-institutionalized US adults aged 18 years or older, but it differs from the NHANES and NHIS in several respects [16]: First, it is entirely conducted via (landline and cell) phone, based on random-digit dialing. Second, it is state-based; all 50 states are individually responsible for data collection while the questionnaire is centrally designed by the Centers for Disease Control and Prevention (CDC). Third, it is the youngest dataset of the three, having been established in 1984.

One adult is interviewed per household in the BRFSS. The documentation notes that certain subgroups of the population have lower telephone coverage (people living in the South; minorities; people with low SES) and that the provided sample weights may not fully adjust for this [17]. 15 states participated in the first round of interviews in 1984; since 1996 all 50 states and D.C. have been included. This study uses BRFSS data starting in 1987 when a sufficient number of states ($N = 33$) had joined. Previous studies have shown that national estimates built from BRFSS data are usually similar to those obtained using truly national surveys such as the NHIS, while cautioning that identical results cannot be expected given the differences in population coverage and methodology [16]. BRFSS files provide self-reports of height and weight as well as, from 1987 onwards, a calculated BMI variable. This study uses the BMI variable contained in the BRFSS. The BRFSS does not collect proxy information.

Inclusion/Exclusion Criteria

The following sample adjustments were performed: i) All persons for whom race/ethnicity recodes were either missing or who did not belong to any of the three race/ethnicity groups were removed. ii) All persons less than 20 or more than 74 years of age were removed (NHANES1 and 2 did not sample people aged 75 or older, and CDC obesity guidelines define adults as those aged 20 years or greater [18]). iii) All persons with missing sample weights or BMI values, or with $BMI < 10$ or $BMI > 70 \text{ kg/m}^2$ were removed (this last step removed a handful of observations with outliers or miscodes). iv) Pregnant women were excluded from the analysis whenever that information was available (NHANES/BRFSS: all years; NHIS: 1997–2008). Application of these criteria led to reductions in observations of 54% (NHANES), 52% (NHIS), and 24% (BRFSS), relative to the full initial samples. Pooled final sample sizes are 49,965 for the NHANES; 1,537,380 for the NHIS; and 3,210,678 for the BRFSS.

Design and Statistical Analysis

This study explores BMI trends along several dimensions using a variety of approaches. The first section presents trends in mean BMI over time, stratified by gender, race/ethnicity, and SES. All graphs of time trends were age-adjusted to the 2000 projected US population using 11 age categories [19]. This section also examines shifts in the BMI distribution. It calculates BMI histograms in 1976 and 2006 by gender and race/ethnicity, using the NHIS due to its long time horizon and large sample size. Complementary analysis uses the 15th, 50th, and 85th percentiles of the BMI distribution to calculate average growth rates in the 85/50 and 50/15 differences, which measure changes in skewness of the BMI distribution over time. The first section concludes by discussing differences between self-reported and exam-based measurements of BMI.

The second section estimates SES-BMI gradients, i.e. the incremental (marginal) effect of education and income on BMI. Education is measured in years of completed schooling; the marginal effect describes the impact of an additional year of schooling. Income is measured in thousands of constant year 2000 USD; the marginal effect describes the impact of an increase in real personal income of USD 1,000.–. Gradients are estimated using ordinary least squares (OLS); additional covariates in the regression models include age, age squared, interactions between age/age squared and year, and year fixed effects. Since education and income both affect BMI, the section also calculates their relative importance by comparing the coefficients on schooling and income in regressions that only contain either schooling or income to those from regressions that contain both variables.

All three datasets used in this study represent complex survey data and this design was taken into account during the analysis by using sample weights and clustering standard errors by primary sampling unit (PSU). All analysis was performed in STATA10 [20].

Results

BMI Time Trends

Overall BMI Trends

Figure 1a and b describe the secular changes in BMI for the different datasets, stratified by gender. BMI measures have consistently increased over the whole period, and the trends are similar across all three surveys. Average BMI has increased from about 25.5 kg/m² in the late 1970s to over 28.5 kg/m² in 2005, while the fraction of the population classified as obese has increased from around 15% to roughly 35% (based on NHANES data). There is a considerable difference between measured BMI values from the NHANES on the one hand and self-reported BMI values from the NHIS and BRFSS on the other (self-reported measures from the NHANES lie somewhere in between; see below).

