ACCOUNTING FOR CHANGES IN HEALTH INEQUALITIES IN SMOKING AND OBESITY IN THE UNITED STATES, 1960-2000

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Introduction

The unequal distribution of health outcomes across social groups such as gender, race, ethnicity, and socioeconomic position has become an important dimension of U.S. public health policy, and the elimination of social inequalities in health is now an explicit public health goal.[1] But measuring progress toward this goal is complicated by a number of factors, such as whether health inequality should be measured on a relative or absolute scale and how inequality across several social groups should be summarized.[2] An equally difficult issue, but one that has received less attention, is the fact that the size of the social groups across which health inequalities are to be eliminated may change as a result of social policies that, at least in the abstract, have little to do with public health. These changes in so-called "upstream"[3] factors such as immigration and education policy may dramatically shift the race-ethnic and educational composition of the population over time, and the impact of such changes on population health may be substantial, especially over longer time periods. For example, Hayward et al. found that the historic 20th century rise in education in the U.S. dramatically increased the active life expectancy of older adults from 1900-1992.[4]

Such changes also clearly have implications for the overall population health impact of social inequalities in health. Some studies ignore such shifts in population composition or treat them as a nuisance,[5-7] while other studies of health inequality trends attempt to account for changes in social groups compositions.[8-10] Changes in population structure may either mitigate or exacerbate health inequalities, and the extent to which they do so may also differ depending on whether one looks at inequality on an absolute or relative scale. For example, the upward shifts in the distribution of education over the past several decades[11] combined with widening educational differences in rates of smoking[6] may lead to worsening relative inequalities but

smaller absolute inequalities as fewer individuals remain in the higher risk educational groups. Taking this kind of population health-oriented view of health inequalities, there could thus be two potential factors contributing to inequality change: change in the *health of social groups* over time and change in the *distribution of social groups* over time. One of the aims of this analysis is to quantify the relative contributions of these two dimensions of health inequality change.

This analysis focuses on inequality trends for two health outcomes, tobacco use and obesity. Both are considered "Leading Health Indicators" for the year 2010,[1] are important contributors to morbidity and mortality among the U.S. population,[12-14] and are health outcomes for which social inequalities are well-documented.[6,15-19] Understanding how inequalities in smoking and obesity have changed over time facilitates a greater understanding of the dynamic links between social position and health and may be a first step in generating hypotheses about the causes of such changes.

This analysis has three aims, reflecting both methodological and substantive purposes: (1) to measure the trend in both relative and absolute inequality for smoking and obesity among age, sex, race, and education groups; (2) to decompose the change in inequality and quantify the relative contribution of changing rates of health and changing population distribution among social groups; and (3) to identify which social groups have been most influential in contributing to the change in inequality.

Methods

Data

The data for this analysis came from two sets of nationally-representative health surveys. Sample weights were used in each survey to account for unequal sampling probabilities and nonresponse. Trends in current smoking were investigated using smoking supplements to the National Health Interview Survey (NHIS), beginning in 1965 and ending in 2003 (n=876,280). Individuals missing information on age, gender, race, and education were excluded (2.0%), leaving an analytic sample of 859,014. Individuals who reported ever smoking 100 or more cigarettes in their lifetime and who currently smoke were considered "current smokers." The proportion of current smokers was calculated for each survey year by age (18-24, 25-44, 45-64, 65 and over), gender, race (white, non-white), and education (<12 years, 12 years, 13-15 years, 16 years or more). Analyses in which education groups were cross-classified by age excluded individuals 18-24. A nonparametric local regression smoothing technique[20] was used to assist in minimizing the sampling variability across survey years. The regression model used a quadratic fit over the span of calendar years and was weighted by the sample size of the age-gender-race-education group. This model can capture the non-linear changes in smoking behavior and has been used in previous analyses of NHIS smoking data.[21,22]

Trends in obesity were assessed using data from five adult samples of the National Health Examination Surveys (NHANES): the Health Examination Survey (1959-62), NHANES I (1971-74), NHANES II (1976-80), NHANES III (1988-94), and NHANES 1999-2002 (n=56,311). For ease of presentation, the midpoint of data collection years for each survey was used as the survey year (1961, 1973, 1978, 1991, 2000). While the examination surveys are not

conducted as frequently as the NHIS, they have the advantage of obtaining measured, rather than self-reported, height and weight. Self-reported height and weight are subject to bias, and the extent of bias differs with social group characteristics,[23,24] which makes using self-reported data for assessing inequalities difficult. Pregnant women were excluded, and individuals were categorized as obese if they had a body mass index (BMI) of 30 or greater. The analysis was restricted to individuals 18-74 years of age with no missing data on age, gender, race, or education. In order to minimize the effect of extreme or implausible values of BMI individuals falling outside the 1st and 99th percentiles of the BMI distribution in each survey year were excluded. The above exclusions yielded an analytic sample of 54,066 individuals. Age was categorized as 18-24, 25-44, 45-64, and 65-74. In order to maintain a consistent grouping across surveys, education was categorized as <12 years, 12 years, or greater than 12 years (NHANES 1999-2002 did not disaggregate those with >12 years of education). Due to small samples in early surveys, race was categorized as white/non-white across all surveys, but some supplementary analyses for the period from 1978 onward are also presented using white/black/other.

Measurement of Inequality

There are many ways to measure health inequality, and different measures of health inequality reflect, implicitly or explicitly, value choices about what dimensions of inequality are thought to be important (see Chapter 2 for a comprehensive review of methods for measuring health inequalities).[25] In this analysis, health inequality was measured using decomposable population-weighted measures of inequality, and was measured on both relative and absolute scales. The use of both absolute and relative measures of inequality provides a more complete picture of health inequality trends. If health inequalities are widening on a relative scale but

narrowing on an absolute scale this may indicate important progress among all social groups, and focusing on either relative or absolute inequality alone may lead to different conclusions about which health inequalities should be prioritized.[26] The use of decomposable population-weighted summary measures of health inequality allows changes in population structure to affect the level of and trend in inequality, and permits the decomposition of inequality change into the effects of changes in health and changes in population distribution. Population-weighted inequality measures thus reflect the population health burden of health inequalities, which may be especially relevant for comparing inequality across time and across different health outcomes.

Two summary measures of inequality were used: the Mean Log Deviation (MLD) as a measure of relative inequality, and the Between-Group Variance (BGV) as a measure of absolute inequality. The formulae for calculating the MLD and BGV are

$$MLD = \sum_{j=1}^{J} p_j - \ln r_j \qquad [1]$$

$$BGV = \sum_{j=1}^{J} p_j (y_j - \mu)^2 \qquad [2]$$

where p_j is the proportion of the population in group j, y_j is the prevalence of smoking/obesity, μ is the total prevalence, and r_j is the ratio of the prevalence of smoking/obesity in group j to the total prevalence (i.e., $r_j = y_j / \mu$). Both measures are population-weighted, are more sensitive to health differences further from the average rate (by the use of the logarithm in the MLD and squaring differences from the mean in the BGV), and may be used for both ordered social groups (education) and unordered groups (gender, race).

Measuring between-group inequality in health using the population-weighted inequality measures above makes clear that changes in the value of inequality over time are a function of two quantities: changes in rates of health, i.e. changing prevalence ratios (r_j), and changes in

population shares (p_j).[27] Both inequality measures used in this analysis are "additively decomposable"[28,29] and can therefore quantify the relative contribution of changes in smoking/obesity rates and changes in population shares to the overall change in inequality.

In order to assess the relative contributions of changes in health and changes in population distribution to the change in total inequality, the following decompositions for the MLD and BGV were used:[30-33]

$$\Delta MLD \cong \sum_j (\overline{r_j} - \overline{\ln r_j})\Delta p_j + \sum_j (\overline{p_j r_j} - \overline{p_j})\Delta \ln y_j \qquad [3]$$

$$\Delta BGV = \sum_j \overline{(y_j - \mu)^2}\Delta p_j + \sum_j \overline{p_j}\Delta(y_j - \mu)^2 \qquad [4]$$

where p_j, r_j, y_j, and μ are defined as before, and the overbar and Δ indicate, respectively, the average and the change between two time points. Using these formulae the total change in between-group inequality can be decomposed into two unique parts. The first term on the right-hand side of equations [3] and [4] measures the effect of changing population shares and the second term measures the effects of changes in smoking/obesity rates on between-group inequality. Thus, the relative contribution of rate changes to inequality change can be calculated by dividing second term in the decompositions by the sum of both terms.

Unfortunately, while the above decompositions can partition the overall inequality change into "rate effects" and "population effects," it does not reveal which social groups have contributed most to the change in inequality and this may be important information in thinking about interventions to reduce inequality. However, one way of assessing the contribution of specific social groups is to compare the observed change in inequality with a counterfactual case in which the rate of health change or population change for a specific social group (e.g., black females ages 25-44 with 12 years of education) is set to the total population rate rather than their observed rate.[27,33,34] Inequality is then recalculated for the last period (e.g., the year 2000), and

the value of the inequality measure obtained in this counterfactual case may then be compared with the observed change. Larger differences between the actual and counterfactual values indicate more influence on the change in inequality.

