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United States Long-Term Trends In Adult Bmi From 1959 To 2018 By Income, Education, And Race/ethnicity

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Abstract

Obesity prevalence has increased dramatically since the 1950s. While cross-sectional comparisons across racial, ethnic, and socioeconomic groups are abundant, there is less work on long-term trends. We assessed trends in average adult body mass index (BMI) in the United States by income, education, and racial/ethnic groups from 1959 to 2018 using the National Health and Nutrition Examination Survey, which assesses repeated cross-sectional, representative samples of the United States population. Height, weight, income, education, and race variables were extracted from raw data files; income data was converted to constant dollars prior to analysis. BMI was calculated from height and weight measurements. Interrupted time series analysis was used to compare trendlines for each decile of household income, education levels, and racial/ethnic groups. SAS version 9.4 was used for all analyses and figures were plotted using OriginPro 2021. Average BMI increased in all groups over the sixty-year period examined and all slopes were positive. BMI trends did not differ by income group or between high school graduates and greater than high school graduates. Less than high school graduates had a slower increase (smaller slope) in BMI compared to greater than high school graduates. Compared to non-Hispanic White participants, Black participants had higher slopes, while Hispanic and other racial groups had slower increases. Interactions among these subgroups also contained a mix of significantly different and statistically similar BMI trends. In summary, disparities in BMI are relatively constant across income categories and education level for high school graduates, though not constant among those with less than high school education, while trends are different among racial groups. These ongoing trends suggest that interventions to effectively address the obesity epidemic should focus on systemic change.

Acknowledgements

I would like to thank my primary adviser, Dr. Debbie Humphries, for her guidance and patience throughout this project. This would not have been possible without you and I am so grateful for all that I have learned from you. I would also like to thank my secondary adviser, Dr. Melinda Irwin, for her guidance throughout my time at Yale inside and outside the classroom.

Table of Contents

Introduction

Obesity is a significant public health concern in the United States. The prevalence of obesity has increased over time; by 2016, almost 40% of American adults were estimated to have body mass index (BMI) greater than 30 kg/m^2 (Hales et al., 2018). Almost half of American adults are projected to have high BMI by 2030 (Wang et al., 2020). Obesity is associated with many adverse health effects, including but not limited to increased risks of premature mortality, diabetes, heart disease, cancer, stroke, respiratory disease, lipid abnormalities, and pregnancy complications (Malnick & Knobler, 2006).

Rates of obesity vary across racial and ethnic groups. Using cross-sectional data to examine obesity trends, Wang et al. (2020) found that non-Hispanic Black women and Mexican American men had the highest prevalence of obesity and the prevalence of those groups are projected to increase through 2030. Min et al. (2021) found that while racial and ethnic disparities in prevalence of obesity persist, severe obesity in non-Hispanic Black women has decreased and disparities in severe obesity among women from different racial and ethnic backgrounds have narrowed. In contrast, racial and ethnic disparities in prevalence of obesity have increased for men, driven in part by growing rates of obesity in Mexican American men. Wang et al. (2020) also found socioeconomic disparities, where obesity was less prevalent among higher income groups. In an analysis of cross-sectional data, Ogden et al. (2020) found similar results, where the highest income group had the lowest obesity prevalence among women, but both the highest and lowest income groups had the lowest prevalence among men. They also found that college graduates had the lowest prevalence of obesity compared to students without a college degree.

These preventable differences in health outcomes among populations are known as disparities. They are present among many social and economic factors affecting vulnerable populations, but a question that is often unanswered is whether the trends among groups differ. Using data from 1960 to 2008, Ljungvall and Zimmerman (2012) found that while baseline obesity disparities exist among groups, the time trends are not statistically different among income, educational, and racial/ethnic groups, so each group is experiencing similar increases in obesity. Ljungvall and Zimmerman's analysis provides valuable insights into obesity trends, and our analysis aimed to further examine these trends to data currently available. The trends found by Ljungvall and Zimmerman imply that large scale change is needed on a societal level to reverse these trends and properly address obesity, as even the most privileged groups face the same trends as less advantaged groups, despite their lower baseline average BMI. Factors such as the retail food environment may be more important in addressing obesity. Ford and Dzewaltowski (2008) review the American food environment and conclude that the quality of the retail food environment affects food choice and impacts health. They hypothesize the following: disparities exist due to geographic access of quality food choices, where they cite food deserts as an example of areas that have less availability of making quality food choices; there is an association between socioeconomic status (SES) and quality food environments, where low SES areas have poorer quality food environments that largely affect racial/ethnic minorities; and there is an association between food environment quality, nutrition, and obesity, where poorer quality environments have negative health impacts. Improving the retail food environment may be a way to change the baseline of health behaviors among Americans and improve health outcomes.

Zimmerman (2011) reviews potential causes of obesity in depth and creates a compelling case that food marketing is the main contributor to obesity in the United States. He notes that longitudinal obesity trends do not vary among the top and bottom income groups, concluding that environmental (or systemic) factors, rather than individual behaviors and socioeconomic factors associated with healthier behavior, have larger effects on obesity. Food marketing is a vital area to address to create a better baseline of obesity and food choice for Americans, but structural change as a whole will be necessary to improve health outcomes. Zimmerman's estimates span the 1960s to the 2000s, but no study has evaluated obesity trends by group using data available in recent years.

The purpose of this thesis is to further examine the trends between income, racial/ethnic, and educational groups using data from 1959 to 2018. We hypothesize that trends in BMI in the United States will not be statistically different among groups. This would mean that disparities between groups are not narrowing nor widening, and would imply that a focus on subgroups without addressing structural factors may not be adequate to improve obesity outcomes.

Methods

Data comes from all waves of the National Health and Nutrition Examination Survey (NHANES) in addition to the first wave of the National Health Examination Survey (NHES). The purpose of NHANES is to assess health outcomes and nutritional behaviors of Americans. NHES data is available from 1959 to 1962; NHANES I data is available from 1971 to 1974; NHANES II data is available from 1976 to 1979; and NHANES III data is available from 1988 to 1994. Starting in 1999, all NHANES data is collected biannually, with the last wave of available data being data from 2017 to 2018. These data are cross-sectional, nationally sampled, and measured through interviews and physical health examinations. The NHANES study

population has grown and changed somewhat since its inception, but has generally been consistent in its mission throughout the decades. Starting in 1999, each wave has about 5,000 participants, who have their sociodemographic data, medical history, and health measurements collected in the study. Similar variables were collected in earlier waves; NHANES I, II, and III had about 30,000 participants, and NHES I had about 7,000 participants. The data is all publicly available from the Centers for Disease Control and Prevention.