BMI Trends Stratified by Gender and Ethnicity

Table 1 and fig. 1c (for the NHIS) describe the rise in BMI across gender and race/ethnicity groups. Disregarding sampling error, all measures have increased for all subgroups over the past 30 years. BMI growth was stronger for women than for men by about two percentage points in all three datasets. Growth rates were roughly similar across race/ethnicity groups. Black women display by far the highest BMI, and White women the lowest (the average difference between these two groups is 2.5 BMI units in the NHIS, 2.8 in the BRFSS and 3 in the NHANES). Hispanic women are roughly in the middle. Among males, prevalence rates are similar across race/ethnicity groups. These characteristics appear very stable over time and have been partially documented before (for the NHANES see [1, 2]; for the BRFSS see [21]; for basic results in the NHIS 1997 see [22]).

Fig. 1. Comparison of means across datasets and self-reports versus measurements. **a** BMI, males. **b** BMI, females. **c** BMI, stratified by gender and race/ethnicity in the NHIS. Age 20–74 years. Weighted and age-adjusted to the 2000 Census.

Table 1. Trends in mean BMI^a

	NHANES (exam-based)					NHIS					BRFSS		
	BMI 1978	BMI 1991	BMI 2005	1978– 2005 %Δ	1991– 2005 %Δ	BMI 1978	BMI 1991	BMI 2005	1978– 2005 %Δ	1991– 2005 %Δ	BMI 1991	BMI 2005	1991– 2005 %Δ
Total	25.47	26.68	28.72	12.75	7.65	24.61	25.46	26.95	9.51	5.82	25.46	27.43	7.75
Males	25.72	26.83	28.70	11.59	6.94	25.31	26.10	27.38	8.15	4.88	26.06	27.84	6.80
Females	25.22	26.51	28.73	13.91	8.36	23.94	24.85	26.54	10.86	6.81	24.83	27.00	8.76
Whites	25.28	26.41	28.36	12.21	7.40	24.40	25.22	26.64	9.16	5.62	25.26	27.10	7.28
Blacks	26.86	28.00	30.48	13.48	8.85	25.99	26.87	28.17	8.40	4.84	26.86	29.03	8.09
Hispanics	25.99	27.40	28.91	11.21	5.51	25.39	26.10	27.64	8.88	5.92	25.82	27.87	7.95
Education ^b													
Low	26.28	27.21	28.85	9.80	6.03	25.48	26.46	27.54	8.09	4.10	26.41	28.23	6.90
Medium	25.43	27.16	29.50	15.98	8.60	24.45	25.63	27.34	11.81	6.66	25.73	28.04	8.98
High	24.86	26.00	28.39	14.20	9.21	24.02	24.96	26.65	10.92	6.77	25.06	27.03	7.90
Income ^c													
Low	26.02	27.37	29.19	12.17	6.63	25.28	26.29	27.62	9.25	5.04	26.23	28.32	7.96
Medium	25.37	26.90	29.61	16.73	10.09	24.57	25.55	27.07	10.20	5.98	25.49	27.79	9.00
High	24.92	25.98	27.93	12.08	7.48	24.04	24.87	26.58	10.59	6.89	25.01	26.81	7.18

^aAge 20–74 years. Weighted and age-adjusted to the 2000 Census.

^bLow, medium and high education represents groups with <12, =12 and >12 years of completed education, respectively.

^cLow, medium and high income represents groups with real personal income of ≤USD 10,000.–, USD 10,000.– to 20,000.– and ≥USD 20,000.– in 2000.

BMI Distribution Shifts

Figure 2a and b present histograms of BMI in the NHIS. The BMI distribution for men looks very similar for the three race/ethnicity groups, both in 1976 and 2006. Whites are consistently the least obese, and Blacks the most, with Hispanics in-between, but the differences are small. Over time, the variance increased modestly (average standard deviation = 3.8 in 1976 and 4.6 in 2006), and the fraction obese roughly tripled (Whites/Black/Hispanics: 8.3%/12.3%/11% in 1976; 25.4%/29.5%/26.5% in 2006).