Results

Trends in Inequality

The observed and regression-smoothed trends in the prevalence of smoking for education groups, by race and gender, are displayed in Figure 1. Among both non-white and white males in 1965 the lowest rates of current smoking were among those with 16 or more years of education, with rates generally higher for non-whites compared to whites. It is also apparent that, while rates of smoking have declined impressively among all education groups, the rate of decline has been slower among the less educated groups since the mid-1970s. For females the pattern is different in 1965, as those with <12 years of education had the lowest rates of current smoking, but, similar to the pattern for males, declines in current smoking have been stronger for more educated groups, particularly those with at least a college degree.

Figure 2 shows trends in the prevalence of obesity for three education groups (<12 years, 12 years, >12 years), by race and gender. Across all four graphs it is clear that the rise in obesity occurs after 1978, and occurs among all education and race-gender groups. The rise appears steeper for white compared to non-white men, and there is actually a reversal of educational differences in obesity among non-white females, with the lowest obesity rates among in 2000 among those with <12 years of education.

Figure 1. Observed and smoothed prevalence of current smoking among education groups, by sex and race, NHIS 1965-2003.

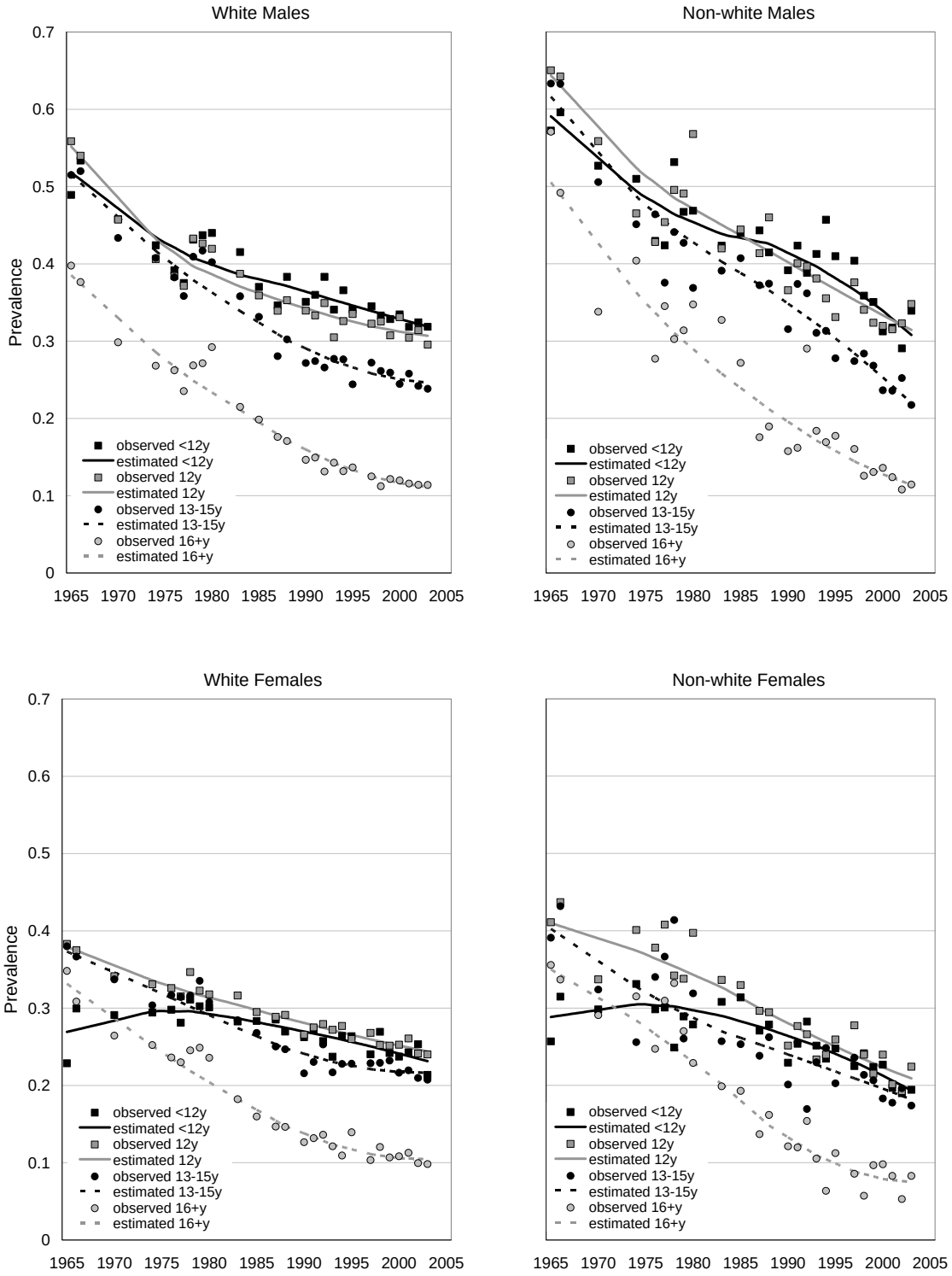

Figure 2. Prevalence of obesity among education groups, by sex and race, NHANES 1959-62 to 1999-2002.

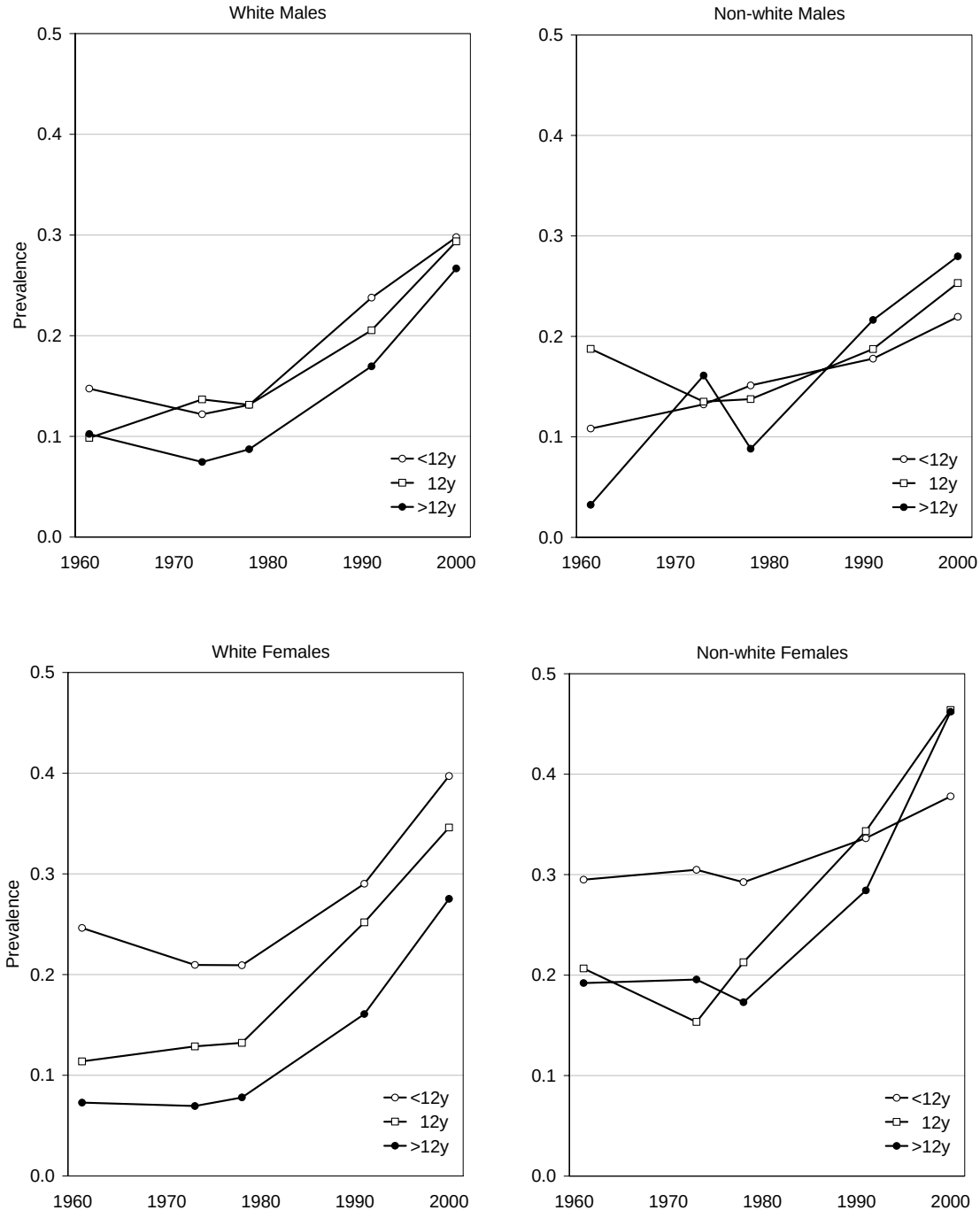

Figure 3. Trends in relative (MLD) and absolute (BGV) inequality in the prevalence of current smoking and obesity among age, gender, race, and education groups, 1960-2003.