SAS 9.4 was used to analyze the data. Analyses were conducted on adults who were at least 20 years old. BMI was the outcome variable of interest, constructed from height and weight variables. BMI greater than or equal to 30 was considered obese. Income was standardized across survey years using data from the Current Population Survey (CPS), which contains variables to adjust income to current dollars. Income of each survey year was first assigned to the midpoint of each family income category. For categories with only a lower limit, the lower limit was used; for example, an income of $100,000 was used for those in the income category of $100,000 or above. Then, incomes were adjusted using the CPI99 variable in CPS, where income was adjusted to 1999 dollars based on the midpoint year of the survey. For surveys containing only two years, the first year was used. The exception to these protocols was NHES data, which used the year 1961, because CPS income standardization data was not available before that year. Income was then adjusted from 1999 dollars to 2019 dollars. Income was grouped into deciles by year, where the lowest and highest deciles were used to compare the lowest and highest income groups.

Other variables of interest include race and education level. For race, NHES, NHANES I, and NHANES II collected participants' race as White, Black, or other. NHANES III added Mexican American to this category, and other Hispanic was added starting in 1999. In 2011, the

category began to include non-Hispanic Asian. Education was coded as less than high school education, high school education, and greater than high school education. Education data for NHES was collected in the following categories: 1 to 4 years of school, 5 to 8 years, 9 to 12 years, 1 to 2 years of college, 3 to 4 years of college, and over 4 years of college. Because no data was collected solely on high school diploma similar to other waves, 1 to 8 years of school was coded as less than high school education, 9 to 12 years of school was coded as high school education, and 1 to 2 years of college and above was coded as greater than high school education.

Interrupted time series (ITS) analysis was used to analyze obesity trends in the United States across income, educational, and racial/ethnic groups. While ITS typically involves comparing slopes before and after an intervention, this analysis uses ITS to compare obesity trends among income, education, and racial/ethnic groups. BMI was the outcome variable in the model. Midpoint year was used as the time variable. Regression lines were fitted for each income, education, or racial/ethnic group, and slopes were compared using the interaction variable of year and income, education, or racial/ethnic group. Analyses were also conducted to test the interactions of income and education, income and race/ethnicity, and education and race/ethnicity. Mean BMI by year and group was also calculated to demonstrate trends over time and graphed using OriginPro 2021.

Results

Mean BMI

Table 1 shows the mean BMI of each income, education, or racial/ethnic group by survey wave. They are also demonstrated visually in Figures 1-3. In Figure 1, mean BMI of the top and bottom income decile are displayed. There is a consistent gap between both lines, where trends

appear to be similar based on visual inspection alone. Figure 2 shows the mean BMI of each survey wave for those with less than a high school diploma, those with a high school diploma, and those with greater than a high school diploma. This graph shows more crossover between the lines, particularly for high school graduates and those with less than a high school degree. Figure 3 shows average BMI trends by racial/ethnic group. Average BMI has more changes over time in this figure.

Regression Analysis

Income

The highest and lowest income deciles did not have statistically different trends in BMI. Results from the ITS analysis are displayed in Table 2. The interaction between time and income group was not significant; the slopes of BMI by year were not significantly different from each other based on income.

Figure 4 displays the regression lines for the top income decile and bottom income decile, where the slopes were not statistically different from each other. This is demonstrated in the figure. Similar to what was visually observed in Figure 1, this graph has a consistent gap between the BMI of these income groups by year.

Education

Trendlines in BMI were significantly different based on level of education when comparing those with less than a high school education to the reference group of those with greater than a high school education. However, those with a high school diploma did not have a significant interaction between time and group compared to the reference. Therefore, the difference in slopes of those who graduated high school and those who attended higher education was not significantly different. These results are displayed in Table 2.

Figure 5 shows the regression lines modeled for each education group. The plot shows a crossover between those with less than a high school education and those with a high school diploma. The slopes between those who attended less than high school and those who attended greater than high school were not significantly different, which can be seen visually in this figure, as the gap between these trendlines narrows over time. Meanwhile, the gap between those with a high school diploma and those with higher education is more consistent over time. This is validated with our results, showing that these slopes are not statistically different.

Race/Ethnicity

Trendlines in BMI were significantly different based on racial/ethnic group, with White as the reference group. Each racial/ethnic group had a significant interaction term. Therefore, every trendline in these groups was significantly different from each other. These results are shown in Table 2.

Figure 6 shows the fitted regression lines for each racial/ethnic group. These slopes were all significantly different from each other and this is seen in the figure, where the gaps between regression lines vary over time.

Interactions

Income and Education

Compared to the interaction of the highest income decile and less than high school education, BMI outcomes of participants from the lowest income decile with less than high school education were not significantly different. Those in the lowest income decile with a high school diploma or upper education had significant differences in BMI trends, in addition to those in the highest income decile with a high school diploma. The differences in BMI trends between those in the highest income decile with greater than high school education was marginally

insignificant (p=0.0575). Table 3 shows the results for the interaction of income and education, and Figure 7 shows the fitted regression lines.

Income and Race/Ethnicity

Compared to the reference group of White participants in the highest income decile, Black, Hispanic, and White participants in the lowest income decile did not have significantly different BMI trends. Meanwhile, all other races in the highest income decile and participants in the other race group who were in the lowest income decile had significantly different slopes compared to the reference group. These results are shown in Table 4, and Figure 8 shows the fitted regression lines.

Education and Race/Ethnicity

Compared to the reference group of White participants with less than high school education, Hispanic participants at all levels of education did not have significantly different. BMI trends. Black participants with less than high school education also did not have significantly different slopes compared to the reference group, in addition to participants in the other race category who had higher education. All other groups had significantly different slopes compared to White participants with less than high school education. These results are shown in Table 5, and the fitted regression lines are shown in Figure 9.

Discussion

This analysis has shown that disparities in BMI trends are not growing or narrowing based on groups of income or education. Further evaluation of interactions between income, education, and race/ethnicity reveal that subgroups are experiencing the same BMI increase over time. Americans in the highest and lowest income deciles are experiencing the same increases in BMI, and these trends are not changing over time. While racial/ethnic groups had significant

differences in BMI trends, the results among education groups were mixed. High school graduates and those who pursued higher education had the same trends, but those with less than high school education had a smaller slope, which means they experienced a slower increase in BMI over time compared to high school graduates.

