Abstract
Education is one of the primary measures of socioeconomic status. Compared to college graduates, Americans with a high school education or less live shorter lives and have generally poorer health. Educational differences in adult mortality have diverged over the past several decades which may reflect widening gaps in cigarette smoking. Using the 1997-2011 National Health Interview Survey Linked Mortality Files, the analysis examines the contribution of smoking to educational differences in all-cause mortality between 1997-2003 and 2005-2011 among adults aged 55-64. The results indicate that in 1997-2003 smoking explains nearly 47% of the mortality gap between those without a high school education and college graduates among men and 21% among women. Smoking also contributes 30% to widening educational gaps in mortality between the two study periods. These results indicate that smoking contributes to widening mortality gaps among those who will enter Medicare within 10 years.
Compared to those in other high income countries, Americans live shorter lives, have higher rates of many major chronic diseases, and are more likely to lack health insurance despite spending more per capita on health care than any other country (1). For most Americans Medicare begins at age 65, which marks an important transition in health insurance coverage regardless of previous status. This transition is particularly important, however, for the previously-uninsured, as Medicare provides stable health insurance coverage in subsequent years (2). An increasing fraction of adults survives to age 65 (3), and the experience of American adults in the years leading up to Medicare coverage is important for understanding their future health care utilization. As the heart of the baby boom generation nears retirement, the health dynamics and trends among adults age 55-64 has received increased focus from scholars and health policy professionals. This group of adults, those who will enter the Medicare program within 10 years, generated a special feature in the congressionally mandated report *Health, United States 2014* prepared by the National Center for Health Statistics (4).

Educational differences in health and mortality outcomes in the United States have received a large amount of attention in the past several decades. Educational gaps in mortality have widened over time and now exceed those observed between blacks and whites or between men and women (5). Between the mid-1990s and early 2000s, educational gaps in US life expectancy grew by more than 1 year among men and women (6). These growing disparities reflect continued life expectancy gains for college graduates alongside stalled mortality declines and even increased mortality for those with less education for some groups. During a period of educational expansion, those without a college degree have fallen increasingly behind their counterparts with a college education, and likely represent a more disadvantaged group than in
the past (7). Since 2000, the fraction of adults with a college degree has grown while the fraction without a high school diploma has declined (6).

The role of cigarette smoking in the health and mortality experience of the US is well-documented (8). Cigarette smoking is associated with many types of cancers, heart disease, diabetes, stroke, and chronic obstructive pulmonary disease—all of which are major causes of death for those aged 55-64. Although smoking prevalence has declined since the mid-20th century, smoking remains the leading preventable cause of premature death in the United States (9), and there are increasingly strong educational gradients in smoking behavior. Compared to the less educated, the more educated are less likely to start smoking, are more likely to successfully quit smoking, and smoke fewer cigarettes per day (10, 11). Educational gaps in smoking prevalence have widened since at least the 1970s and are currently the highest in US history (6). The health implications of these trends have gained increasing attention from scholars and health policy researchers, particularly given the focus on reducing socioeconomic disparities in health (12, 13). The contribution of smoking to educational differences in mortality has received some attention recently, although it is unclear whether this has occurred for all age groups.

This paper examines widening educational differences in mortality among American adults aged 55-64. The analysis considers the contribution of cigarette smoking to educational differences in mortality among adults in this age range across two periods: 1997-2003 and 2005-2011. The results demonstrate that while mortality declined for this age group as a whole between the early and the late period, there were widening gaps in mortality by education for both men and women. During period 1997-2003, cigarette smoking explains 47% of the gap between college graduates and those without a high school diploma among men and 21% among
women, while also explaining 30% of the widening of this gap between the two periods among women and 14% among men.

Data and Methods

The analysis uses data from the restricted-use National Health Interview Survey Linked-Mortality files (NHIS-LMF)\(^1\), which are maintained by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC). This analysis includes data from the 1997-2009 portion of the NHIS-LMF, with mortality follow-up through 2011. NHIS is a large, nationally-representative survey of the US non-institutionalized civilian population that collects information on demographic, health, and behavioral characteristics in annual cross sections. The NHIS-LMF also has the beneficial characteristic that respondent vital status is identified through the end of 2011 through probabilistic linkage to the National Death Index. This allows researchers to examine mortality differences by a wide range of socioeconomic, demographic, and behavioral characteristics that is not possible with traditional vital statistics data. The NHIS response rate ranges from 82% to 91%.