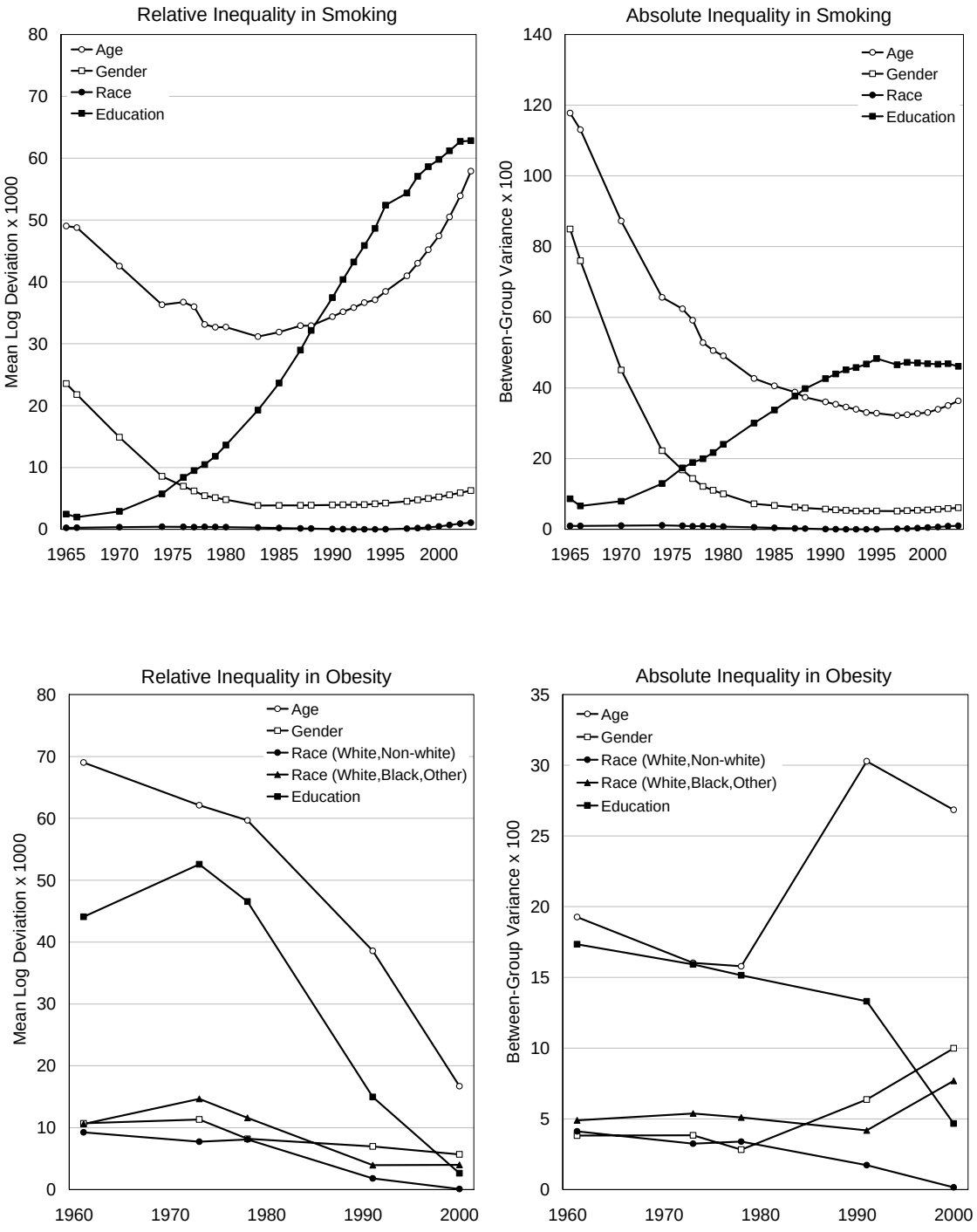

Figure 3 shows trends in relative (MLD) and absolute (BGV) inequality for current smoking (upper panel) and obesity (lower panel), for age, gender, race, and education groups analyzed separately. Relative inequality in smoking has increased dramatically among education groups since 1965, while gender inequality has substantially declined. Absolute inequality in smoking has declined among all social groups except education, which increased from 1965 to 1995 and has remained constant since. Relative inequality in obesity was largest between age and education groups in 1961, both of which declined substantially from 1978-2000. Absolute inequality in obesity also declined for education groups, but has increased for age and gender since 1978. It is also worth noting that, while relative inequality among race groups has declined, the trend in absolute inequality is increasing since 1991 if race is categorized as white/black/other but decreasing if categorized as white/non-white. This indicates that the use of the grouping "non-whites" masks heterogeneity within this group. It is also worth noting that in 1965 there was far less absolute inequality in obesity than for smoking (note the difference in the scales), which reflects the fact that rates of smoking were so high in the 1960s. The use of relative inequality measures alone would not capture this difference. There was little change in obesity rates from 1961-1978, and therefore little change in inequality. Therefore, the subsequent analysis of inequality change was limited to the period 1978-2000 (results from 1961-2000 were similar since the obesity rates of social groups remained relatively constant from 1961-1978).

Table 1 shows the results for changes in inequalities in current smoking for age, gender, race, and education groups, and for all possible social group cross-classifications. Of necessity, the amount of inequality increases with increasing social group stratification, such that in 1965 there

is more relative inequality between the six age-gender groups (85.8) than between either age (49.0) or gender (23.5) groups alone. In 1965 most of the relative inequality in smoking was between age groups and gender groups, but over the past 40 years gender inequality has declined by 73.4% while age inequality increased by 18.1% and educational inequality has increased by almost 2500%. The pattern in 1965 was similar for absolute inequality (BGV), but both age and gender inequality declined, while absolute inequality by education actually increased by 434.5%. For the most detailed social group cross-classification ("Age, Gender, Race, Education," last row) relative inequality in current smoking has increased by 50.5% and absolute inequality has declined by 49.6%.

Table 2 shows the results for changes in inequalities in obesity from 1978-2000, and the picture is different than for smoking. The largest inequalities at the beginning of the period were between age groups and education groups, but relative inequalities in obesity have declined for all social groups, regardless of how they are cross-classified. However, the rise in obesity has led to increased inequality for most social groups when measured on an absolute scale. The increase is particularly large for inequality among age groups, where the BGV increased 70% from 15.8 to 26.8, though in terms of relative change the increase in gender inequality was larger. The only exceptions to rising absolute inequality were for education groups, which exhibited declines in both relative and absolute inequality from 1978-2000, and for race groups when categorized as white/non-white. Separating out black and other within the non-white group leads to a small increase in absolute inequality, from 5.1 in 1978 to 7.7 in 2000.

Decomposition of Inequality Change

Table 1 also shows that both changes in the rates of smoking and changes in population distribution have contributed to inequality changes, but their relative contribution differs by social group category. For example, relative inequality in smoking among age groups has increased by 18.1%, and the decomposition shows that only 26% of this increase is due to changing rates of smoking, while 74% is due to changes in the distribution of age groups over time. Differential declines in smoking rates played a stronger role in the increase in educational inequality in smoking, accounting for 84% of the increase in inequality. In general, changes in smoking rates tended to make larger contributions to both relative and absolute inequality change, but the effects of population change are sizeable for some cross-classifications (40% of the relative change among age-race groups, 45% of the absolute change among age-race-education groups).

In some cases, the relative contribution of rate change and population change are >100% or less than 0%. This indicates situations where changes in smoking rates and population changes exerted opposing effects on inequality. For example, the net change in the MLD among age-gender groups was -22.9 (a decline of 26.7%), and the decomposition indicates that 139.5% of this change was due to changes in rates of smoking, while -39.5% was due to population changes. Because the net effect is a decline, this means that if the population shifts across age-gender groups had not occurred, changes in smoking rates alone would have decreased relative inequality by even more than they did (i.e., a decline of greater than 22.9). Similarly, if there were no changes in rates of smoking, changes in population structure alone would have widened relative inequality.

Table 2 presents the same decomposition for changes in obesity inequalities. Similar to smoking, the contribution of obesity changes is relatively larger than population changes. For many of the three-way and the four-way social group cross-classifications, population changes made important contributions to the decline in relative inequality and tended to mitigate the absolute inequality-producing effects of changes in obesity rates. For example, for the most detailed cross-classification ("Age, Gender, Race, Education," last row), changes in population structure from 1978-2000 accounted for roughly 15% of the 73.4% decline in the MLD, and the BGV would have increased by even greater than 56.8% were it not for the inequality-reducing effects of population change.