Racial differences for women are more pronounced. There is a bigger difference between Whites and Hispanics, and between them and Blacks, whose obesity rate in 1976 was about twice as high as those of Whites and Hispanics. BMI variance has increased over time (average standard deviation = 4.9 in 1976 and 5.9 in 2006), as did obesity prevalence (Whites/Black/Hispanics: 8.9%/21.6%/12.1% in 1976; 24.5%/38.9%/27.2% in 2006).

BMI Distribution Skewness

Looking at trends over time across percentiles of the BMI distribution provides additional evidence regarding distributional changes. Similar exercises in the NHANES [23, 24] and BRFSS [25, 26] have documented that the BMI distribution has both shifted to the right and become more right-skewed, explaining the disproportional growth in severe obesity noted earlier. This is also apparent in the NHIS. The average growth rate in the 85/50 gap (0.05 BMI units per year) exceeds growth in the 50/15 gap (0.02 BMI units) for White males. This difference is statistically significant ($p < 0.0001$ for a two-sided Wald test of parameter equality across the two linear growth equations). Black males (growth in the 85/50 BMI percentile gap = 0.042 units per year; 50/15 gap = 0.025; $p = 0.0079$), Hispanic males (0.028/0.015; $p = 0.0197$), and White females (0.064/0.044; $p < 0.0001$) also experienced

Fig. 2. BMI Histogram for **a** males and **b** females in the NHIS. Age 20–74 years. Weighted. The vertical line represents obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$).

Table 2. Marginal effects of schooling and income on BMI; males, NHIS^a

	1976–1979			1980–1989			1990–1999			2000–2006		
	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
All males												
Schooling	<i>-0.087</i>		<i>-0.083</i>	<i>-0.091</i>		<i>-0.080</i>	<i>-0.097</i>		<i>-0.087</i>	<i>-0.081</i>		<i>-0.072</i>
Income		<i>-0.009</i>	<i>-0.003</i>		<i>-0.012</i>	<i>-0.006</i>		<i>-0.010</i>	<i>-0.005</i>		<i>-0.005</i>	<i>-0.003</i>
N	91,195	91,195	91,195	262,292	262,292	262,292	207,452	207,452	207,452	58,539	58,539	58,539
R ²	0.050	0.046	0.051	0.053	0.050	0.054	0.040	0.037	0.040	0.034	0.033	0.035
White males												
Schooling	<i>-0.080</i>		<i>-0.075</i>	<i>-0.093</i>		<i>-0.080</i>	<i>-0.109</i>		<i>-0.099</i>	<i>-0.106</i>		<i>-0.095</i>
Income		<i>-0.008</i>	<i>-0.003</i>		<i>-0.012</i>	<i>-0.007</i>		<i>-0.009</i>	<i>-0.005</i>		<i>-0.006</i>	<i>-0.003</i>
N	79,061	79,061	79,061	219,392	219,392	219,392	160,953	160,953	160,953	40,621	40,621	40,621
R ²	0.049	0.046	0.049	0.053	0.051	0.054	0.044	0.041	0.044	0.042	0.039	0.042
Black males												
Schooling	<i>-0.049</i>		<i>-0.055</i>	<i>-0.039</i>		<i>-0.047</i>	<i>-0.007</i>		<i>-0.024</i>	<i>-0.030</i>		<i>-0.053</i>
Income		0.000	0.005		0.001	<i>0.005</i>		<i>0.006</i>	<i>0.008</i>		0.005	<i>0.007</i>
N	7,353	7,353	7,353	26,003	26,003	26,003	22,538	22,538	22,538	7,419	7,419	7,419
R ²	0.054	0.053	0.055	0.051	0.050	0.051	0.021	0.022	0.022	0.018	0.019	0.019
Hispanic males												
Schooling	<i>-0.115</i>		<i>-0.118</i>	<i>-0.087</i>		<i>-0.075</i>	<i>-0.046</i>		<i>-0.033</i>	<i>0.033</i>		<i>0.031</i>
Income		<i>-0.012</i>	0.002		<i>-0.017</i>	<i>-0.009</i>		<i>-0.011</i>	<i>-0.008</i>		0.003	0.001
N	4,781	4,781	4,781	16,897	16,897	16,897	23,961	23,961	23,961	10,499	10,499	10,499
R ²	0.066	0.056	0.066	0.060	0.057	0.061	0.043	0.043	0.043	0.033	0.033	0.033

