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Abstract

Background: While increases in obesity over the past 30 years have adversely affected population health, there have been concomitant improvements due to reductions in smoking. Better understanding of the joint effects of these trends on longevity and quality of life will help policymakers target resources more efficiently.

Methods: For each year from 2005 to 2020, we forecast life expectancy and quality-adjusted life expectancy for a representative 18 year old, assuming a continuation of past trends in smoking from the National Health Interview Survey (1978-79, 1990-91 and 2004-06), and past trends in body-mass index (BMI) from the National Health and Nutrition Examination Survey (1971-75, 1998-1994, and 2003-06). The 2003 Medical Expenditure Panel Survey was used to examine the effects of smoking and BMI on health-related quality of life.

Results: The negative effects of increasing BMI overwhelmed the positive effects of declines in smoking in multiple scenarios. In the base case, increases in the remaining life expectancy of a typical 18 year old are held back by 0.71 years or 0.91 quality-adjusted years between 2005 and 2020. If all U.S. adults became normal weight non-smokers by 2020, LE is forecast to increase by 3.76 life years or 5.16 quality-adjusted years.

Conclusions: If past obesity trends continue unchecked, the negative impact on U.S. population health is forecast to overtake the positive effect from declining smoking rates, which could erode the pattern of steady gains in health experienced since early in the 20th century.

INTRODUCTION

Trends in behavioral risk factors can have a profound impact on population health.[1, 2] Estimates suggest that obesity accounts for 5 to 15% of deaths each year in the United States,[2-5] and smoking accounts for 18% each year.[1] Eliminating smoking could increase population life expectancy by as much as 1 to 2 years.[6, 7] In contrast, if obesity continues to grow at historical rates, a leveling off or even *reversal* of past life expectancy trends has been predicted.[8]

Beyond their impact on mortality, obesity and smoking also affect quality of life.[9-14] Smoking is a major risk factor for cardiovascular disease, chronic lung disease, and several cancers. Obesity leads to cardiovascular disease, diabetes, and joint problems.

Recent U.S. trends in smoking and obesity have been in opposite directions; over the past fifteen years, smoking rates have declined by 20 percent, while obesity rates have increased by 48 percent.[15] Estimating the *joint* impact of smoking and obesity trends on mortality *and* quality of life is important to yield a complete picture of their effects on population health. While previous studies have examined the joint effects of obesity and smoking on mortality, they have not used nationally representative data or examined quality of life.

This study forecasts the impact of obesity and smoking trends on future U.S. life expectancy and quality-adjusted life expectancy. We use data from the past three decades to forecast future obesity and smoking rates, and estimate their joint impact on length and quality of life (QOL).

METHODS

Data Sources and Definitions

Three surveys, each nationally representative of the civilian, non-institutionalized U.S. population,[16-19] were used to measure prevalence of risk factors and their impact on mortality and QOL in adults.

Data on body mass index (BMI) were obtained from physical measures in the National Health and Nutrition Examination Survey (NHANES).[17] Respondents were classified using World Health Organization (WHO) criteria[20] as normal weight (BMI 18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), obese (30.0–34.9 kg/m^2, obesity class I), or morbidly obese (≥35.0 kg/m^2, obesity classes II and III). Those with BMI <18.5 kg/m^2 were excluded because low BMI can be indicative of pre-existing illness.[21] To measure historical trends, mean BMI by 10-year age-gender groups was calculated for four time periods: 1971-75 (NHANES I; N=4992),[22] 1988-1994 (NHANES III; N=17,689), 1999-2002 (first two waves of continuous NHANES; N=10,132), and 2003-2006 (two subsequent waves of continuous NHANES; N=10,436).

Smoking trends were obtained from the National Health Interview Survey (NHIS).[18, 23] The population was divided into four groups: current smokers; former smokers who quit more than 10 years prior; former smokers who quit within the prior 10 years; and never smokers. Smoking rates were examined by 10-year age-gender groups for four time windows: 1978-79 (N=23,488), 1990-1991 (N=83,770), 1999-2001 (N=95,623) and 2004-2006 (N=86,069).

The impacts of smoking and obesity on quality of life were estimated using the 2003 Medical Expenditure Panel Survey (MEPS),[16, 24] which included a self-rating of health on a scale from zero (worst health imaginable) to 100 (best).[25] Analyses included the 80% of respondents with complete data on smoking, obesity, and self-rated health (N=18,913).

Risks of all-cause mortality for joint smoking/obesity categories were calculated using mortality follow-up data for NHANES I, II and III (combined N=24,758). Period life tables for the U.S. population were obtained from the National Center for Health Statistics (NCHS) and the Social Security Administration (for ages top coded in NHCS tables).[26, 27]

Forecasting Approach

Our analysis proceeded in four parts. First, we forecasted future prevalence of smoking and obesity by simulating a continuation of past trends. Historical changes in smoking and BMI were calculated going back approximately 15 years. Respondents were divided into four smoking and four obesity categories, for 16 groups in total. To control for changing demographics, smoking and weight categories were weighted to 2000 national totals for each 10-year age-gender group.[28]

Using NHANES 2003-2006 as a baseline, we then forecasted the joint distribution of future smoking and obesity categories. An annual percentage increase in BMI consistent with historical change was simulated for each person. For smoking, we probabilistically assigned a percentage of current smokers to become former smokers and a percentage of current and short-term former smokers to become long-term quitters or non-smokers each year, to simulate a continuation of past rates of change. We then recalculated annual population shares in each of the 16

BMI/smoking categories. Finally, for each future year we smoothed the population distribution by regressing an indicator for being in each BMI/smoking category on age and age squared.

The second step was to estimate relative risks of all-cause mortality for each of the smoking/obesity categories using Cox proportional hazard models in combined NHANES I, II and III follow-up data. We used attained age as the time scale.[29] Covariates were baseline age in 5-year intervals, gender, and race.

The third step was to generate life tables for each smoking and BMI category. We began with age-specific mortality rates from 2004 life tables. Using the smoking-BMI relative risks of death and our estimates of smoking and BMI shares at each age, we calculated mortality rates at each age for each smoking-BMI category. These rates were used to simulate life expectancy (LE) for each smoking and BMI category.