The findings that several trendlines do not differ have important implications for addressing obesity in the United States. All fitted regression lines had a positive slope as well, so prevalence of this public health problem will continue to increase over time. Results by income were most striking, as they demonstrate that despite disparities in BMI across income levels, the top and bottom income groups in this dataset are experiencing the same upward slope. The gap is not widening, but it is also not narrowing, which shows that there is much to be done to address this problem and widespread, societal change may be necessary. This need for broader public health strategies is echoed in the results for education groups, where those with a high school degree and those with higher education both experienced the same increase in BMI over time. This is another disparity present that does not appear to be changing. However, those with less than a high school diploma did experience a significantly different trendline than the other education groups. Further research should be conducted on this topic to uncover why this slope is slightly flatter than the other groups and to identify which strategies have been effective in narrowing this gap. In addition, the impacts of historical events or policy should be evaluated to understand whether there has been a recent change to create this flatter slope influenced by major changes in society.

For race/ethnicity, the trendlines were also significantly different from each other. Based on these results and Figure 6, it appears that some of these disparities between groups are narrowing, while others are becoming wider. This may be an area where more tailored

interventions are helpful in improving outcomes among each group. Further research should also be conducted about the differences in obesity trends among various racial/ethnic groups, because this data was limited in what could be studied. Long-term data on a wide range of racial/ethnic groups was not available throughout each survey wave evaluated, so there may be factors that could not be assessed in this analysis and may be understudied.

These findings are similar to those of Ljungvall and Zimmerman (2012), who find time trends in obesity to be similar among income, educational, and racial/ethnic groups overall, with some exceptions. These results also show that obesity is increasing among every group, which is consistent with Wang et al.'s (2020) projections. Zimmerman (2011) also graphs obesity trends in his study of potential systemic causes of obesity, and his results are reflected in the results of this analysis.

These findings matter in addressing the obesity epidemic. Worldwide, increases in BMI are associated with higher all-cause mortality (Global BMI Mortality Collaboration, 2016). As Rodgers and Collins (2012) describe, addressing this crisis will require reforms throughout all levels of society. As these results show, current efforts to reduce disparities and decrease the prevalence of obesity are not working. Creating a new baseline for health is necessary and this likely requires structural change. Current focus on subgroups has not been successful in reducing disparities. Interventions that target areas such as the food industry, infrastructure, food marketing, stigma, resources available to communities, and many more areas will be needed on a societal level to properly address this crisis.

Tables and Figures

	Income		Education			Race			
Survey	Lowest Income Decile	Highest Income Decile	Less Than High School Education	High School Education	Greater Than High School Education	White	Black	Hispanic	Other Race
NHES	25.458	24.979	26.185	24.987	24.521	25.215	26.206	.	25.343
NHANES I	25.887	24.537	26.145	25.141	24.050	25.127	26.599	.	23.888
NHANES II	25.221	24.588	25.855	24.926	24.075	24.891	26.240	.	23.515
NHANES III	27.151	26.594	27.392	27.272	26.459	26.385	27.868	27.522	26.202
1999-2000	27.921	27.545	28.729	28.545	27.945	27.683	29.729	28.567	28.028
2001-2002	27.971	27.596	28.432	28.347	27.982	27.869	29.229	28.366	26.087
2003-2004	28.608	28.351	28.564	28.728	28.147	27.822	30.060	28.827	25.914
2005-2006	28.766	28.263	28.933	29.097	28.529	28.224	30.341	28.690	27.126
2007-2008	28.963	28.500	29.151	29.120	28.749	28.463	30.103	29.378	26.057
2009-2010	28.255	27.917	29.653	29.240	28.851	28.677	30.803	29.465	26.480
2011-2012	28.737	27.555	29.164	29.558	28.321	30.068	30.569	28.771	25.266
2013-2014	29.163	27.539	29.171	29.638	28.866	30.417	30.641	29.040	25.907
2015-2016	29.911	28.542	29.661	29.964	29.324	31.180	30.683	29.529	26.211
2017-2018	30.176	28.823	29.561	30.132	29.831	30.965	31.216	29.922	27.292

Table 1. Average BMI for every survey wave among each income, educational, and racial/ethnic group. *Note: Data on race/ethnicity was collected different throughout NHANES and NHES. In this table, "Other" includes Mexican American and other Hispanic until NHANES III, where these categories were included in the survey. Starting in 1991, this analysis includes a group for Hispanic participants, and "Other" refers to races/ethnicities that are not Black, White, or Hispanic.*

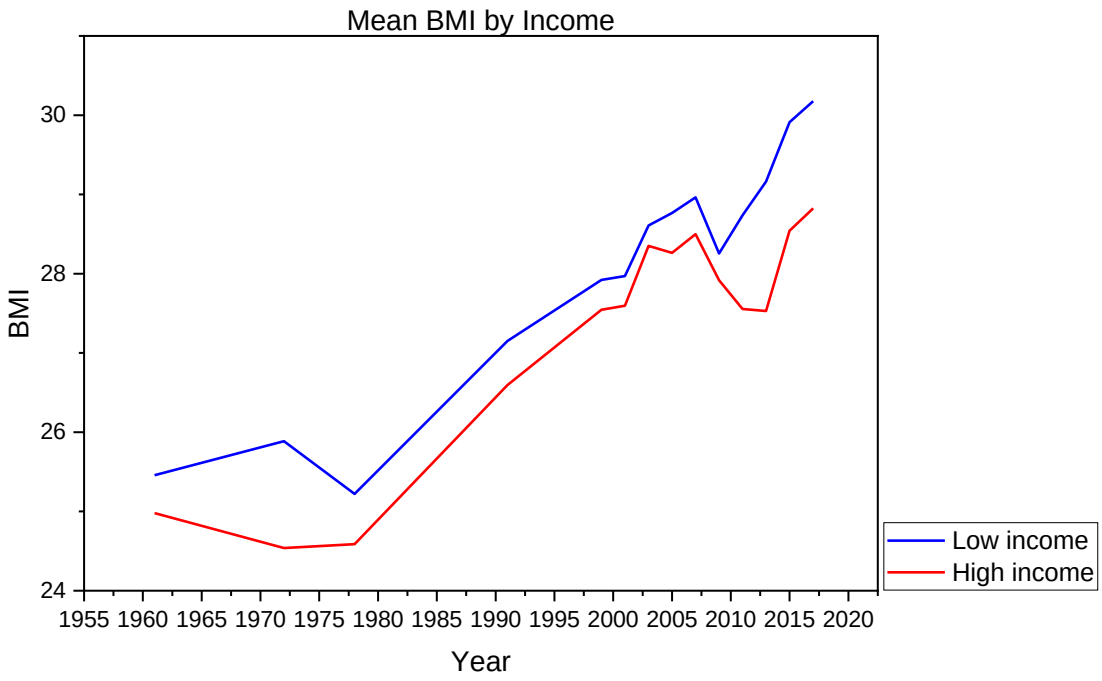

Figure 1. Mean BMI of the top income decile and bottom income decile from 1961 to 2017.