Influence of Particular Social Groups on Inequality Change

While the decompositions presented in Table 1 and

Table 2 give the overall effects of health changes and population changes on inequality, they cannot identify which groups were most important to inequality change. The results of the counterfactual analyses for age, gender, race, and education groups are presented in Table 3. The influence of a particular group is measured by comparing the change in inequality under counterfactual conditions to the observed change in inequality. For example, for relative inequality change in smoking among age groups Table 3 shows that the two most influential effects on the change in the MLD were faster-than-average population growth among those 65 and over and slower-than-average smoking declines among those 18-24. Had the 65 and over population grown at an annual rate of 1.6% from 1965-2003 (the total population rate) instead of their actual rate of 2.0%, relative inequality would only have increased by 6.2% instead of the actual increase of 18.1%. Similarly, if rates of smoking had declined among 18-24 year-olds at the population annual rate of 1.7% instead of their actual rate of 1.3%, the MLD would only have increased 10.4% instead of the observed 18.1%. Recall that the major change for smoking was the large increase in educational inequality. The counterfactual results for education clearly show that changes among college-educated individuals account for the bulk of this change. Were it not for higher annual rates of decline in smoking (-3.2% vs. -1.7% for the total population) and faster-than-average population growth (3.7% vs. 1.6%), educational inequality in smoking would still have increased, but by far less than it did. However, the rapid population growth (4.9%) of those with 13-15 years of education, a group whose smoking rates are in the middle of the distribution, kept inequality from rising even more than it did.

The faster-than-average rate of obesity growth among those 18-24 (5.4% vs. 3.7% for the total population) and slower-than average rate among those 45-64 (3.2% vs. 3.7%) were most influential for declines in relative obesity inequality. Slower-than-average obesity growth among

non-whites kept relative inequality among race groups from increasing. A separate analysis for white/black/other showed that the slower growth in obesity was primarily due to the slower growth among blacks rather than "other race" individuals. Interestingly, the high rate of obesity growth among those with >12 years of education was most influential in the decline in the MLD (-30.4% counterfactual change vs. -91.4% observed) and the BGV (169.4% vs. -69.2% observed).

Table 1. Change in relative (MLD) and absolute (BGV) between-group inequality in the prevalence of smoking, and the contribution of changing smoking rates and changing population size to inequality change between 1965 and 2003 NHIS, by age, sex, race and education.

	Relative Inequality (MLD x 1000)				%Contribution to MLD change of changes in:		Absolute Inequality (BGV x 100)				%Contribution to BGV change of changes in:	
Subgroup	1965	2003	Δ65-03	%Δ	Smoking Rates	Population Change	1965	2003	Δ65-03	%Δ	Smoking Rates	Population Change
Age (18-24,25-44,45-64,65-74)	49.0	57.9	8.9	18.1	25.9	74.2	117.8	36.3	-81.4	-69.1	110.6	-10.6
Gender (Male, Female)	23.5	6.3	-17.3	-73.4	100.0	0.0	84.9	6.1	-78.9	-92.8	100.0	0.0
Race (White, Non-white)	0.2	1.1	0.8	331.1	78.6	21.4	0.9	1.0	0.0	4.9	-986.0	1096.0
Education (<12y,12y,13-15y,16+y)	2.4	62.8	60.4	2467.0	84.3	15.7	8.6	46.1	37.5	434.5	86.8	13.2
Age, Gender	85.8	62.8	-22.9	-26.7	139.5	-39.5	198.4	42.1	-156.3	-78.8	106.9	-6.9
Age, Race	49.3	63.5	14.2	28.8	60.1	39.9	118.9	42.5	-76.4	-64.2	112.5	-12.5
Age, Education*	57.7	139.5	81.7	141.6	95.6	4.4	141.2	104.2	-37.0	-26.2	66.6	33.4
Gender, Race	24.0	7.9	-16.1	-67.0	109.9	-9.9	87.6	7.2	-80.4	-91.8	105.8	-5.8
Gender, Education	28.2	69.4	41.2	146.3	85.2	14.8	101.0	55.2	-45.8	-45.3	83.3	16.7
Race, Education	2.8	64.8	62.0	2247.5	84.9	15.1	9.8	48.3	38.5	392.3	89.0	11.0
Age, Gender, Race	86.8	69.4	-17.4	-20.0	165.6	-65.6	201.6	48.3	-153.3	-76.0	110.6	-10.6
Age, Gender, Education*	99.6	144.4	44.8	44.9	100.8	-0.8	231.1	110.0	-121.1	-52.4	79.5	20.5
Age, Race, Education*	58.1	144.7	86.6	149.1	96.8	3.2	142.4	111.5	-30.9	-21.7	55.1	44.9
Gender, Race, Education	28.7	72.0	43.4	151.4	84.1	15.9	103.6	57.4	-46.3	-44.7	87.6	12.4
Age, Gender, Race, Education*	100.6	151.3	50.7	50.5	98.4	1.6	233.6	117.8	-115.8	-49.6	80.3	19.7

*Ages18-24 excluded from analyses where age and education are cross-classified

Table 2. Change in relative (MLD) and absolute (BGV) between-group inequality in the prevalence of obesity and the contribution of changing obesity rates and changing population size to inequality change between 1976-80 and 1999-2002 NHANES, by age, sex, race* and education.

	Relative Inequality (MLD x 1000)				%Contribution to MLD change of changes in:		Absolute Inequality (BGV x 100)				%Contribution to BGV change of changes in:	
Subgroup	1978	2000	Δ78-00	%Δ	Obesity Rates	Population Change	1978	2000	Δ78-00	%Δ	Obesity Rates	Population Change
Age (18-24,25-44,45-64,65-74)	59.7	16.7	-43.0	-72.0	82.6	17.4	15.8	26.8	11.1	70.1	130.1	-30.1
Gender (Male, Female)	8.2	5.7	-2.5	-30.7	100.8	-0.8	2.8	10.0	7.2	253.6	100.0	0.0
Race (White, Non-white)	8.1	0.1	-8.0	-98.9	205.3	-105.3	3.4	0.2	-3.2	-95.3	161.7	-61.7
Race (White, Black, Other)	11.6	4.0	-7.6	-65.5	140.0	-40.0	5.1	7.7	2.6	50.6	30.1	69.9
Education (<12y,12y,>12y)	45.4	3.9	-41.5	-91.4	110.6	-10.6	15.1	7.5	-7.6	-50.5	94.2	5.8
Age, Gender	67.5	21.7	-45.8	-67.8	84.4	15.6	19.4	35.7	16.2	83.6	117.6	-17.6
Age, Race	70.7	18.1	-52.6	-74.4	89.1	10.9	20.1	28.9	8.8	43.9	119.9	-19.9
Age, Education	101.6	20.0	-81.6	-80.3	83.7	16.3	26.8	34.2	7.4	27.6	216.3	-116.3
Gender, Race	17.3	8.7	-8.6	-49.7	283.7	-183.7	7.9	15.5	7.6	97.0	1.8	98.2
Gender, Education	56.5	9.6	-46.9	-83.0	102.7	-2.7	21.4	18.3	-3.1	-14.6	-8.0	108.0
Race, Education	51.3	3.7	-47.7	-92.9	119.3	-19.3	17.5	6.6	-10.9	-62.4	114.8	-14.8
Age, Gender, Race	80.6	26.1	-54.5	-67.6	100.0	0.0	25.8	43.4	17.7	68.6	73.6	26.4
Age, Gender, Education	122.6	28.0	-94.6	-77.2	82.6	17.4	33.9	47.2	13.3	39.1	180.8	-80.8
Age, Race, Education	112.7	23.5	-89.2	-79.1	81.3	18.7	30.5	41.0	10.5	34.3	240.0	-140.0
Gender, Race, Education	64.4	13.2	-51.2	-79.5	122.6	-22.6	25.0	24.2	-0.8	-3.2	453.5	-353.5
Age, Gender, Race, Education	145.6	38.7	-106.8	-73.4	85.3	14.7	39.7	62.3	22.6	56.8	152.7	-52.7

*Due to small sample sizes, cross-classified analyses that include race are for whites/non-whites.

Table 4 and Table 5 present the counterfactual analyses for smoking and obesity, respectively, for the most detailed social group cross-classification (age-gender-race-education groups). Again, larger differences between the counterfactual change in inequality and the observed change indicate more influential groups. For relative inequality change in smoking, Table 4 shows that the largest effect on MLD change was the increase in smoking among white females 65 and over with >12 years of education (counterfactual %ΔMLD=66.5 vs. 49.0 observed). This was an inequality-reducing effect because in 1965 this group had one of the lowest rates of smoking (7.8%), so the fact that their smoking rate increased slightly (0.8% annually) while the rest of the population declined (-1.7% annually) narrowed relative inequality. Also influential, but inequality-promoting, were the faster-than-average smoking declines among white males with 16 or more years of education. For example, had the declines in smoking among the highest educated white males 65 and over been similar to the population average rate, relative inequality would only have increased by 39.6% rather than 49%. The effects of differential population growth tended to be smaller, but some specific changes were important. In fact, the fifth and sixth most influential changes were faster-than-average population growth among white women 25-44 and 45-64 with 13-15 years of education, which were inequality-reducing because their rates of smoking were very near the average rate.