The impact of smoking and BMI on QOL was estimated using regression analysis[30] relating self-rated health to smoking/obesity categories and sociodemographic variables. Because MEPS asks only about current smoking status, we assumed that QOL for former smokers was the same as that of never smokers. Predicted summary health scores were then estimated for each of the smoking/BMI categories by 10-year age groups. These quality of life scores were weighted by our population forecasts to estimate the effects of obesity and smoking on quality-adjusted life expectancy (QALE) for each future year.

To estimate the impact these risk factors *may* already have had on life expectancy, we forecasted the change in life expectancy between 1990 and 2004, holding smoking and obesity rates constant at 1990 levels. We then compare the forecasted to the observed change in life expectancy over the interval.

Sensitivity Analyses

Our baseline simulation assumed a continuation of smoking and BMI trends through 2020 equal to the change over the previous 15 years. We formed alternate projections using historical changes from longer (30 year) and shorter (5 year) time windows. Also, because evidence suggests that the rate of obesity growth may be decelerating,[31, 32] we estimated the threshold rate of increase in BMI above which the adverse effects begin to surpass the beneficial effects of smoking declines. We also simulated the effects of eliminating smoking and reducing all BMI's to normal (BMI < 25) by 2020. Finally, we performed sensitivity analyses using alternate relative risks of all cause mortality from two prospective studies of health professionals that, while not nationally representative, consider the joint effects of smoking and BMI.[21, 33]

RESULTS

Historical smoking rates and mean BMI are shown in Table 1. On average, smoking declined by 1.4 percent and BMI increased by 0.5 percent per year over the 15 years prior to 2005. Over the 30 and 5 year historical windows, the annual rate of decline in smoking was higher (1.7% and 2.0% per year, respectively), and the rate of increase in BMI was lower (0.4% and 0.3% per year, respectively).

Assuming that historical 15-year trends continue through 2020, forecasted trends in the prevalence of smoking and distribution of BMI are shown in Figure 1 (smoothing details are given in the Appendix). Over the 15 year period, we project a 21% decline in current smoking, a 44% decline in former smoking within 10 years, and a 5% increase in those quitting 10 or more years previously. Over that same time frame, the share of the population that is normal weight is projected to decline by 35%. Nearly half the population (45%) is forecast to be obese by 2020.

Relative risks of all-cause mortality for the 16 smoking/BMI groups are shown in the Appendix. Mortality increased with current smoking and with greater weight, consistent with Flegal and colleagues' findings.[3] Table 2 shows mean predicted QOL scores. Regression results are provided in the Appendix. Smokers had lower QOL than non-smokers at all ages, and QOL declined with increasing BMI across age groups.

Fifteen year forecasts of life expectancy and QALE, accounting for changes in smoking alone, BMI alone, and both combined, are shown in the first row of Table 3 and in Figure 2 for a typical 18 year old. By itself, continued declines in smoking at rates seen over the past 15 years would lead to an increase in LE of 0.31 years in addition to the trend in LE due to other factors and an increase in QALE of 0.41 years. In contrast, a continuation of increases in BMI would lead to health changes that are larger and in the opposite direction. Life expectancy would be reduced by 1.02 years relative to trend and QALE by 1.32 years. The net effect of the two combined is a reduction of 0.71 in life expectancy relative to trend or 0.91 in QALE. This pattern of results is seen for all years between 2005 and 2020, and becomes more pronounced over time. Sensitivity

analyses using alternate mortality risks from prospective studies yielded similar results (Figure 2c).

Turning to historical trends, a typical 18 year old's life expectancy increased by 2.44 years between 1990 and 2004. This is in contrast to a forecasted life expectancy increase of 2.98 years had smoking and obesity rates remain unchanged from 1990 levels. Thus, adverse smoking and obesity trends reduced, but did not overwhelm, the impact of other factors over the 1990-2004 period. The black lines in Figures 2 depict a continuation of the rate of increase not explained by changes in obesity and smoking.

Table 3 summarizes the results of simulations using alternative forecasts of changes in smoking and BMI. Five and thirty year changes have slightly more rapid declines in smoking and less rapid increases in BMI. However, even in these scenarios, the negative impact of increasing BMI surpassed the positive impact of falling smoking rates, eroding growth in both life expectancy and QALE. Indeed, there would be a negative effect on LE and QALE as long as the growth in BMI exceeds 0.15 percent per year (not shown).

The hypothetical elimination of smoking by 2020 increased an 18 year old's LE and QALE by 1.73 and 2.17 years respectively, and returning the entire population to normal weight had similar effects. The combined effect of eliminating smoking *and* obesity was a net gain of 3.76 life years or 5.16 quality-adjusted life years (table 3 and Figures 2a and 2b).

DISCUSSION

The negative effects of increasing obesity on U.S. population health are forecasted to surpass the benefits from continued reductions in smoking through the next decade. Further, these adverse health effects are forecasted to become larger over time. The magnitude is large. A 0.71 year reduction in life expectancy – our estimate of the combined impact of reduced smoking and increased obesity – is about one-quarter of the 2.98 year increase in life expectancy at age 18 that we forecast would have occurred between 1990 and 2004 without changes in these risk factors. Our results do not imply that life expectancy will fall; more likely, life expectancy will continue to rise but less rapidly than it otherwise would.

The hypothetical scenario in which everyone is a normal weight non-smoker by 2020, though perhaps not achievable, illustrates the dramatic toll these behavioral risk factors can jointly take. Perfect risk factor control would add over 5 years of quality-adjusted life.

Our forecasts suggest that a continuation of past trends would ultimately result in almost half the U.S. adult population meeting WHO criteria for obesity by 2020, a prediction consistent with Wang and colleagues.[34] That said, it is difficult to predict future smoking and obesity trends with accuracy. Risk factor trends are susceptible to policy and environmental factors, and there is evidence that BMI trends may be decelerating.[31, 32] However, increases in BMI among adults are likely to occur with the maturation of the current cohort of U.S. children, among whom obesity rates are at a historical high.[22] Further, in sensitivity analyses using different historical rates of change in risk factors, the negative effects of obesity trends continue to outweigh the positive effects of smoking declines as long as BMI increases exceed even minimal levels.