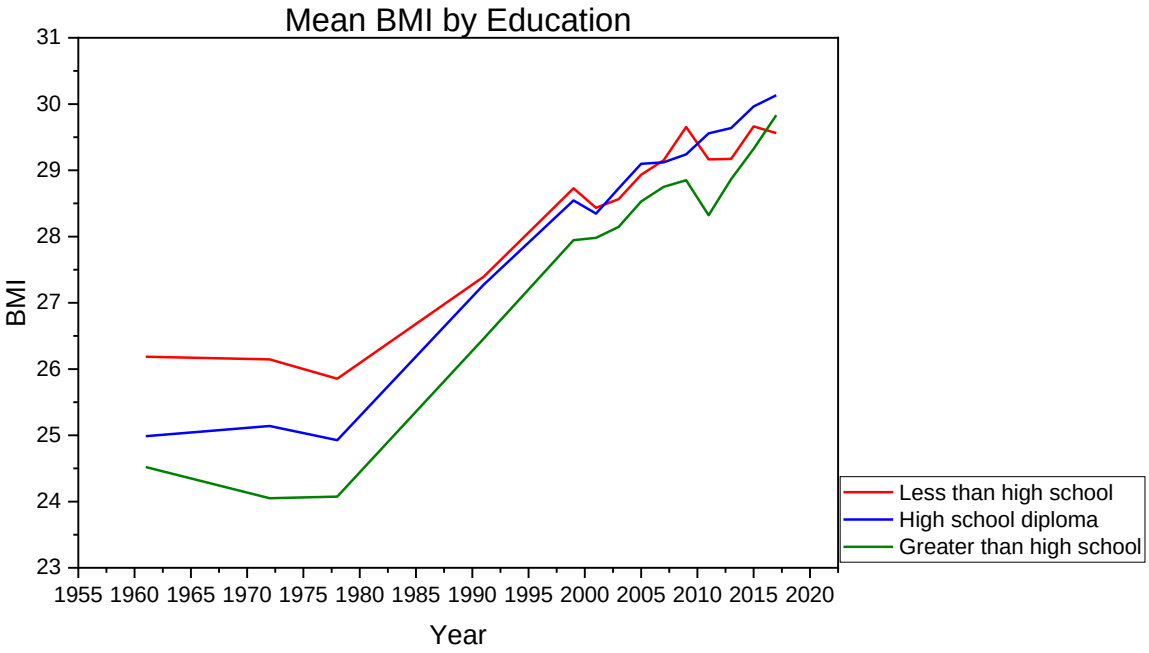

Figure 2. Mean BMI of each education group from 1961 to 2017.

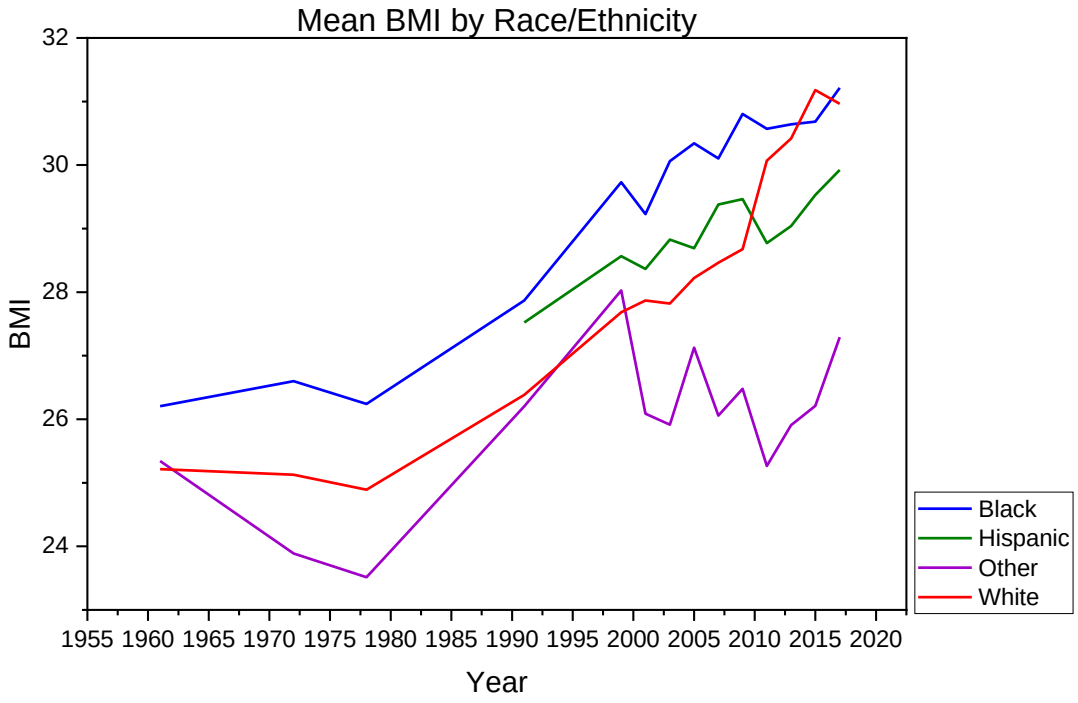

Figure 3. Mean BMI of each racial/ethnic group from 1961 to 2017. *Note: Data on race/ethnicity was collected differently throughout NHES and NHANES history. In this figure, "Other" includes Mexican American and other Hispanic until NHANES III, where these categories were included in the survey. Starting in 1991, this analysis includes a group for Hispanic participants, and "Other" refers to races/ethnicities that are not Black, White, or Hispanic.*

Variable	Estimate	Standard Error	P-value
Income			
Year	0.08948	0.003907	<.0001
Low income (reference)	.	.	.
High income	10.9386	10.2002	0.2836
Interaction	-0.00584	0.005114	0.2533
Education			
Year	0.1238	0.002105	<.0001
Less than high school	84.9511	5.5212	<.0001
High school diploma	7.1456	6.4855	0.2706
Greater than high school (reference)	.	.	.
Interaction (less than high school)	-0.04209	0.002767	<.0001
Interaction (high school diploma)	-0.00324	0.003248	0.3183
Race			
Year	0.09581	0.001626	<0.001
White (reference)	.	.	.
Black	-19.4243	6.3424	0.0022
Hispanic	33.4393	9.5378	0.0005
Other	114.61	12.5283	<.0001
Interaction (black)	0.01049	0.003181	0.001
Interaction (Hispanic)	-0.01643	0.004760	0.006
Interaction (other)	-0.05825	0.006249	<.0001

Table 2. Results of ITS analysis.