Table 5 presents the counterfactual results for changes in obesity inequality. Had the annual growth rate of obesity among white females 18-24 years old with >12 years of education been 3.7% (the total population rate) rather than 10.5% (their actual growth rate), the change in MLD would have been -58.0% instead of the observed -73.4% and the BGV would have increased by 80.7% instead of 56.8%. This pattern was similar for white women 25-44 with >12 years of education. Thus, the decline in relative inequality would have been smaller and the increase in

absolute inequality would have been greater were it not for disproportionate obesity growth among young, relatively well-educated white women. This is due to the fact that in 1978 these two groups had obesity rates at the extreme low end of the distribution (1.5% and 6.2%, respectively). By way of contrast, white males 65-74 years old with 12 years of education also experienced disproportionately rapid annual growth in obesity (6.2% annually), but because in 1978 their obesity prevalence was 9.8%, near the popluation average of 13.2%, this rapid growth had little effect on the change in either relative inequality (-73.4 counterfactual vs. -73.4 observed) or absolute inequality (56.4 counterfactual vs. 56.8 observed). For the change in absolute inequality, non-white females 25-64 with <12 years of education were most influential. Had the rate of obesity growth among 25-44 and 45-64 year-old non-white females with <12 years of education (1.4% and 0.7%, respectively) been equal to the population rate (3.7%), absolute inequality would have increased by 104.1% and 172.9%, instead of the observed increase of 56.8%. Obesity changes among the least educated black women thus kept absolute inequality from increasing more than it actually did. Changes in population distribution from 1978 to 2000 were less important to inequality change, but in general relative inequality would have decreased more (and absolute inequality increased more) if not for population declines among young whites and increases among middle-aged well-educated whites.

Table 3. Subgroup-specific effects of rate change and population change on the percent change in relative (MLD) and absolute (BGV) between-group inequality in smoking and obesity for age, sex, race and education groups.

		Effect of Rate Changes			Effect of Population Changes		
		%Growth Rate	%ΔMLD	%ΔBGV	%Growth Rate	%ΔMLD	%ΔBGV
Current Smoking, 1965-2003							
Age	18-24	-1.3	10.4	-72.7	1.2	16.8	-69.3
	25-44	-1.8	23.5	-66.6	1.6	18.3	-69.1
	45-64	-1.7	18.1	-69.1	1.6	17.7	-69.2
	65+	-1.8	14.7	-69.7	2.0	6.2	-71.8
	Observed change	**-1.7**	**18.1**	**-69.1**	**1.6**	**18.1**	**-69.1**
Gender	Male	-2.0	-45.3	-83.7	1.7	-73.4	-92.8
	Female	-1.4	-39.8	-85.4	1.6	-73.4	-92.8
	Observed change	**-1.7**	**-73.4**	**-92.8**	**1.6**	**-73.4**	**-92.8**
Race	White	-1.7	172.8	-35.8	1.4	307.7	-0.7
	Non-white	-2.2	-30.4	-80.6	3.1	179.6	-31.6
	Observed change	**-1.7**	**331.1**	**4.9**	**1.6**	**331.1**	**4.9**
Education	<12 years	-1.0	2267.5	371.9	0.3	2293.7	408.6
	12 years	-1.3	2065.9	306.6	0.1	2157.6	392.5
	13-15 years	-1.7	2459.4	432.3	4.9	3137.6	573.5
	16+ years	-3.2	363.2	47.7	3.7	1433.9	247.1
	Observed change	**-1.7**	**2467.0**	**434.5**	**1.6**	**2467.0**	**434.5**
Obesity, 1978-2000							
Age	18-24	5.4	-35.0	204.6	-0.3	-67.6	91.0
	25-44	3.5	-73.7	59.1	1.5	-71.4	73.5
	45-64	3.2	-60.2	169.8	1.7	-71.8	70.1
	65-74	3.3	-69.3	92.8	1.0	-72.0	70.1
	Observed change	**3.7**	**-72.0**	**70.1**	**1.2**	**-72.0**	**70.1**
Gender	Male	3.8	-11.4	340.5	1.3	-30.8	253.6
	Female	3.6	-20.3	313.3	1.1	-30.8	253.6
	Observed change	**3.7**	**-30.7**	**253.6**	**1.2**	**-30.7**	**253.6**
Race	White	3.9	-92.7	-70.5	0.2	-99.0	-95.7
	Non-white	2.4	38.3	669.3	5.1	-99.3	-97.1
	Observed change	**3.7**	**-98.9**	**-95.3**	**1.2**	**-98.9**	**-95.3**
	White	3.9	-61.2	67.1	0.2	-70.5	28.8
	Black	2.8	-2.0	408.5	1.6	-67.0	43.3
	Other	4.2	-38.0	142.3	10.5	-71.5	31.9
	Observed change	**3.7**	**-65.5**	**50.6**	**1.2**	**-65.5**	**50.6**
Education	<12 years	2.6	-74.3	71.3	-0.4	-94.4	-69.3
	12 years	3.8	-95.7	-77.1	-0.0	-94.3	-69.0
	>12 years	5.3	-30.4	169.4	3.0	-94.5	-69.7
	Observed change	**3.7**	**-94.3**	**-69.2**	**1.2**	**-94.3**	**-69.2**

Table 4. Subgroup-specific effects of differential growth in smoking rates and population change on the percent change in relative (MLD) and absolute (BGV) inequality between age-gender-race-education groups, NHIS 1965-2003.

				Smoking Effect			Population Effect		
Age	Gender	Race	Education	%Growth Rate	%ΔMLD	%ΔBGV	%Growth Rate	%ΔMLD	%ΔBGV
25-44y	Male	White	<12y	-1.3	46.3	-52.5	1.4	50.9	-48.4
			12y	-1.2	43.1	-54.3	-0.1	52.8	-45.6
			13-15y	-1.7	50.2	-49.7	4.2	53.5	-47.7
			16+y	-3.1	43.6	-51.5	2.5	50.8	-48.4
		Non-white	<12y	-2.1	50.7	-49.4	-0.1	50.3	-48.0
			12y	-2.1	51.2	-49.1	1.9	50.5	-48.7
			13-15y	-2.8	51.9	-48.8	7.7	52.1	-48.2
			16+y	-3.7	49.7	-49.7	6.9	50.8	-48.7
	Female	White	<12y	-0.9	48.3	-50.7	1.1	50.1	-48.7
			12y	-0.4	41.7	-54.6	-1.3	51.1	-45.2
			13-15y	-1.2	48.7	-50.4	4.8	55.4	-46.9
			16+y	-3.2	40.9	-52.1	4.1	49.6	-48.6
		Non-white	<12y	-1.7	50.4	-49.6	0.8	50.2	-48.6
			12y	-1.8	50.5	-49.6	0.8	49.8	-48.9
			13-15y	-2.7	50.2	-49.7	7.5	52.2	-48.2
			16+y	-4.9	44.0	-50.9	7.3	46.5	-48.8
45-64y	Male	White	<12y	-1.1	47.8	-51.2	-1.3	51.2	-47.0
			12y	-1.4	48.0	-50.9	0.2	48.2	-49.1
			13-15y	-1.9	50.7	-49.5	5.1	54.9	-47.0
			16+y	-3.0	43.8	-51.4	4.0	50.6	-48.4
		Non-white	<12y	-1.1	49.8	-50.0	-0.2	50.7	-48.1
			12y	-1.0	49.3	-50.3	3.3	50.3	-48.8
			13-15y	-2.4	50.8	-49.4	8.1	51.3	-48.4
			16+y	-4.2	49.0	-49.9	8.8	49.9	-48.6
	Female	White	<12y	0.1	50.6	-49.8	-1.2	46.8	-49.6
			12y	-1.0	50.2	-49.7	0.1	44.7	-50.5
			13-15y	-1.6	50.6	-49.5	5.3	56.2	-46.6
			16+y	-3.1	42.6	-51.4	4.3	48.6	-48.9
		Non-white	<12y	-0.2	51.2	-49.4	0.1	49.7	-48.9
			12y	-0.9	50.8	-49.5	3.1	51.0	-48.5
			13-15y	-0.8	50.8	-49.5	9.1	51.5	-48.4
			16+y	-2.3	50.0	-49.7	7.4	50.0	-48.6
65+y	Male	White	<12y	-2.4	48.9	-49.9	-0.7	50.9	-48.7
			12y	-2.7	47.1	-50.3	2.4	50.1	-48.7
			13-15y	-3.0	47.4	-50.2	6.2	49.0	-48.8
			16+y	-4.6	39.6	-51.1	4.9	43.2	-49.6
		Non-white	<12y	-1.8	50.4	-49.6	1.7	50.5	-48.7
			12y	-2.8	50.4	-49.6	4.2	50.5	-48.6
			13-15y	-1.3	50.6	-49.6	9.1	50.5	-48.6
			16+y	-3.2	49.9	-49.6	8.8	49.7	-48.6
	Female	White	<12y	0.8	66.5	-47.7	-0.1	51.6	-48.6
			12y	-1.2	55.4	-48.9	2.4	48.7	-48.9
			13-15y	-1.3	52.7	-49.3	5.7	46.9	-49.2
			16+y	-1.7	50.6	-49.6	4.0	48.0	-49.0
		Non-white	<12y	0.7	54.6	-49.1	2.4	50.3	-48.6
			12y	-0.6	51.3	-49.5	3.9	50.1	-48.7
			13-15y	1.0	52.2	-49.4	8.5	50.1	-48.7
			16+y	-1.6	50.5	-49.6	6.0	49.9	-48.7
		Observed change		**-1.7**	**49.0**	**-48.6**	**1.6**	**49.0**	**-48.6**

Table 5. Subgroup specific effects of differential growth in obesity rates and population change on relative (MLD) and absolute (BGV) inequality between age-gender-race-education groups, NHANES I (1976-80) to NHANES 1999-2002.