While adverse behavioral risk factors cannot be completely eliminated, even modest weight loss[35] and reductions in smoking[12] can have substantial effects on population health. Research has demonstrated the clinical efficacy of several smoking cessation[36] and obesity[35, 37-39] interventions.[36] The challenge is to increase their use[40] while continuing to develop and test other interventions. Effective public health and behavioral economics interventions are crucial for fostering continued smoking cessation efforts[41] and for combating the roots of obesity, which include sedentary lifestyles, widespread availability of high-calorie food in large portions, and reduced time for at-home food preparation.[32, 42-45]

As most of the ill health effects of obesity occur through chronic diseases, it is encouraging that control of cardiovascular disease risk factors such as high cholesterol and hypertension has improved over the past 40 years, particularly among those who are overweight and obese.[46] An important exception to this trend is diabetes,[46,47] which is at an all time high and continues to increase rapidly. Improved treatment of obesity-related diseases is thus vital to improving the nation's health.

Our study examined the joint impact of obesity and smoking trends on length and quality of life in the United States. A prior study estimated the impact of smoking and obesity trends on disability-adjusted life expectancy in the Netherlands.[48] The magnitude and direction of their findings were comparable to ours despite the marked difference in methods (they used a chronic disease microsimulation model). A strength of our study was the use of nationally representative

data as a base for forecasts and underlying rates. In projecting forward past co-occurring trends in both risk factors, we incorporate factors such as the weight gain among smokers who quit.[49]

Our study also has some limitations. While it quantifies the effects of obesity and smoking, it can not account for the many other factors that determine life expectancy and QOL, such as advances in medicine and public health. Historically, the positive impact of these factors has overwhelmed the effects of smoking and obesity; our results are depicted relative to an assumed continuation of this trend. There is ongoing debate about the impact of different BMI levels on mortality.[5, 50] However, our relative risks of mortality come directly from nationally representative data and our findings are robust to sensitivity analyses using other published relative risks.[21, 48] Consistent with past studies,[3,4,21,33] mortality analyses did not include SES; alternate analyses controlling for education yielded very similar results (Table A3). Our quality of life estimates are cross-sectional, which was required in order to measure the joint effects of smoking and obesity in a nationally representative sample. Comparison to a prospective study of QOL and weight loss suggests that actual quality changes associated with obesity may be greater than we estimate.[51].

The forecasts reported are at a population level and do not apply to a particular person losing weight or quitting smoking. We also made some assumptions typical for population level estimates.[1-4, 8, 11] For example, we assume that risk increases instantaneously when a BMI threshold is crossed. However, because baseline risk is relatively low, actual increases in mortality are not observed right away. Further, while we simulate changes in smoking and BMI in each future year, our forecasts assume that once those levels are reached, they remain unchanged throughout an individual's life. Finally, our analyses are not stratified by

socioeconomic status.[8, 32, 52, 53] BMI has increased disproportionately for blacks, which may further heighten disparities in the future.

Conclusion

The detrimental effect of increasing obesity on population health is tempered only somewhat by the decline in smoking. Efforts to improve health should focus on stabilization or reversal of BMI trends, continued reductions in tobacco use, and better control of clinical risk factors brought on by obesity and smoking. Inadequate progress in these areas could result in an erosion of the pattern of steady health gains experienced in the U.S. since the early 20th century.

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Disclosure

No authors reported potential conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript.

Author Contributions

STS accessed and analyzed study data (all of which were publicly available), and takes responsibility for the integrity of the data and accuracy of the data analysis. STS, DMC, and ABR were responsible for study concept and design, and interpretation of data analyses. SS drafted the manuscript, with multiple rounds of editing and critical review by DMC and ABR.

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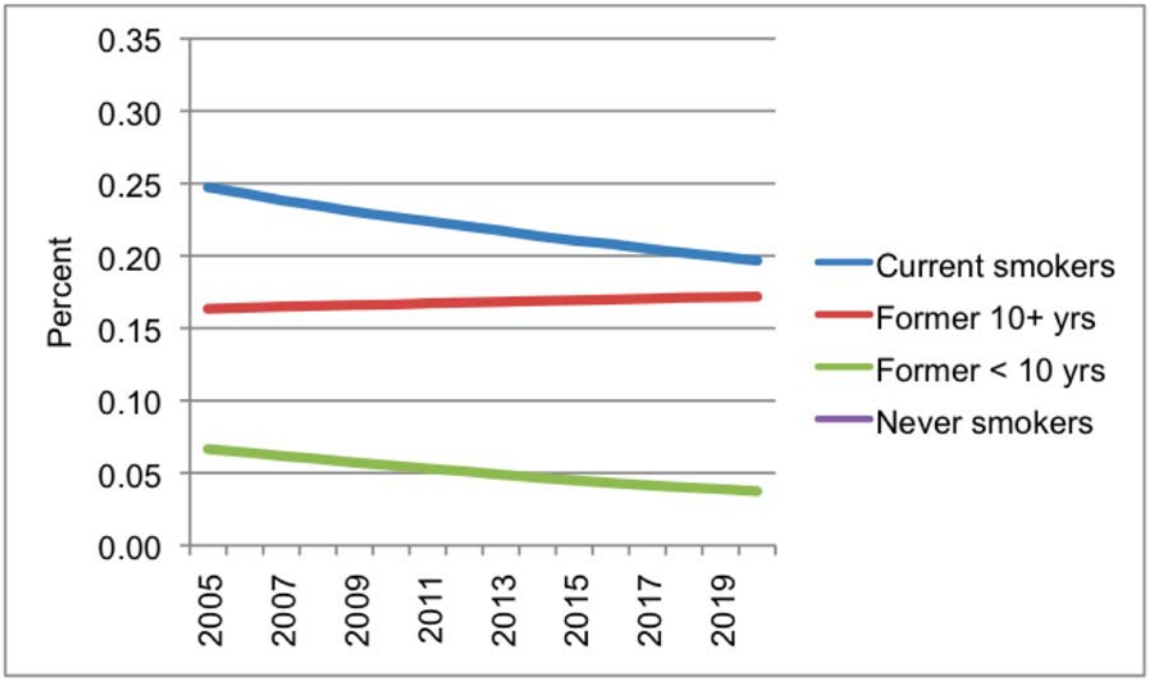
Table 1: Historical Trends in Smoking Prevalence and Mean BMI Among U.S. Adults, 1973−2005.