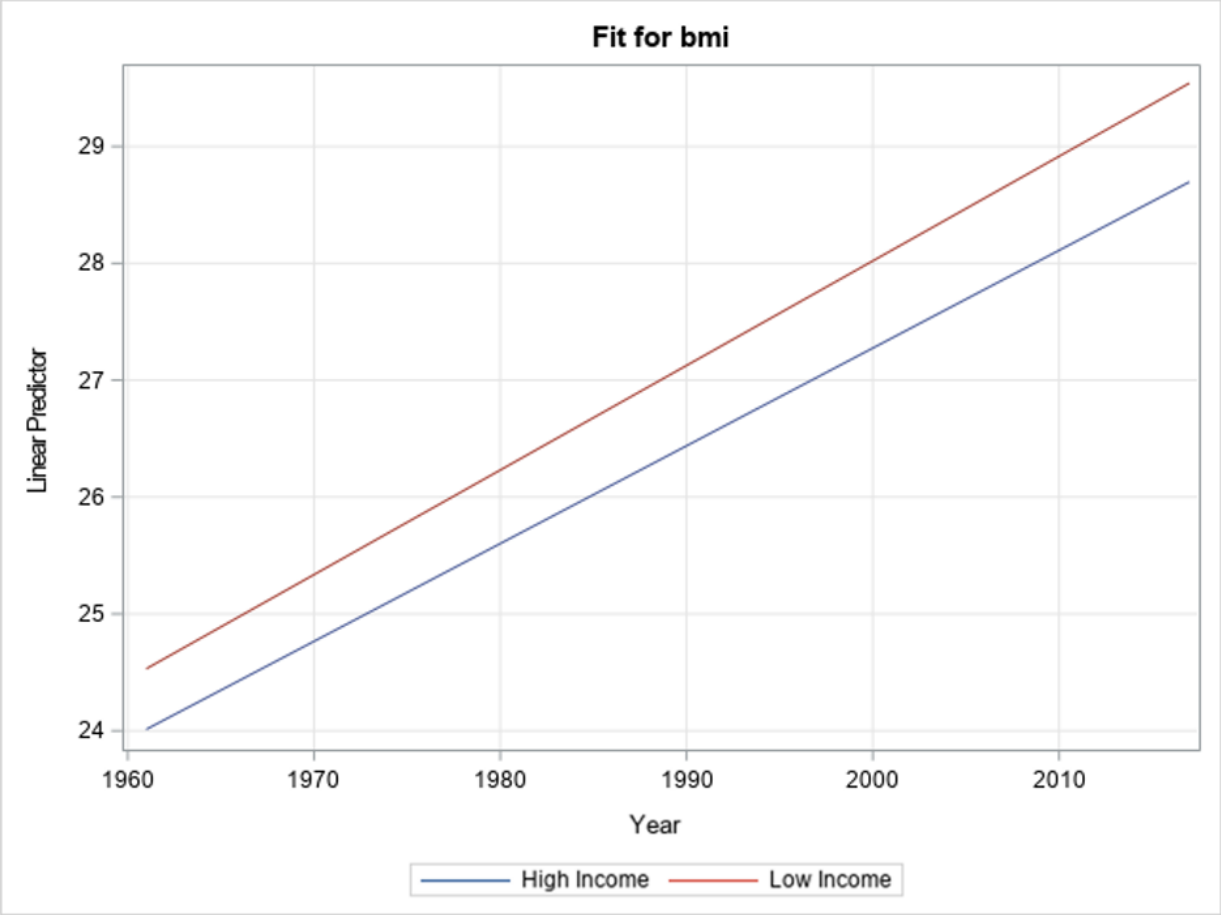

Figure 4. Fitted regression lines predicting BMI of the top income decile and bottom income decile.

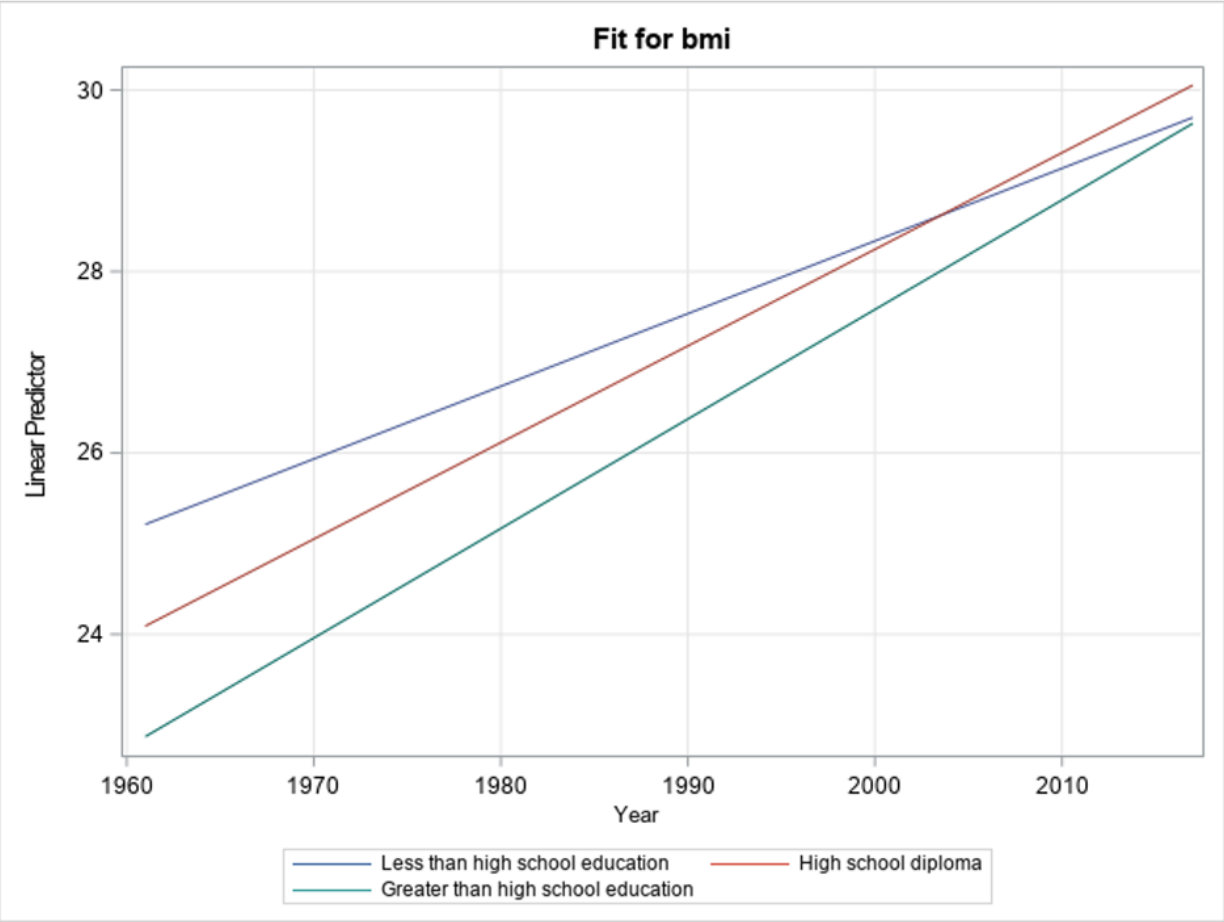

Figure 5. Fitted regression lines predicting BMI for each education group.