^aSchooling measured in years. Income measured in thousands of constant USD 2,000.–. Cells report the coefficients of schooling and real personal income from pooled regressions of BMI on schooling (column [1]), real personal income (column [2]), or both (column [3]). Covariates include age, age squared, age by year, age squared by year, and year fixed effects. All regressions use the NHIS sample weights; standard errors have been clustered by PSU. Italic entries are statistically significant at 5%.

similar shifts. Black females (0.024/0.042; $p = 0.0129$) display an opposite shift; their distribution became a little less right-skewed. This is also indicated for Hispanic females, but the differences are not statistically significant (0.026/0.033; $p = 0.31$).

Self-Reported versus Measured BMI

It is well known that BMI variables based on self-reported height and weight and those based on measurements are usually different [11]. Figure 3a–d presents self-reported (NHANES, NHIS, BRFSS) and measured (NHANES) height and weight over the entire sample period to examine differences across datasets. Results suggest that, in all three datasets, both genders overreport height (with men showing greater bias) and females consistently underreport their weight. The results in the NHIS corroborate previous studies in the NHANES and BRFSS [27, 28].

Translating differences in height and weight to differences in BMI, several things can be noted: i) Using the BRFSS or the NHIS, self-report bias is about twice as large for females as for men (an average of two BMI units compared to one; see fig. 1a–c). ii) Survey design seems to matter: the bias is greater in the telephone-based BRFSS compared to the NHANES [27],

Table 3. Marginal effects of schooling and income on BMI; females, NHIS

	1976–1979			1980–1989			1990–1999			2000–2006		
	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
All females												
Schooling	<i>-0.319</i>		<i>-0.249</i>	<i>-0.322</i>		<i>-0.232</i>	<i>-0.337</i>		<i>-0.242</i>	<i>-0.312</i>		<i>-0.223</i>
Income		<i>-0.065</i>	<i>-0.042</i>		<i>-0.067</i>	<i>-0.048</i>		<i>-0.055</i>	<i>-0.039</i>		<i>-0.037</i>	<i>-0.026</i>
N	102,707	102,707	102,707	294,069	294,069	294,069	232,135	232,135	232,135	67,662	67,662	67,662
R ²	0.096	0.086	0.106	0.085	0.084	0.098	0.061	0.061	0.072	0.050	0.050	0.059
White females												
Schooling	<i>-0.272</i>		<i>-0.221</i>	<i>-0.281</i>		<i>-0.212</i>	<i>-0.299</i>		<i>-0.227</i>	<i>-0.308</i>		<i>-0.237</i>
Income		<i>-0.049</i>	<i>-0.032</i>		<i>-0.053</i>	<i>-0.038</i>		<i>-0.042</i>	<i>-0.029</i>		<i>-0.029</i>	<i>-0.020</i>
N	86,883	86,883	86,883	237,713	237,713	237,713	172,212	172,212	172,212	44,574	44,574	44,574
R ²	0.088	0.079	0.095	0.081	0.079	0.091	0.060	0.058	0.067	0.053	0.050	0.059
Black females												
Schooling	<i>-0.322</i>		<i>-0.235</i>	<i>-0.307</i>		<i>-0.221</i>	<i>-0.321</i>		<i>-0.227</i>	<i>-0.233</i>		<i>-0.142</i>
Income		<i>-0.088</i>	<i>-0.060</i>		<i>-0.078</i>	<i>-0.054</i>		<i>-0.061</i>	<i>-0.043</i>		<i>-0.035</i>	<i>-0.028</i>
N	10,285	10,285	10,285	36,996	36,996	36,996	32,531	32,531	32,531	10,888	10,888	10,888
R ²	0.123	0.121	0.132	0.099	0.099	0.107	0.059	0.059	0.066	0.042	0.045	0.048
Hispanic females												
Schooling	<i>-0.262</i>		<i>-0.197</i>	<i>-0.263</i>		<i>-0.182</i>	<i>-0.247</i>		<i>-0.158</i>	<i>-0.156</i>		<i>-0.088</i>
Income		<i>-0.087</i>	<i>-0.058</i>		<i>-0.088</i>	<i>-0.062</i>		<i>-0.073</i>	<i>-0.054</i>		<i>-0.041</i>	<i>-0.034</i>
N	5,539	5,539	5,539	19,360	19,360	19,360	27,392	27,392	27,392	12,200	12,200	12,200
R ²	0.106	0.101	0.117	0.093	0.094	0.106	0.066	0.071	0.079	0.047	0.054	0.056