	Historical Period				Annual Rate of Change		
	1973−79	1990	2000	2005	~30 year	~15 year	~5 year
Current smokers	33.3%	25.7%	23.1%	20.9%	-1.7%	-1.4%	-2.0%
Former smokers < 10 years	11.5%	12.7%	8.5%	7.5%	-1.6%	-3.6%	-2.4%
Former smokers 10+ years	8.2%	12.6%	13.8%	13.1%	1.6%	0.3%	0.9%
BMI (mean, kg/m^2)	25.2	26.5	27.9	28.3	0.4%	0.5%	0.3%

Notes: All prevalence estimates and means are weighted by the age and gender distribution of the 2000 Census Population. Smoking data are from NHIS years that included questions on smoking, including time since quitting:1978-79, 1990-91, 1999-2001, and 2004-2006. Historical time periods covered for smoking are thus 26.5 years, 14.5 years, and 5 years. BMI data are from NHANES I (1971-1975), NHANES III (1988-1994), and continuous NHANES 1999-2002 and 2003-2006. Using the mid-points of each of the time periods covered by these surveys, the historical time periods covered for BMI are 31.5 years, 13.5 years, and 4 years.

Figure 1: Forecasted Distribution of Risk Factors, 2005-2020

Panel A: Smoking



Panel B: Body Mass Index

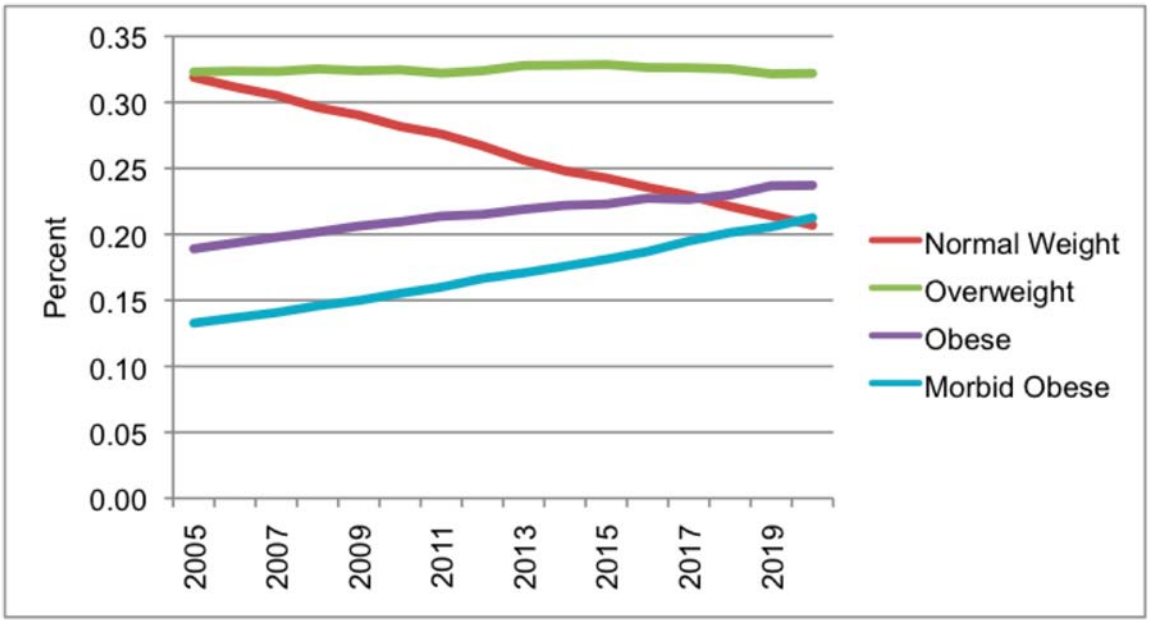


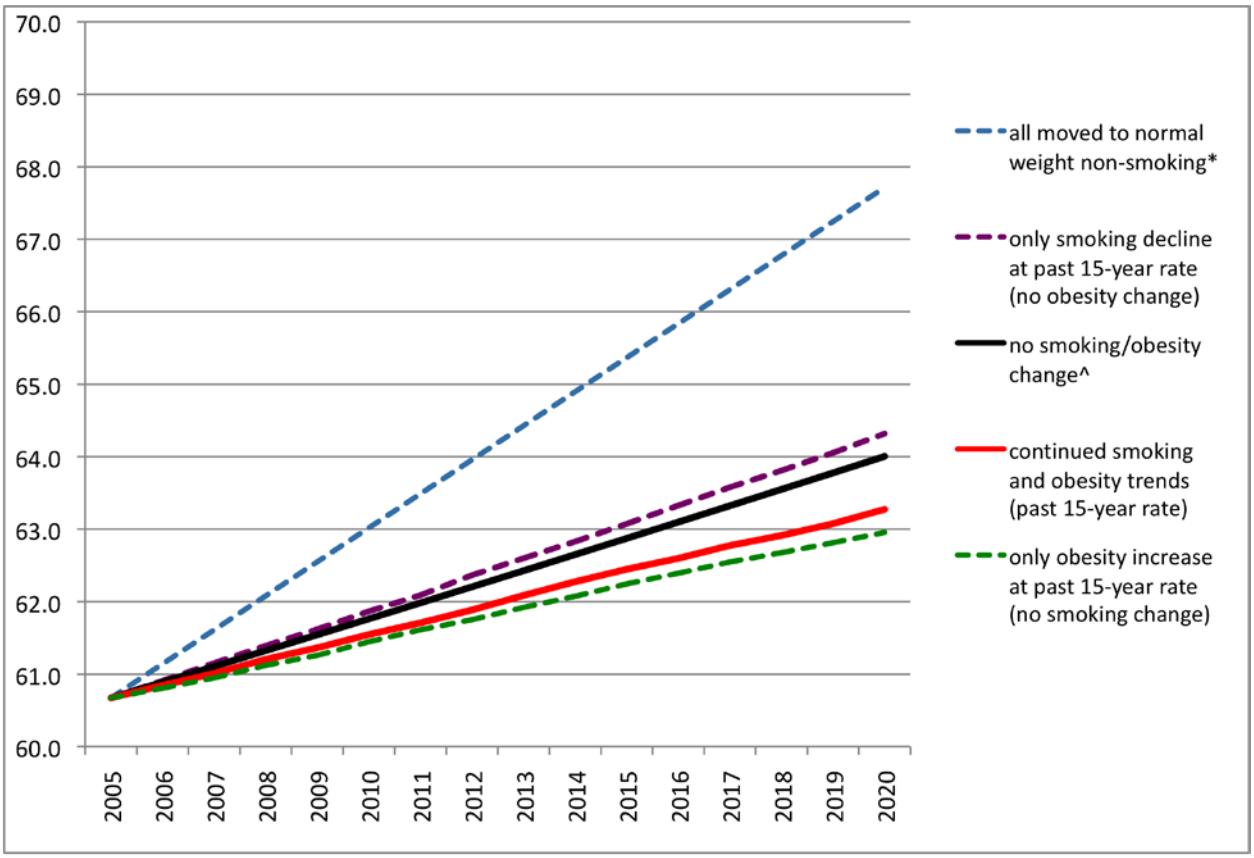
Table 2: Summary Quality of Life Scores by Risk Factor Level