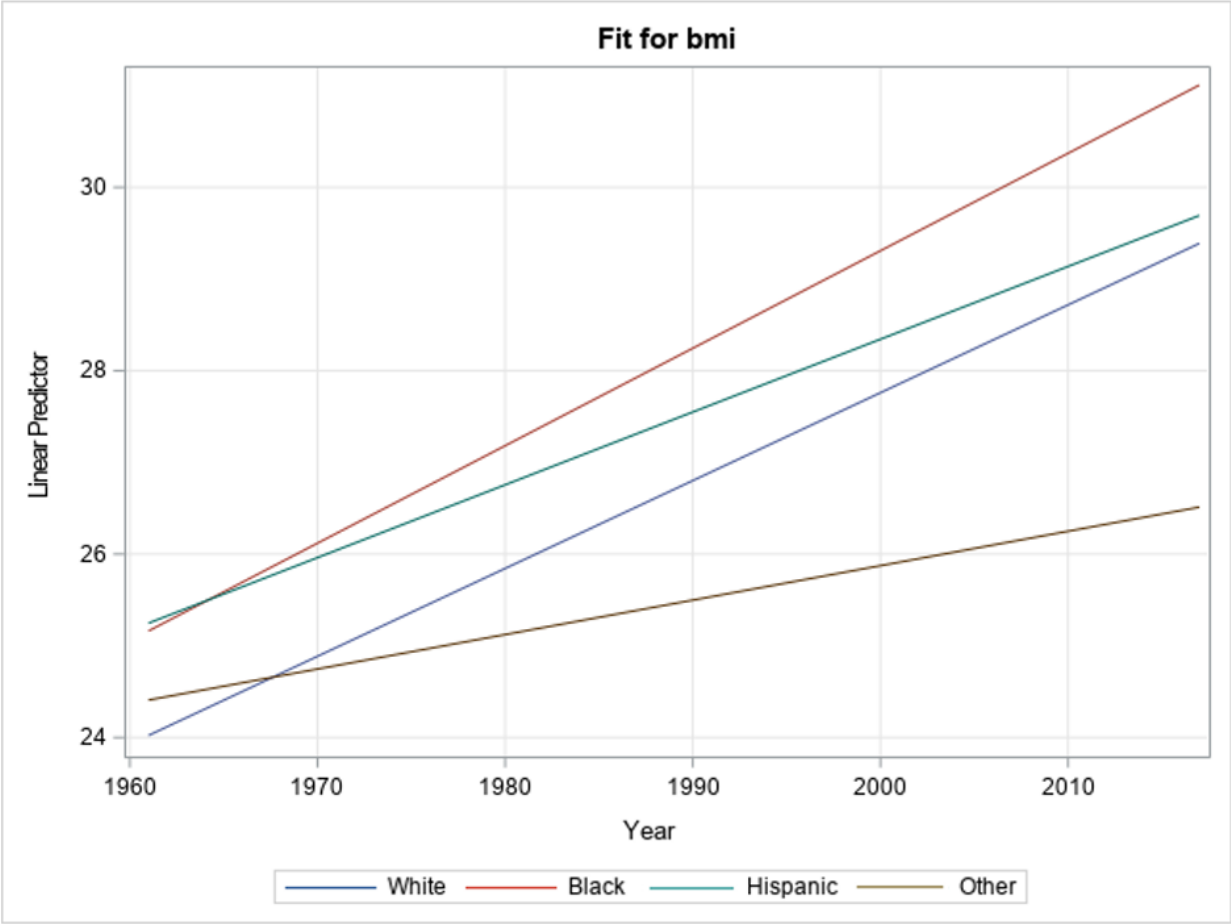

Figure 6. Fitted regression lines predicting BMI for each racial/ethnic group.

Variable	Estimate	Standard Error	P-value
Year	0.07627	0.008369	<.0001
Low income * high school diploma	-135.22	25.8724	<.0001
Low income * greater than high school	-134.45	25.0624	<.0001
Low income * less than high school	-3.5084	19.4898	0.8571
High income * high school diploma	-75.8319	23.0026	<0.0010
High income * greater than high school	-37.0351	18.7670	0.0485
High income * less than high school (reference)	.	.	.
Low income * high school diploma * year	0.06774	0.01299	<.0001
Low income * greater than high school * year	0.06648	0.01258	<.0001
Low income * less than high school * year	0.00185	0.00982	0.8507
High income * high school diploma * year	0.03789	0.01157	0.0011
High income * greater than high school * year	0.01794	0.00944	0.0575
High income * less than high school * year	.	.	.

Table 3. Results of ITS analysis for the interaction between income and education.