^aSchooling measured in years. Income measured in thousands of constant USD 2,000.–. Cells report the coefficients of schooling and real personal income from pooled regressions of BMI on schooling (column [1]), real personal income (column [2]), or both (column [3]). Covariates include age, age squared, age by year, age squared by year, and year fixed effects. All regressions use the NHIS sample weights; standard errors have been clustered by PSU. Italic entries are statistically significant at 5%.

but there is also a difference between the NHIS and the NHANES self-reports, both of which are based on in-person interviews. iii) Shifts in the BMI distribution over time are similar, regardless of whether self-reports or measurements are used, and underreporting of BMI increases with BMI [28, 29]. iv) Although the use of self-reports underestimates the prevalence of obesity, time trends are consistent between measured and self-reported data.

The SES-BMI Gradient

A concise way of examining the relationship between BMI and SES is to look at gradients (marginal effects). Table 2 and table 3 answer the following questions: i) How do these gradients differ by race/ethnicity and gender? ii) Have these gradients changed over time? iii) Given that both education and income have a positive effect on health, how much of the education effect can be accounted for through changes in income level (e.g., more education being associated with a higher income), and how much of the income effect can be accounted for through changes in education level? Estimates are presented using data from the NHIS. Results for all males and all females (combined across race/ethnicity groups) in the BRFSS

Fig. 3. Comparison of means across datasets and self-reports versus measurements. **a** height, males; **b** height, females; **c** weight, males; **d** weight, females. Age 20–74 years. Weighted and age-adjusted to the 2000 Census.

and NHANES are very similar and available in the online supplementary material (Appendix table 1 and 2, available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=337018>).

Regarding the first question, an extra year of schooling is associated with a modest decrease in BMI for men (about 0.08 units) and a sizeable decrease for women (0.25–0.3 units). Schooling gradients for Black men are about half as large as those for Whites. These differences are consistent with lower wage returns to education for Blacks, possibly caused by lower-quality schooling [30]. There are no such differences among females, although the effects for Hispanic females are always somewhat lower than those for Whites and Blacks. Looking at the effect of income, an extra USD 1,000.– in real personal income is associated with a modest decrease in BMI of about 0.005–0.016 units for men and 0.04–0.07 units for women. Among males, only Whites show a consistently inverse relationship. For females the effects are similar across race/ethnicity groups, with Hispanics displaying the strongest effects.

The marginal effects of schooling and income are not easily comparable due to their different scales. One way to address this is to compare the effects of a one-standard-deviation increase in the respective variables. Using the pooled 1976–2006 NHIS dataset, a one-standard-deviation increase in schooling is associated with a change in BMI of –0.25 (White

males), -0.12 (Black males), and -0.17 units (Hispanic males), while a one-standard-deviation increase in real personal income is associated with a change in BMI of -0.09 (White males), 0.11 (Black males), and -0.05 units (Hispanic males). For women, these estimates are -0.60 , -0.64 , and -0.59 (schooling), and -0.49 , -0.56 , and -0.62 (real personal income). This highlights two observations: i) In this population, education and income have associations with BMI of similar magnitude among women, while among men education has a bigger impact; ii) the relationships for women are 2.5–12 times stronger than for men.