	Normal Weight	Overweight	Obese	Morbidly Obese
Former/Never Smokers				
18-24	0.90	0.89	0.86	0.80
25-34	0.88	0.88	0.84	0.78
35-44	0.86	0.85	0.82	0.76
45-54	0.84	0.84	0.80	0.75
55-64	0.82	0.81	0.78	0.72
65-74	0.78	0.77	0.74	0.68
75+	0.72	0.71	0.68	0.64
Current Smokers				
18-24	0.84	0.83	0.81	0.74
25-34	0.82	0.81	0.78	0.72
35-44	0.79	0.79	0.76	0.70
45-54	0.78	0.77	0.74	0.69
55-64	0.76	0.75	0.72	0.67
65-74	0.72	0.71	0.66*	0.61*
75+	0.67	0.67	0.66*	0.61*

Note: Predicted Scores from Regression of EQ-5D Visual Analog Scale in MEPS 2003.
*Because of small numbers, quality of life for obese and morbidly obese smokers was estimated jointly for everyone over age 65.

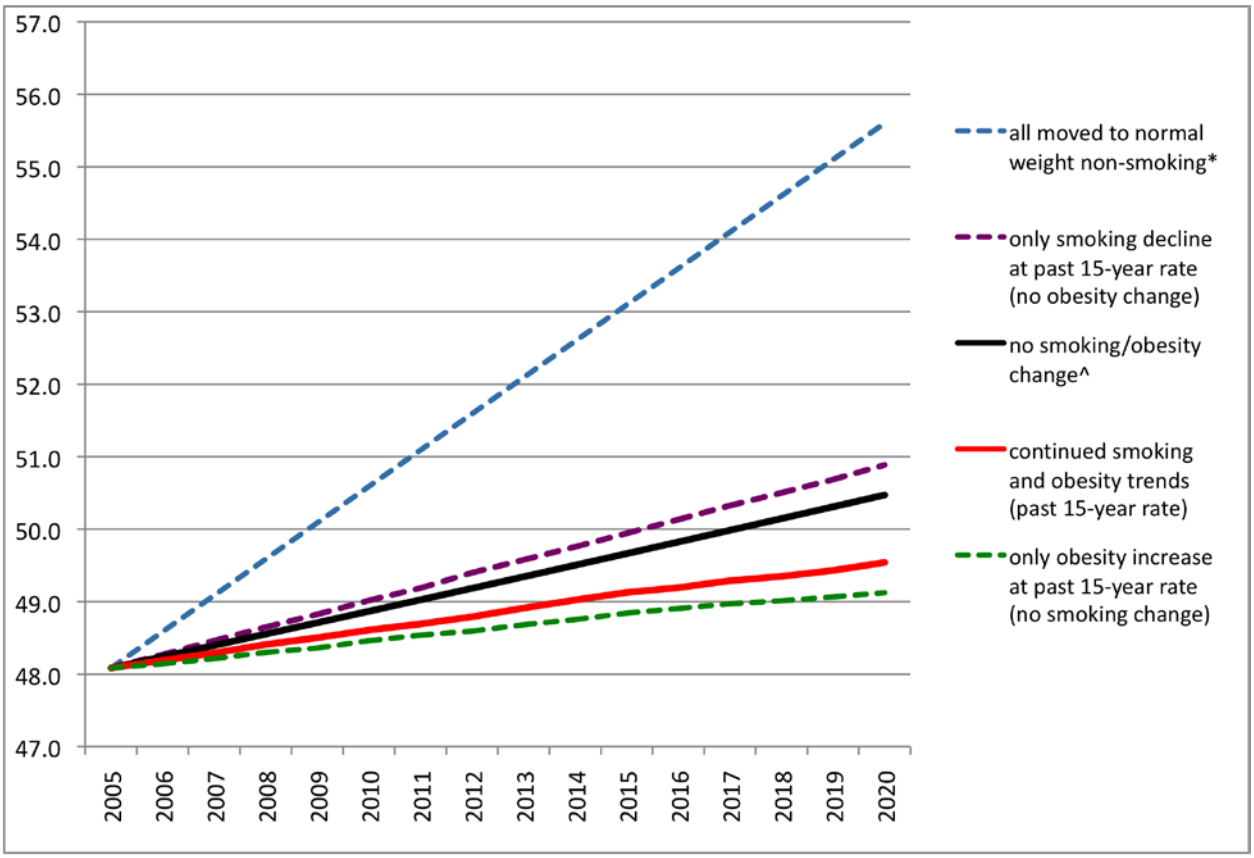
Figure 2: Forecasted Life Expectancy and Quality-Adjusted Life Expectancy at age 18 from 2005 to 2020, Considering Trends in Smoking Alone, BMI Alone, and Both Combined