				Obesity Effect			Population Effect		
Age	Gender	Race	Education	%Growth Rate	%ΔMLD	%ΔBGV	%Growth Rate	%ΔMLD	%ΔBGV
18-24y	Male	White	<12y	6.9	-71.6	63.3	-1.4	-73.5	56.0
			12y	2.4	-74.6	52.8	-2.2	-71.2	64.5
			>12y	5.9	-70.2	67.4	-1.7	-72.9	58.6
		Non-white	<12y	0.9	-75.9	48.6	6.0	-75.2	50.9
			12y	6.5	-71.4	62.2	4.3	-73.6	55.8
			>12y	4.7	-73.0	58.5	3.7	-73.4	57.0
	Female	White	<12y	1.8	-73.8	54.8	-1.0	-73.3	57.4
			12y	6.5	-71.8	63.4	-2.7	-73.8	54.6
			>12y	10.5	-58.0	80.7	-1.9	-71.3	64.5
		Non-white	<12y	3.9	-73.4	56.8	4.4	-73.3	57.5
			12y	3.6	-73.4	56.8	1.5	-73.4	56.9
			>12y	5.2	-72.7	60.2	4.2	-73.3	57.4
25-44y	Male	White	<12y	0.2	-75.1	49.6	-1.5	-72.3	61.2
			12y	3.4	-73.4	56.6	0.3	-73.6	55.4
			>12y	5.3	-66.9	85.1	1.4	-73.3	57.2
		Non-white	<12y	1.9	-72.7	62.5	6.5	-73.0	59.4
			12y	2.7	-73.0	59.7	4.5	-73.2	58.0
			>12y	5.3	-70.3	67.9	6.0	-73.8	55.1
	Female	White	<12y	2.8	-72.7	63.3	-3.4	-73.5	56.9
			12y	3.1	-73.5	56.4	-2.1	-74.3	51.7
			>12y	5.9	-64.8	93.0	2.6	-72.9	59.5
		Non-white	<12y	1.4	-69.1	104.1	4.7	-73.3	57.1
			12y	1.7	-71.1	80.4	3.2	-73.3	57.2
			>12y	3.2	-72.8	62.2	6.9	-73.1	58.1
45-64y	Male	White	<12y	5.4	-74.4	48.2	-4.1	-72.3	68.7
			12y	3.2	-72.8	61.3	-0.1	-73.6	56.0
			>12y	3.8	-73.4	56.8	4.1	-72.4	63.0
		Non-white	<12y	0.9	-73.6	56.8	3.1	-73.5	56.6
			12y	0.4	-71.4	78.7	6.3	-73.3	57.6
			>12y	6.8	-71.0	66.4	8.4	-73.1	58.8
	Female	White	<12y	3.4	-72.8	63.0	-3.8	-71.1	81.4
			12y	4.5	-74.4	48.3	-1.3	-73.2	59.8
			>12y	3.4	-73.1	59.2	5.5	-72.1	64.1
		Non-white	<12y	0.7	-64.9	172.9	4.2	-73.5	55.3
			12y	3.2	-73.0	61.1	4.9	-73.6	54.3
			>12y	3.6	-73.3	57.8	10.2	-73.7	53.8
65-74y	Male	White	<12y	3.8	-73.4	56.6	-3.2	-73.7	55.4
			12y	6.2	-73.4	56.4	1.7	-73.4	56.8
			>12y	3.8	-73.4	56.9	4.7	-73.1	58.4
		Non-white	<12y	3.7	-73.4	56.8	1.6	-73.4	56.9
			12y	0.0	-73.6	56.2	6.8	-73.5	56.5
			>12y	2.8	-73.4	56.7	9.2	-73.4	56.9
	Female	White	<12y	3.2	-73.0	60.5	-3.4	-73.1	60.1
			12y	4.5	-74.1	50.9	1.6	-73.4	56.4
			>12y	3.4	-73.3	57.3	3.4	-73.2	57.9
		Non-white	<12y	0.6	-70.6	95.0	2.4	-73.4	56.6
			12y	5.0	-73.5	55.4	6.1	-73.5	56.0
			>12y	4.4	-73.5	56.3	10.0	-73.4	56.6
		Observed change		**3.7**	**-73.4**	**56.8**	**1.2**	**-73.4**	**56.8**

Discussion

This analysis has shown that the social patterning of smoking and obesity has changed considerably over the past 40 years with respect to age, gender, race, and education, but the pattern of change over time differs for the two outcomes. In 1965 smoking was primarily stratified by age and gender, but as smoking rates halved over the next 40 years, gender differences declined sharply (as males quit smoking), age differences declined (as all adults quit) then rose again (as rates among the young increased and the population aged), and both relative and absolute inequality between educational groups increased dramatically (as rates fell very rapidly among the better educated). In contrast, obesity rates in the early 1960s were primarily patterned by age and education, and remained so until the late 1970s, after which the rapid rise in obesity in all social groups led to declining relative inequalities, particularly for education. However, the rise in obesity among all social groups actually increased age, gender, and racial inequalities when measured on the absolute scale.

In terms of comparing the level of inequality across social group categories, inequality between race groups tended to be rather small relative to inequality by age, gender, and education—especially for smoking. However, this analysis was limited to the use of only black and white race categories due to small sample sizes in early surveys and inconsistent race/ethnic categories across surveys. More recent surveys allow for comparing the results to inequality measured across expanded race-ethnic groups. By way of example, for current smoking using the 2003 NHIS, the use of four groups (Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Other, Hispanic) yields an MLD of 6.8 and a BGV of 5.5 (compared to 0.1 and 0.1 for only black/white); separating out Asian and Hispanic subgroups for a total of 14 race-ethnic groups yields respective values of 16.2 and 11.0. These values are still far smaller than the

observed 2003 MLD and BGV of 61.6 and 38.3 for only four education groups, and the use of 12 education groups generates values of 74.8 and 55.0. There is thus clearly more educational than racial inequality in smoking, and this does not appear to be an artifact of the crude categorization of race used in this analysis. Thus more can potentially be learned about social inequality in smoking from understanding educational rather than race/ethnic differences. Or in other words, race/ethnic differences are not as important a form of social stratification for smoking as are educational differences. For obesity, using five race-ethnic groups in the 1999-2002 HANES generates an MLD of 8.4 and a BGV of 12.6, compared with 3.1 and 6.5 for two groups. So even using expanded race-ethnic categories in 2000 there was more relative inequality in obesity between blacks and whites in 1980 than there is today across five race-ethnic groups, but the decline in relative inequality in obesity may be overestimated and the increase in absolute inequality underestimated in this analysis. On the whole, while the crude categorization of race as black/white certainly underestimates the amount of inequality, using expanded race-ethnic categories would not appear to alter the basic findings of this analysis.

Over the entire time span studied here the better educated generally smoked less and were less obese, but the magnitude of this health advantage changed over time, increasing for smoking and decreasing for obesity. What explains the different patterns of inequality change for smoking and obesity? The observed changes are difficult to reconcile with the notion that there is a necessary or fundamental relationship between socioeconomic position and health, which argues that more advantaged social groups invariably use their material, social, and intellectual resources to maximize their health advantage.[35,36] If it is the resources of the better educated that allowed them to be more successful at quitting or not initiating smoking, the same set of resources would also appear, over time, to have put them increasingly at risk for obesity. This is

not to suggest that material and social resources are unimportant determinants of health-damaging or health-enhancing exposures; they clearly matter, especially for health behaviors.[37] But perhaps a better explanation for the observed changes is that the extent to which differences in socioeconomic resources are expressed as behavioral or health differences depends upon the extent to which they are linked to the factors that lead one to smoke or become obese. The relationship between socioeconomic resources and health is historically contingent and one that may not invariably reproduce a pattern of better health among the more advantaged and worse health among the disadvantaged. Framing the issue of health inequality change in this fashion emphasizes the importance of understanding both the distribution of resources and the mechanisms that link social position to health, rather than putting the mechanisms in the background.[36]

More rapid declines in smoking among the better educated have been documented in previous U.S. studies,[6,38] and have been observed across a number of different countries.[39,40] The contribution of this analysis is the finding that changes in the population distribution (e.g., secular improvements in educational attainment) made a nontrivial contribution to inequality change from 1965-2003. Changes in age distribution accounted for roughly 75% of the increase in smoking inequality among age groups, and the upward shift of the distribution of education accounted for 16% of the increase in both relative and absolute educational inequality. This suggests that evaluating inequality change by looking only at changes in smoking prevalence would lead one to underestimate the magnitude of inequality change in smoking. Moreover, the two most influential changes on educational inequality in smoking were the rapid decline in smoking and the substantial population growth among those with 16 or more years of education. Rather than mitigating the population health effects of differential declines in smoking by

shifting more individuals into lower risk education groups, it appears that one consequence of rising education, *from the perspective of inequality*, has been to further concentrate smoking among the more disadvantaged. From the perspective of *overall health*, however, this may still be viewed as beneficial as more individuals are now in lower-risk groups. These two differing perspectives reveal that there may be important trade-offs between improving average health and reducing health inequality.[41]