The second question concerns changes in the gradients over time. Previous studies have found increasing education gradients in mortality and other health outcomes over time, which may contribute to the observed increase in health inequalities [30]. The author is not aware of any results relating to BMI. For White males and, to a lesser extent, White females, coefficient estimates in the NHIS suggest that schooling gradients have increased in absolute value over time, but the differences are not statistically significant. For Black males and females the gradients have stayed roughly constant. Among both Hispanic males and females schooling gradients have *decreased* in absolute value (indeed, for Hispanic men, they were slightly positive in 2000–2006), possibly due to the increases in immigration of low-educated Hispanics over that time period. There are no clear trends in the income-BMI gradients among men. Among women of all race/ethnicity groups the gradients have decreased a bit in absolute value.

With regard to the last question – the relative importance of education and income – the evidence suggests that, for males, income accounts for only a small part of the education effect, while education accounts for a significant share of the income effect. According to table 2 and table 3, including income in a regression of BMI on schooling reduces the schooling coefficient by 10% for males, while the opposite reduces the income coefficient by 50%. For females these effects are similar at around 30%.

Discussion

To the author's knowledge, this study is the first to estimate marginal effects of SES on BMI across various gender and race/ethnicity groups. Marginal effects summarize the SES-BMI gradient in a single number, facilitating comparisons across groups and over time. Previous studies have extensively documented a strong inverse relationship between SES and obesity for women while for men the relationship is much weaker. This has been observed in this study as well, for all race/ethnicity groups and datasets. However, the effects of education and schooling are distinct and vary by gender. For men, a one-standard-deviation increase in education (about 3 years of schooling) is associated with a reduction in BMI of about 0.2 units, while a one-standard-deviation increase in real personal income (about USD 16,000.–) is correlated with a 0.07 unit decrease in BMI (for Black men, more income is associated with an increase in BMI of 0.11 units). For women, on the other hand, such increases are associated with declines in BMI of about 0.5–0.6 units. This suggests that: i) In this population, education and income have similar effects for women while for men education is stronger; ii) effects are considerably stronger for women than for men.

Previous work in the NHIS [30] found that income, health insurance coverage, and other controls together account for about one third of the total effect of education on BMI in White males. A related study [31], also examining White males, reported a 16% decrease in the education coefficient for BMI in the NHIS and 13% in the Health and Retirement Study when income was included. The current study provides more detail on this relationship. Among males, income accounts for 10% of the total effect of education on BMI; for females, the effect is about 30%. These estimates are also similar across the three datasets.

Earlier studies of the NHANES and BRFSS have shown that the growth in extreme obesity is due to certain changes in the BMI distribution which has both shifted to the right and become more right-skewed over time [3, 10]. Such shifts can also be found in the NHIS long-run perspective from 1976 to 2006. It is strongest for White and Black men as well as White females. The distribution for Black females shifted strongly to the right as well, but became less skewed. Hispanic females experienced an even shift. Overall, this casts Hispanics as either relatively similar to Whites and Blacks (men), or somewhere in between these other two groups (women), in terms of overall prevalence and distribution shifts.

The other question this study investigated concerns similarities and differences across three big national health datasets – the NHANES, NHIS, and BRFSS. Differences across surveys in BMI prevalence and time trends could be due to various reasons, such as measurement bias, sampling bias, or non-response bias [32]. The specific questions that were asked in the surveys to elicit self-reports of height and weight are virtually identical (online supplementary material, available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=337018>). The exam-based measurements in the NHANES were taken by trained technicians following standard protocols and as such presumably suffer little from measurement bias. Conversely, there is substantial evidence that height and weight based on self-reports is heavily biased, and this is evident when comparing BMI variables from the NHIS and BRFSS to the exam-based measures. Moreover, while the NHANES and NHIS both use in-person surveys, the BRFSS is conducted via phone. Phone respondents may exhibit more social desirability response bias [33]; all other things equal, BMI measurements in the BRFSS might therefore be lower than those in the NHIS and NHANES.