Panel A: Life Expectancy at Age 18



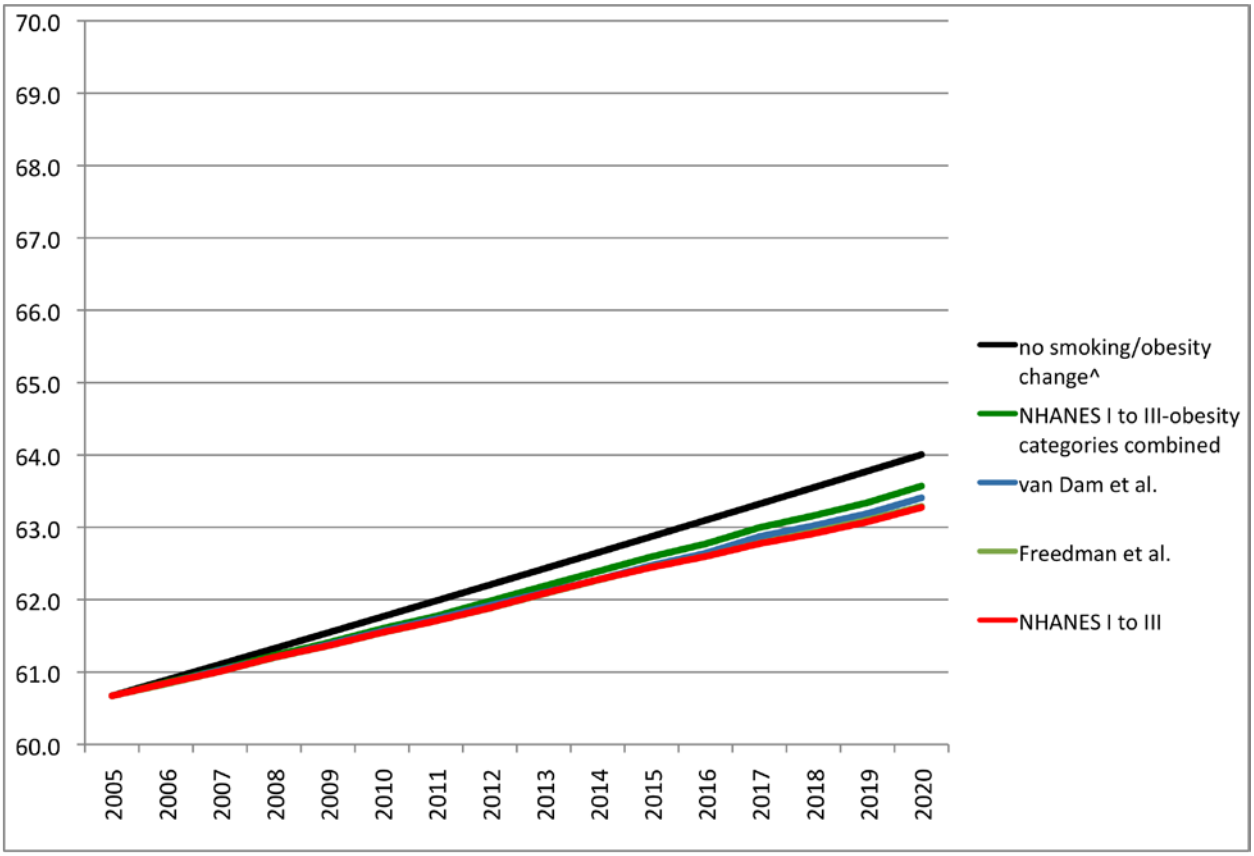
*Returning the entire population to normal weight (BMI 18.5 – 25) and setting all current smokers to former smokers of 10+ years
^ Continuation of the 1990 to 2004 rate of increase in LE independent of changes in obesity and smoking over that time period.

Panel B: Quality-Adjusted Life Expectancy at age 18



*Returning the entire population to normal weight (BMI 18.5 – 25) and setting all current smokers to former smokers of 10+ years.
^ Continuation of the 1990 to 2004 rate of increase in LE independent of changes in obesity and smoking over that time period.

Panel C: Comparison using Mortality Risks from Different Sources to Forecast Life Expectancy at Age 18 with Continued 15-year Trends in Smoking and Obesity



Note: Comparison of forecasted continuation of 15-year smoking and obesity trends using relative risks of all-cause mortality from NHANES I, II and III (calculated in this study) and from two prospective studies (Freedman et al., 2006; Van Dam et al., 2008). For comparison to van Dam et al., new relative risks were calculated in NHANES combining obese and morbid obese categories. Note that the van Dam et al. relative risks were from a female sample (the Nurse's Health Study). To obtain relative risks for joint smoking-obesity categories from this study, a multiplicative relationship between smoking and obesity was assumed.

Table 3: Impact of Alternate Assumptions About Smoking and BMI Trends on Life Expectancy and Quality Adjusted Life Expectancy at Age 18

	Change from 2005 to 2020					
	Smoking Alone#		BMI Alone*		Smoking and BMI Jointly~	
Scenario: Simulated continuation of:	LE	QALE	LE	QALE	LE	QALE
Historical 15-year rate of change (baseline)	0.31	0.41	-1.02	-1.32	-0.71	-0.91
Historical 30 year rate of change	0.32	0.43	-0.76	-1.00	-0.43	-0.56
Historical 5 year rate of change	0.41	0.52	-0.58	-0.75	-0.10	-0.17
Everyone nonsmoking and/or normal weight^	1.73	2.17	1.40	2.44	3.76	5.16

BMI= Body-Mass Index; LE= Life Expectancy; QALE= Quality Adjusted Life Expectancy

#shows the impact of continuing trends in smoking while leaving BMI unaffected.
*shows the impact of continuing trends in BMI while leaving smoking status unaffected.
~shows the impact of continuing trends in both smoking and BMI
^current smokers set to former smoker of 10+ years and all others set to nonsmokers.