However, the question of why declines in smoking have been so much more rapid among higher educated groups is worth exploring further. Knowledge about the risks of smoking was likely higher among the more educated during the 1950s and 1960s, but by the early 1980s fully 90% of the US population thought smoking harmful,[42] so the differential declines since then are not likely attributable to differences in risk knowledge (nor are the time lags in smoking between men and women).[43] In addition, there do not appear to be differences among socioeconomic groups in the desire to quit smoking,[44,45] but important differences in the completion and maintenance of cessation.[45] This may point to differences across socioeconomic groups in social norms, occupational environments, and the social symbolism of smoking behavior.[46] This is reflected in the enormous heterogeneity in smoking across U.S. occupations, ranging from around 5% for physicians and clergy to nearly 60% for roofers, drywall installers, and bartenders.[47] Some of this diversity is the result of education, but the social norms and residential and occupational environments surrounding smoking are likely to play an important role as well. Changes in the social gradient in smoking may thus be more related to the timing and diffusion of smoking behavior across the population than to differences in education, per se. Pampel, for example, showed that relative educational gradients in smoking across European countries were larger among countries in which the smoking epidemic had diffused through the

population earlier.[48] A similar pattern has also been observed across birth cohorts in the United States.[49] Understanding the diverse processes that serve to concentrate smoking among the least advantaged over time is worth additional exploration.

For obesity, the influence of population change on inequality was much smaller than for smoking, which is likely to be a function both of the shorter period of analysis and the fact that changes in obesity rates have been so dramatic for all social groups. What might account for the more rapid increases among the higher educated? It would not appear to be an artifact of the data used here. Another study using NHANES data also showed declines in educational inequality in obesity,[50] and the analysis of state trends in Chapter 3 showed the same pattern. Nor would it appear an artifact of using limited education categories. Using expanded education categories for NHANES II and NHANES III showed that annual growth rates in obesity from 1978 to 1991 were 2.6%, 4.4%, 6.1%, and 5.5% among those with <12, 12, 13-15, and 16 or more years of education, respectively (data not shown). One might also argue that rates increased faster among the better educated because rates were already very high among the lower educated and could not reasonably increase to the same extent. But this pattern was most pronounced among the young, where overall obesity rates are lower, and declining socioeconomic inequalities (with variations by age and gender) have also been observed in a number of countries with obesity rates far lower than the U.S., such as Spain,[51] Switzerland,[52] Sweden,[53] Canada,[54] and the Netherlands.[55]

Importantly, more rapid obesity growth among the better educated occurred despite their advantages in reported dietary quality[56] and leisure-time physical activity,[57] both of which have improved since the 1960s and are not likely to explain the rise in obesity, which is primarily due to increased caloric intake. Cutler et al. found that the bulk of added calories in the U.S. diet

since 1978 have come from consuming more meals rather than increased intake per meal, primarily in the form of increased snacking,[58] which is consistent with the increase in the proportion of energy in the U.S. diet derived from carbohydrates.[59] There is some evidence that frequency of snacking is actually higher among the better educated[59,60] and their children.[61] There have also been secular increases in the consumption of commerically-prepared food and the per-capita number of restaurants, and higher status individuals are more likely to consume meals away from home.[62] Ironically, it also seems plausible that perhaps some of the disproportionate growth rate in obesity among the better educated since 1978 may be an unintended consequence of more effective smoking cessation among this group during the late 1960s and 1970s.[38] Flegal et al.[63] found that over 10 years smoking cessation explained 20-25% of the increase in overweight among U.S. men and women, and the rise in cigarette prices has been associated with increased obesity.[64] While the weight gain that tends to follow smoking cessation does not account for a substantial portion of the population-wide increase in obesity, it may nevertheless contribute to education differences in the rate of obesity growth.

A number of authors have suggested an important role for changes in technology as a major contributor to changes in obesity, both in terms of long-term shifts toward more sedentary occupations[65,66] and, more recently, of declining food prices, rising food supply, and declines in the time cost of food preparation[58,67] If changes in technology are driving the rise in obesity, it is not clear that they would necessarily favor more advantaged social groups. Innovative technology is often adopted first by higher status groups,[68] and the combination of shifts toward more sedentary occupations and increased labor force participation of women may increase the demand for time- and labor-saving food preparation technology among the better educated. In fact, the more rapid growth in obesity among the better educated could be seen as supportive of

the idea that changes in technology are an important cause of the U.S. rise in obesity, as they were likely to have the most to gain from technological innovation. Understanding the reasons for faster obesity growth among the better-educated (particularly for younger white women) is certainly of interest, especially given the dominant focus on obesity among lower socioeconomic groups. However, whatever explains this differential growth may be of little value in helping to understand the rapid rise in obesity in the U.S. population. The fact that obesity has increased so precipitously among virtually all age, gender, race, and education groups indicates that looking at social group differences may not reveal the common factors underlying weight change in the population.

While the primary aim of this analysis was to understand secular changes in social inequalities in smoking and obesity, a secondary aim was to evaluate alternative methods for measuring health inequalities that may be useful for monitoring trends and generating hypotheses about the causes of health inequalities. As was pointed out in the methods section, health inequality may change because of changes in health and changes in population. This analysis found that, depending on the outcome and the social group category, population changes had a measurable effect on health inequality change. This methodology could thus be applied using other health outcomes or other social group categories that are likely to change over time such as occupation, marital status, or geography. For example, using similar methods Goesling and Firebaugh[33] found that between-country inequality in life expectancy increased from 1990 to 2000, and found that changes in life expectancy (primarily declines in Sub-Saharan Africa and increases in South Asia) accounted for 75% of the rise in inequality, but changes in population distribution (primarily rapid growth in Sub-Saharan Africa) accounted for 25%. This method of accounting for changes in health inequality may be useful because it can both quantify the

relative contribution of health versus population shifts to inequality change, and can identify the social groups most influential to inequality change.

References

1. U.S. Department of Health and Human Services. *Healthy People 2010: Understanding and Improving Health.* Washington, DC: U.S. Government Printing Office; 2000.

2. Keppel KG, Pearcy JN, Klein RJ. *Measuring Progress in Healthy People 2010.* Hyattsville, MD: National Center for Health Statistics; 2004. Healthy People 2000 Statistical Notes, no. 25.

3. Kaplan GA. What's wrong with social epidemiology, and how can we make it better? *Epidemiol Rev.* 2004;26:124-135.

4. Hayward MD, Crimmins EM, Zhang Z. Consequences of educational change for the burden of chronic health problems in the population. In: Gauthier AH, Chu C, Tuljapurkar S, eds. *The Distribution of Private and Public Resources Across Generations*. New York: Oxford; forthcoming.

5. Feldman JJ, Makuc DM, Kleinman JC, Cornoni-Huntley J. National trends in educational differentials in mortality. *Am J Epidemiol.* 1989;129:919-933.

6. Pierce JP, Fiore MC, Novotny TE, Hatziandreu EJ, Davis RM. Trends in cigarette smoking in the United States. Educational differences are increasing. *JAMA.* 1989;261:56-60.

7. Steenland K, Henley J, Thun M. All-cause and cause-specific death rates by educational status for two million people in two American Cancer Society cohorts, 1959-1996. *Am. J. Epidemiol.* 2002;156:11-21.

8. Pamuk ER. Social-class inequality in infant mortality in England and Wales from 1921 to 1980. *European Journal of Population.* 1988;4:1-21.

9. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986 [published erratum appears in N Engl J Med 1993 Oct 7;329(15):1139]. *N Engl J Med.* 1993;329:103-109.

10. Schalick LM, Hadden WC, Pamuk E, Navarro V, Pappas G. The widening gap in death rates among income groups in the United States from 1967 to 1986. *Int J Health Serv.* 2000;30:13-26.

11. Mare RD. Changes in educational attainment and school enrollment. In: Farley R, ed. *State of the Union : America in the 1990s*. New York : Russell Sage Foundation; 1995; Vol.1: Economic trends:155-213.

12. McGinnis JM, Foege WH. Mortality and morbidity attributable to use of addictive substances in the United States. *P Assoc Am Physician.* 1999;111:109-118.

13. Hummer RA, Nam CB, Rogers RG. Adult mortality differentials associated with cigarette smoking in the USA. *Popul Res Policy Rev.* 1998;17:285-304.

14. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA.* 2005;293:1861-1867.

15. Fiore MC, Novotny TE, Pierce JP, Hatziandreu EJ, Patel KM, Davis RM. Trends in cigarette smoking in the United States. The changing influence of gender and race. *JAMA.* 1989;261:49-55.