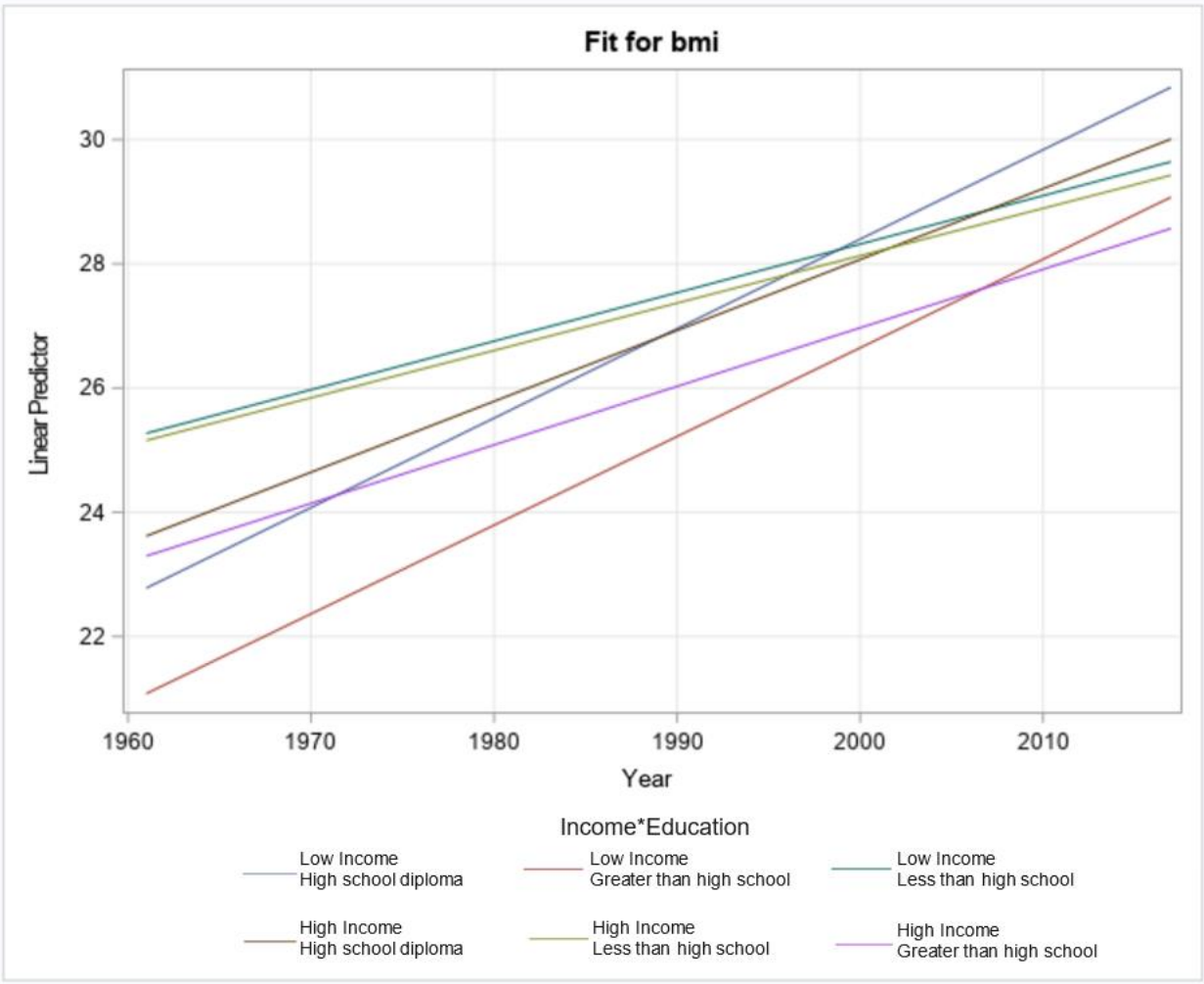

Figure 7. Fitted regression lines predicting BMI for the interaction of income and education.

Variable	Estimate	Standard Error	P-value
Year	0.08781	0.00444	<.0001
Low income * black	-1.6533	15.9272	0.9173
Low income * Hispanic	12.1333	31.4705	0.6998
Low income * other	88.6894	34.6605	0.0105
Low income * white	-6.9394	15.5021	0.6544
High income * black	-80.9821	26.4167	0.0022
High income * Hispanic	88.3164	31.0020	0.0044
High income * other	129.81	35.2169	0.0002
High income * white (reference)	.	.	.
Low income * black * year	0.00173	0.00800	0.8288
Low income * Hispanic * year	-0.00559	0.01571	0.7219
Low income * other * year	-0.04492	0.01722	0.0095
Low income * white * year	0.00362	0.00780	0.6428
High income * black * year	0.04156	0.01320	0.0016
High income * Hispanic * year	-0.04373	0.01544	0.0046
High income * other * year	-0.06590	0.01754	0.0002
High income * white * year (reference)	.	.	.

Table 4. Results of ITS analysis for the interaction between income and race/ethnicity.

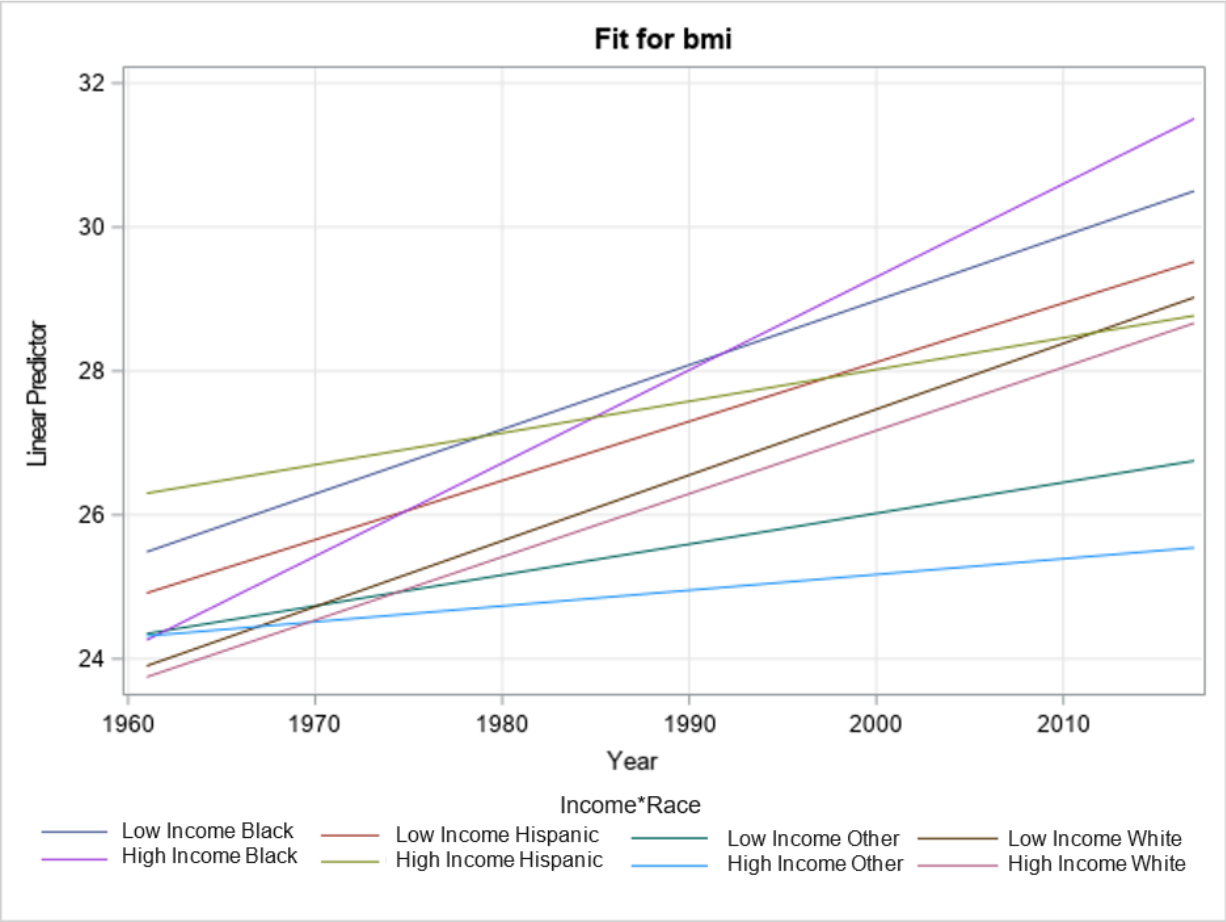

Figure 8. Fitted regression lines predicting BMI for the interaction of income and race/ethnicity.