Appendix

This appendix provides additional information on the calculations in the paper, "Forecasting the Impact of Obesity and Smoking Trends on Future U.S. Quality-Adjusted Life Expectancy". For all statistical analyses, population weights appropriate to each of the three surveys were used,[16-19] and analyses were performed using SAS© software version 9.1 for UNIX[53] and Stata© version 10.[54]

Smoothing Smoking and Obesity by Age

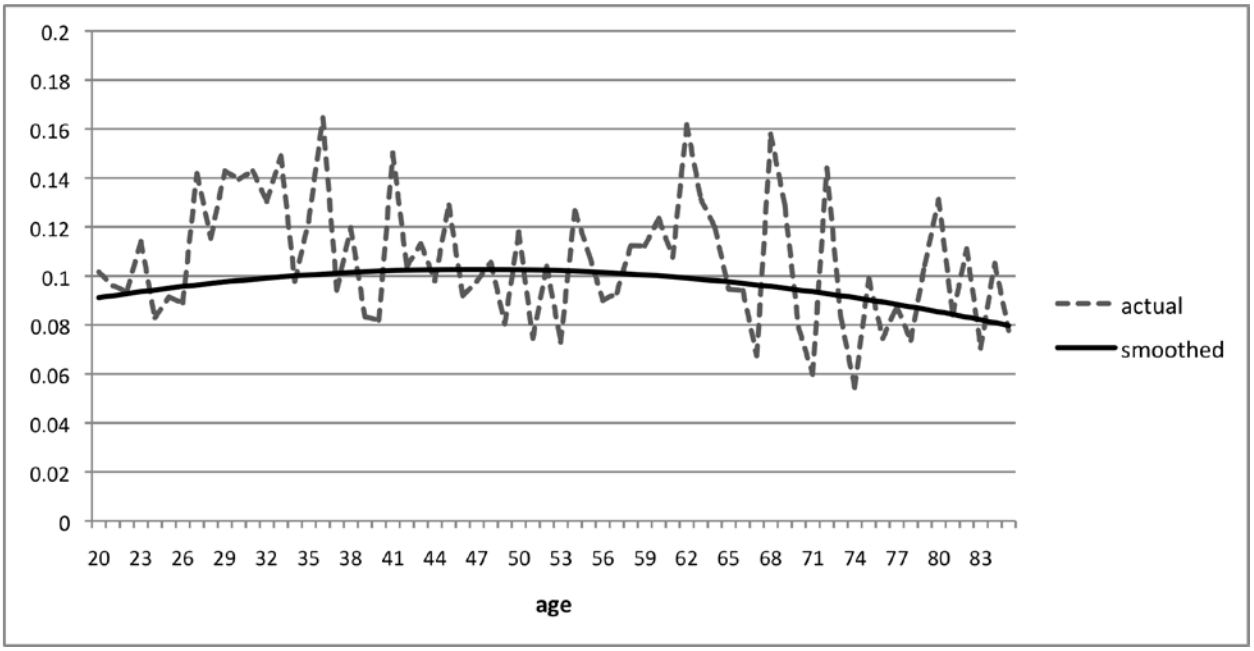
Table A1 shows the coefficient estimates used to predict the distribution of combined smoking and BMI categories in the NHANES 2003-2006 data. These regressions are used to smooth the rates in each cell by age. Figure A1 shows an example of data at each age and the smooth trend for never smoking obese individuals.

Table A1: Coefficients from 12 OLS Regressions Used to Predict the Distribution of Combined BMI and Smoking Categories, NHANES 2003-2006

		Normal Weight		Overweight		Obese		Morbid Obese	
		beta	p-value	beta	p-value	beta	p-value	beta	p-value
Never	Intercept	0.548	<.0001	0.178	<.0001	0.077	0.002	-0.027	0.214
Smokers	Age	-0.015	<.0001	-0.000	0.758	0.001	0.229	0.005	<.0001
	Age Squared	0.000	<.0001	0.000	0.751	-0.000	0.168	-0.000	<.0001
Former	Intercept	0.074	<.0001	0.028	0.019	-0.012	0.223	-0.018	0.022
Smokers	Age	-0.002	<.0001	0.000	0.598	0.001	0.003	0.001	0.000
< 10 years	Age Squared	0.000	.0001	0.000	0.582	0.000	0.002	0.000	0.000
Former	Intercept	0.001	0.966	-0.085	<.0001	-0.061	<.0001	-0.074	<.0001
Smokers	Age	0.000	0.567	0.003	<.0001	0.003	<.0001	0.003	<.0001
10+ years	Age Squared	0.000	0.000	0.000	0.986	0.000	0.055	0.000	<.0001
Current	Intercept	0.192	<.0001	0.052	0.015	0.024	0.143	0.006	0.678
Smokers	Age	-0.002	0.044	0.002	0.007	0.002	0.023	0.002	0.005
	Age Squared	0.000	0.986	0.000	<.0001	0.000	0.001	0.000	0.000

Categorization based on BMI (kilograms/meters^2): 18.5-<25 (normal weight/referent), 25-<30 (over weight), 30-<35 (obese), 35+ (morbid obese). Current smokers and short and long-term former smokers were those who had ever smoked at least 100 cigarettes and who still smoked, had quit less than 10 years ago, or had quit 10 years or more, respectively.

Figure A1: Rates of Obese Never Smokers by Age in NHANES 2003-2006



Mortality Relative Risks

We estimate the relative risk of all-cause mortality using data from combined NHANES I, II, and III surveys, matched to subsequent death records. Table A2 shows the sample characteristics for the mortality data.