16. Sobal J, Stunkard AJ. Socioeconomic status and obesity: a review of the literature. *Psychol Bull.* 1989;105:260-75.

17. Ball K, Crawford D. Socioeconomic status and weight change in adults: a review. *Soc Sci Med.* 2005;60:1987-2010.

18. Cooper R, Cutler J, Desvigne-Nickens P, et al. Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States : findings of the national conference on cardiovascular disease prevention. *Circulation.* 2000;102:3137-3147.

19. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999-2000. *JAMA.* 2002;288:1723-1727.

20. Cleveland WS, Devlin SJ. Locally weighted regression: an approach to regression analysis by local fitting. *J Am Stat Assoc.* 1988;83:596-610.

21. Anderson CM, Burns DM. Pattern of adolescent initiation rates over time: National and California data. In: Burns DM. *Smoking and Tobacco Control Monograph 14: Changing Adolescent Smoking Prevalence*. Bethesda, MD: US Dept. of Health and Human Services, National Cancer Institute; 2001:157-70.

22. Burns DM, Major JM, Anderson CM, Vaughn JW. Changes in cross-sectional measures of cessation, numbers of cigarettes smoked per day, and time to first cigarette–California and national data. In: Burns DM. *Smoking and Tobacco Control Monograph 15: Those Who Continue to Smoke: Is Achieving Abstinence Harder and Do We Need to Change Our Interventions?* Bethesda, MD: US Dept. of Health and Human Services, National Cancer Institute; 2003:101-25 .

23. Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the Third National Health and Nutrition Examination Survey, 1988-1994. *J Am Diet Assoc*. 2001;101:28-34.

24. Villanueva, E. V. The validity of self-reported weight in US adults: a population based cross-sectional study. *Bmc Public Health* 2001; 1(1):[11] Available at http://www.biomedcentral.com/1471-2458/1/11.

25. Harper S, Lynch J. Measuring health inequalities. In: Oakes J, Kaufman J, eds. *Methods in Social Epidemiology*. New York: Wiley; forthcoming.

26. Mechanic D. Policy challenges in addressing racial disparities and improving population health. *Health Aff.* 2005;24:335-338.

27. Firebaugh G, Goesling B. Accounting for the recent decline in global income inequality. *Am J Sociol.* 2004;110:283-312.

28. Shorrocks AF. The class of additively decomposable inequality measures. *Econometrica.* 1980;48:613-626.

29. Sen AK, Foster JE. *On Economic Inequality*. Expanded ed. Oxford: Clarendon Press; 1997.

30. Mookherjee D, Shorrocks A. A decomposition analysis of the trend in UK income inequality. *Econ J.* 1982;92:886-902.

31. Kitagawa EM. Components of a difference between two rates. *J Am Stat Assoc.* 1955;50:1168-1194.

32. Jenkins SP. Accounting for inequality trends: decomposition analyses for the UK, 1971-86. *Economica.* 1995;62:29-63.

33. Goesling B, Firebaugh G. The trend in international health inequality. *Popul Dev Rev.* 2004;30:131-146.

34. Bourguignon F, Morrisson C. Inequality among world citizens: 1820-1992. *Am Econ Rev.* 2002;92:727-744.

35. Link BG, Phelan J. Social conditions as fundamental causes of disease. *Journal of Health & Social Behavior.* 1995;Supplement:S80-94.

36. Phelan JC, Link BG, Diez-Roux A, Kawachi I, Levin B. "Fundamental causes" of social inequalities in mortality: a test of the theory. *J Health Soc Behav.* 2004;45:265-85.

37. Lynch J, Kaplan G. Socioeconomic position. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York: Oxford University Press; 2000:13-35.

38. Gilpin EA, Pierce JP. Demographic differences in patterns in the incidence of smoking cessation; United States 1950-1990. *Ann Epidemiol.* 2002;12:141-150.

39. Cavelaars AE, Kunst AE, Geurts JJ, et al. Educational differences in smoking: international comparison. *BMJ.* 2000;320:1102-7.

40. Giskes K, Kunst AE, Benach J, et al. Trends in smoking behaviour between 1985 and 2000 in nine European countries by education. *J Epidemiol Commun H.* 2005;59:395-401.

41. Oliver A, Healey A, Le Grand J. Addressing health inequalities. *Lancet.* 2002;360:565-567.

42. Viscusi WK. *Smoking: Making the Risky Decision*. New York: Oxford University Press; 1992.

43. Ahmed PI, Gleeson GA. *Changes in Cigarette Smoking Habits Between 1955 and 1966.* Washington: US Department of Health, Education, and Welfare, National Center for Health Statistics; 1970. Vital and Health Statistics Series 10, no. 59.

44. Droomers M, Schrijvers CTM, Mackenbach JP. Why do lower educated people continue smoking? Explanations from the longitudinal GLOBE study. *Health Psychol.* 2002;21:263-272.

45. Warner KE, Burns DM. Hardening and the hard-core smoker: concepts, evidence, and

implications. *Nicotine Tob Res.* 2003;5:37-48.

46. Gusfield JR. The social symbolism of smoking and health. In: Rabin RL, Sugarman SD. *Smoking Policy : Law, Politics, and Culture.* New York : Oxford University Press; 1993:49-68.

47. Lee DJ, Leblanc W, Fleming LE, Gomez-Marin O, Pitman T. Trends in US smoking rates in occupational groups: The National Health Interview Survey 1987-1994. *J Occup Environ Med.* 2004;46:538-548.

48. Pampel FC. Inequality, diffusion, and the status gradient in smoking. *Soc Probl.* 2002;49:35-57.

49. Pampel FC. Diffusion, cohort change, and social patterns of smoking. *Soc Sci Res.* 2005;34:117-139.

50. Zhang Q, Wang YF. Trends in the association between obesity and socioeconomic status in US adults: 1971 to 2000. *Obes Res.* 2004;12:1622-1632.

51. Gutierrez-Fisac JL, Regidor E, Banegas JRB, Artalejo FR. The size of obesity differences associated with educational level in Spain, 1987 and 1995/97. *J Epidemiol Commun H.* 2002;56:457-460.

52. Galobardes B, Costanza MC, Bernstein MS, Delhumeau C, Morabia A. Trends in risk factors for lifestyle-related diseases by socioeconomic position in Geneva, Switzerland, 1993-2000: health inequalities persist. *American Journal of Public Health: Am J Public Health.* 2003;93:1302-1309.

53. Lissner L, Johansson SE, Qvist J, Rossner S, Wolk A. Social mapping of the obesity epidemic in Sweden. *Int J Obesity.* 2000;24:801-805.

54. Torrance GM, Hooper MD, Reeder BA. Trends in overweight and obesity among adults in Canada (1970-1992): evidence from national surveys using measured height and weight. *Int J Obesity.* 2002;26:797-804.

55. Visscher TLS, Kromhout D, Seidell JC. Long-term and recent time trends in the prevalence of obesity among Dutch men and women. *Int J Obesity.* 2002;26:1218-1224.

56. Popkin BM, Zizza C, Siega-Riz AM. Who is leading the change? U.S. dietary quality comparison between 1965 and 1996. *Am J Prev Med.* 2003;25:1-8.

57. Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Publ Health.* 2005;26:421-443.

58. Cutler DM, Glaeser EL, Shapiro JM. Why have Americans become more obese? *J Econ Perspect.* 2003;17:93-118.

59. Briefel RR, Johnson CL. Secular trends in dietary intake in the United States. *Annu Rev Nutr.* 2004;24:401-431.

60. Schoenborn CA, Danchik KM. *Health Practices Among Adults: United States, 1977*. Washington: US Department of Health and Human Services; 1980. Advance Data From Vital and Health Statistics, no. 64.

61. Jahns L, Siega-Riz AM, Popkin BM. The increasing prevalence of snacking among US children from 1977 to 1996. *J Pediatr.* 2001;138:493-498.

62. Kant AK, Graubard BI. Eating out in America, 1987-2000: trends and nutritional correlates. *Prev Med.* 2004;38:243-249.

63. Flegal K, Troiano R, Pamuk E, Kuczmarski R, Campbell S. The influence of smoking cessation on the prevalence of overweight in the United States. *New Engl J Med.* 1995;333:165-70.

64. Chou S-Y, Grossman M, Saffer H. An economic analysis of adult obesity: results from the behavioral risk factor surveillance system. *J Health Econ.* 2004;23:565-587.

65. Lakdawalla D, Philipson T. *The Growth of Obesity and Technological Change: A Theoretical and Empirical Examination*. Cambridge, MA: National Bureau of Economic Research; 2002. NBER Working Paper 8946. Available at: http://www.nber.org/papers/w8946.

66. Philipson TJ, Posner RA. The long-run growth in obesity as a function of technological change. *Perspect Biol Med.* 2003;46:S87-S107.

67. Finkelstein EA, Ruhm CJ, Kosa KM. Economic causes and consequences of obesity. *Annu*

Rev Publ Health. 2005;26:239-257.

68. Rogers EM. *Diffusion of Innovations*. 5th ed. New York: Free Press; 2003.