Variable	Estimate	Standard Error	P-value
Year	0.08312	0.00260	<.0001
High school diploma * black	-66.7831	13.1696	<.0001
High school diploma * Hispanic	-26.8756	19.8288	0.1753
High school diploma * other	74.1624	31.6650	0.0192
High school diploma * white	-80.9696	8.6417	<.0001
Greater than high school * black	-138.61	13.4893	<.0001
Greater than high school * Hispanic	-4.2760	18.7219	0.8193
Greater than high school * other	2.5598	21.1498	0.9037
Greater than high school * white	-87.7894	7.8285	<.0001
Less than high school * black	7.0999	9.7619	0.4670
Less than high school * Hispanic	-0.6564	15.4533	0.9661
Less than high school * other	144.35	20.2504	<.0001
Less than high school * white (reference)	.	.	.
High school diploma * black * year	0.03386	0.00660	<.0001
High school diploma * Hispanic * year	0.01361	0.00989	0.1688
High school diploma * other * year	-0.03799	0.01579	0.0162
High school diploma * white * year	0.04044	0.00435	<.0001
Greater than high school * black * year	0.06987	0.00674	<.0001
Greater than high school * Hispanic * year	0.00208	0.00933	0.8238
Greater than high school * other * year	-0.00273	0.01054	0.7952
Greater than high school * white * year	0.04352	0.00394	<.0001
Less than high school * Black * year	-0.00309	0.00491	0.5299
Less than high school * Hispanic * year	0.00049	0.00773	0.9500
Less than high school * Other * year	-0.07319	0.01014	<.0001
Less than high school * white * year (reference)	.	.	.

Table 5. Results of ITS analysis for the interaction between education and race/ethnicity.

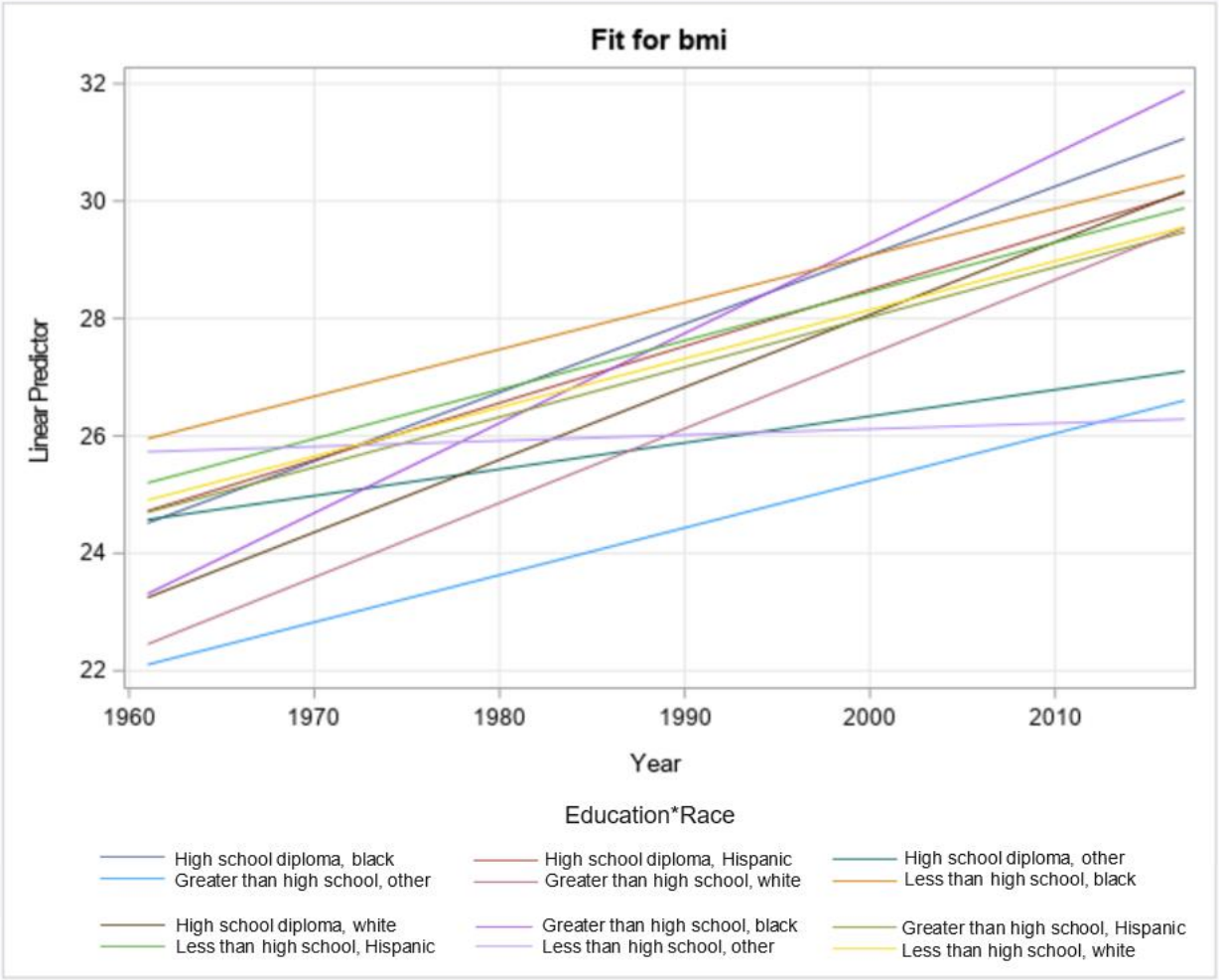

Figure 9. Fitted regression lines predicting BMI for the interaction of education and race/ethnicity.

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