Table A3 shows the Cox proportional hazards model for death by smoking-BMI cell. Separate models were fit for deaths that occurred before and after age 60. Deaths in those age 60+ were right censored in the first model, and deaths under age 60 were left censored in the second. (The SAS entry= option was used with proc phreg.) Forty-three percent of the sample in our analyses attained age 60 or greater. Those lost to follow-up were assigned a survival time of ½ the possible survival interval before the time when they were lost, but were censored on mortality. Models also included race: white (including Hispanic), black, and other, and age in 5-year age groups (coefficients not shown). These analyses omit those who died within the first 4 years of follow-up. Alternate analyses not omitting any deaths did not yield appreciably different relative risks.

Table A2: Sample Characteristics of NHANES I, II and III Data used for Mortality Analyses Ages 25-70

	NHANES I	NHANES II	NHANES III
Baseline Survey years	1971-1975	1976-190	1988-1994
Year of mortality follow-up	1992	1992	2000
Unweighted sample size*	5,959	7,578	11,221
Number of deaths -total	1,242	1,145	569
-under age 60	204	136	189

*respondents age 25 to 70 at baseline with data on BMI and smoking in baseline interview excluding those underweight at baseline and deaths within the first 4 years of follow-up.

Table A3: Relative Risks of Death from all Causes among Respondents Aged 25-70 in NHANES I, II and III Combined

Group	Multivariate Hazard Ratio	95% CI		Hazard Ratio Controlling for College Education
Attained age under 60				
Normal weight never smokers	1.00	--	--	1.00
Overweight never smokers	0.86	0.44	1.68	0.86
Obese never smokers	1.10	0.62	1.98	1.09
Morbid obese never smokers	2.73	1.54	4.82	2.66
Normal weight former smokers < 10 years	1.09	0.62	1.92	1.11
Overweight former smokers < 10 years	1.35	0.70	2.59	1.25
Obese former smokers < 10 years	1.31	0.53	3.22	1.25
Morbid obese former smokers < 10 years	1.62	0.57	4.62	1.55
Normal weight former smokers 10+ years	0.51	0.19	1.33	0.51
Overweight former smokers 10+ years	0.74	0.34	1.62	0.74
Obese former smokers 10+ years	1.18	0.33	4.24	1.17
Morbid obese former smokers 10+ years	1.47	0.39	5.54	1.44
Normal weight current smokers	2.10	1.39	3.18	2.02
Overweight current smokers	1.37	0.80	2.33	1.31
Obese current smokers	2.39	1.23	4.65	2.32
Morbid obese current smokers	3.95	2.00	7.79	3.74
Attained age 60 or over				
Normal weight never smokers	1.00	--	--	1.00
Overweight never smokers	0.84	0.68	1.05	0.83
Obese never smokers	1.11	0.87	1.43	1.10
Morbid obese never smokers	1.68	1.28	2.21	1.63
Normal weight former smokers < 10 years	1.48	1.15	1.92	1.50
Overweight former smokers < 10 years	1.39	1.10	1.75	1.34
Obese former smokers < 10 years	1.51	1.04	2.19	1.47
Morbid obese former smokers < 10 years	1.42	0.78	2.59	1.41
Normal weight former smokers 10+ years	0.85	0.64	1.13	0.86
Overweight former smokers 10+ years	1.08	0.85	1.37	1.08
Obese former smokers 10+ years	1.32	0.96	1.82	1.30
Morbid obese former smokers 10+ years	1.92	1.10	3.37	1.90
Normal weight current smokers	2.30	1.93	2.75	2.25
Overweight current smokers	1.99	1.58	2.50	1.94
Obese current smokers	3.03	2.31	3.96	2.94
Morbid obese current smokers	4.04	3.29	5.89	4.28

Categorization based on BMI (kilograms/meters^2): 18.5-<25 (normal weight/referent), 25-<30 (over weight), 30-<35 (obese), 35+ (morbid obese). Current smokers and short and long-term former smokers were those who had ever smoked at least 100 cigarettes and who still smoked, had quit less than 10 years ago, or had quit 10 years or more, respectively.
In combining the three waves of NHANES, sampling weights from each individual survey were used. Weights specific to follow-up were required for NHANES I;[55] baseline weights were used for NHANES II and III. Strata variables from the three surveys were considered independent. Alternate analyses that weighted the sampling weights from each wave of NHANES by the sample size in that wave yielded very similar results.

Measuring Quality of Life

Table A4 shows the predictions of quality of life by smoking and obesity status. Predicted summary health scores are calculated by 10-year age groups for smokers and nonsmokers and for each of the 4 weight categories. Predicted scores are treated as disutilities (decrements to health on a 0-1 scale on which 1 and 0 are equal to perfect health and death, respectively). Utilities (quality of life scores) for each group are obtained by subtracting predicted disutilities from 1. Our weights are derived from a 100-point visual analog rating scale, which typically yields lower utilities than standard gamble or time-tradeoff methods. However, it was the differences across groups that were more important to our forecasts than the absolute values.

Table A4: Multivariate Linear Regression of 100-Point Self Rating of Health (transformed to a 0-1 scale) on Smoking, Obesity, and Sociodemographic Variables in MEPS 2003

Covariates	Population percent	beta	p-value
Current smoker	22.1	-0.053	<.0001
BMI (kilograms/meters^2)			
18.5-<25 (normal weight/referent)	37.8	--	--
25-<30 (over weight)	36.5	-0.008	0.0012
30-<35 (obese)	16.1	-0.039	<.0001
35+ (morbid obese)	9.5	-0.090	<.0001
Age and Gender			
Age		-0.007	<.0001
Age squared		0.000	0.0053
Age cubed		0.000	0.0033
Male	48.7	0.044	<.0001
Age x Male		-0.001	<.0001
Race/Ethnicity			
Black	10.7	0.003	0.5948
Non-White Other	5.8	-0.025	<.0001
Income (relative to 400% of poverty and above)			
< 100% poverty	10.5	-0.098	<.0001
100-<125% poverty	4.0	-0.075	<.0001
125-<200% poverty	13.1	-0.055	<.0001
200-<400% poverty	30.4	-0.027	<.0001
400% poverty and over (referent)	42.1	--	--

Covariates	Population percent	beta	p-value
Intercept		1.028	<.0001
Summary statistics			
N		18,530	
R^2		0.160	

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