All three datasets are designed to produce samples representative of the non-institutionalized civilian US population, yet sampling bias could arise in various ways. The NHANES, for instance, used 65 PSUs in its first series, 64 in the second, 81 in the third, and 15 per year since 1999 [13]. Given the wide variation in obesity rates across states [10], it is possible that sites with higher or lower obesity prevalence were over-represented in any given series [32]. The BRFSS, on the other hand, being based on phone interviews, is subject to wide and systematic variations in landline phone coverage and has only recently started to sample households with cell phones but no landline. The NHIS uses in-person interviews and selects a much higher number of PSUs (up to 428, time-varying [15]), but suffers from re-designs every 10–15 years that might affect comparability over time.

There might also be biases due to non-response, depending on both the response rates and the differences between responders and non-responders. In the NHANES, interview response rates have decreased from over 90% to about 80% while response rates for the medical examinations have been fairly constant around 75–80% [13]. Response rates in the BRFSS averaged 65–70% from inception to about 1996 and have since dropped to around 50% [34]. Non-response rates in the NHIS have increased from around 4% in the early 1990s to more than 12% by 2005 [35]. Lower response rates are worrisome on their own, but they only affect non-response bias to the extent that there are significant differences between responders and non-responders [32]. To the author's knowledge, no information regarding differences between responders and non-responders is available for any of these three health surveys.

Sampling bias and non-response bias may explain some of the differences in demographics observed across the three surveys. For instance, the BRFSS has a lower percentage of females and Blacks as well as higher average educational attainment and personal income compared to the NHANES and NHIS. Conversely, the NHANES has a higher fraction of people with less than 12 years of schooling than the other two surveys. Since these SES variables are positively related to BMI, it is possible that the NHANES overestimates obesity prevalence while the BRFSS underestimates it [32].

And yet, given these differences and potential biases, most BMI-related measures and trends are quite similar across the three surveys (with the exception of underreported prevalence rates in the NHIS and BRFSS, which rely on self-reports). They have similar ranks for at-risk groups and display similar marginal effects. This suggests that the NHIS and BRFSS are quite valid for studying associations between demographics, socioeconomic status and BMI, and are especially valuable for subgroup analysis, where the NHANES lacks statistical power. Note that some issues do require correct prevalence estimates, such as calculating the excess health care costs associated with obesity and overweight.

The potential increase in self-reporting bias due to the correlation between BMI level and self-reporting bias in BMI is an area of concern [27, 29]. More exam-based measures would alleviate this issue; it is encouraging that the BRFSS is launching a pilot project to take physical measurements of part of its sample [36].

Lastly, this study found that measurements based on self-reports available in the NHANES differ not only from those calculated using exam-based variables but also from self-reported measures in the other two datasets (this is also briefly alluded to in [37, 38]). This is a surprising result and warrants further research. Speculatively, the bias usually found in self-reported measurements might have been reduced in the NHANES due to knowledge about the upcoming physical exam. It also suggests that adjusting self-reports in other datasets using the difference between self-reports and measured height and weight in the NHANES is not valid (performed, for instance, in [39, 40]). More generally, exploring differences in self-reported and measured BMI by race/ethnicity and SES would be an interesting topic for future research.

This study is not without limitations. Selecting the most relevant results for presentation necessitated the exclusion of other findings (e.g. age stratification of BMI trends). The outcome of interest is BMI, which is a flawed measure of obesity [12]; however, it is still widely used and the only measure available in all three datasets analyzed in this study. SES-BMI gradients were derived using OLS; coefficients represent correlations and do not necessarily allow a causal interpretation. The model also assumes a linear relationship between SES and BMI. The results on SES-BMI gradients are derived for a US population and further research in other populations would be desirable to assess generalizability. Lastly, the study did not examine the sensitivity of results regarding data preparation methods and inclusion/exclusion criteria.

In summary, while there are clear differences in demographics, survey methods, and BMI measurement techniques across the three datasets, their accounts of BMI trends and of associations between SES and BMI are similar. The exact patterns and distributional shifts vary by gender and race/ethnicity. Race/ethnicity differences exist even after accounting for education and income. These disparities should be studied further to identify environmental and/or biological components explaining the differential patterns.

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