The analysis splits the linked mortality file data into two time periods: 1997-2003 and 2005-2011, denoting the early and late periods of analysis. These periods are chosen to combine enough years to obtain stable estimates of mortality for each group. For a given period, deaths and person-years are confined to those occurring during those years, and survivors from the early period are allowed to age into the population at risk in the late period (7). As a result, individuals may contribute exposure in both periods as long as they are within the focal age group. The analysis focuses on those soon to enter Medicare—individuals aged 55-64. Sample participants

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\(^{1}\) Restricted-use NCHS data are accessible through the NCHS Research Data Center (http://www.cdc.gov/rdc/index.htm). Documentation for the NHIS-LMF can be found at http://www.cdc.gov/nchs/data_access/data_linkage/mortality.htm
age into and out of the analytic sample over the course of follow-up as they reach age 55 or 65 respectively. 2 4,508 individuals were excluded due to missing data on the covariates (mostly education). The final sample includes individuals who were aged 55-64 at some point during either the early or late period, with 51,160 individuals contributing person-years in the early period and 119,938 contributing in the late period.

Independent Variables

The analysis examines socioeconomic disparities in health and mortality inequalities with respect to education. Education is the preferred measure of SES in health research because it is available for all individuals regardless of labor force status and because it is established relatively early in life and does not respond to health shocks in old age (14). Education is based upon the highest level of education attained at the time of the survey. Respondents are categorized into 4 groups: less than high school education, high school graduate or equivalent, some college (including associates degree), 3 and college graduate or more. The analysis also controls for other sociodemographic covariates that may be associated with health and mortality over time: race/ethnicity, marital status, and family income based on the Income to Poverty Ratio using census-defined poverty lines in each year. Family income is missing for a large fraction of respondents in most NHIS sample years. To improve data completeness, NHIS releases annual imputed income files which contain multiple income imputations for each respondent (15). Respondents are categorized into three income ratio groups: less than 100% of the poverty line

2 An alternative specification in which only respondents interviewed 2004 and later are included in the 2005-2011 period does not change the substantive results, although it does reduce the sample size and statistical power.
3 Consistent with previous research on the topic, individuals with some college education but no four-year degree are included in the analysis but are not the main focus of comparisons. This is largely for analytical simplicity and ease of interpretation of the results, and is standard practice in studies of educational differences in mortality.
(low income), 100-399% of the poverty line (middle income), and 400% or more of the poverty line (high income).

**Statistical Analysis**

The analysis estimates mortality risk for adults aged 55-64 by education in each analytical period using a continuous-time proportional hazards model. This model predicts the hazard of death as a function of education adjusting for sociodemographic covariates. Respondents are weighted to correct for linkage eligibility in the LMF, but the complex survey design is not accounted for because pooling across surveys makes nationally-representative estimates difficult to obtain and interpret. To estimate the contribution of cigarette smoking to these trends, the analysis uses an indirect estimation technique developed by Preston et al. (16) and adapted to the US context by Fenelon and Preston (9). Smokers die from a number of underlying causes, including several types of cancers, cardiovascular diseases, and respiratory diseases. The indirect method apportions deaths into those considered attributable to smoking and those not considered attributable to smoking. The fraction of lung cancer deaths attributable to smoking, $A_L$, is calculated as:

$$A_L = \frac{M_L - \lambda_L^N}{M_L}$$

where $M_L$ is the observed age-sex-education-specific lung cancer death rate in a given period and $\lambda_L^N$ is the age-sex-specific lung cancer death rate observed among non-smokers in the Cancer Prevention Study II, the largest epidemiological study providing such estimates.

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Although more than 90% of lung cancer deaths among men and more than 80% among women are attributable to smoking, lung cancer accounts for only about 30% of smoking-attributable mortality. The indirect estimation technique uses the heavy influence of smoking on lung cancer to estimate the smoking-attributable fraction for all other causes of death.
For all other causes of death besides lung cancer, the method uses the statistical relationship between lung cancer mortality and mortality from all other causes of death observed across the 50 U.S. states during a recent period. Using negative binomial regression, mortality from all other causes is modeled separately for males and females as a function of lung cancer mortality, age group, state, year, and a set of lung cancer mortality and age interactions. The model coefficients pertaining to lung cancer mortality are combined in a single set of coefficients \( \beta'_L \) which vary by age and sex and reflect the “imprint” of smoking on causes of death other than lung cancer. The fraction of all other deaths attributable to smoking, \( A_O \), is estimated as:

\[
A_O = 1 - e^{-\beta'_L(M_L-\lambda^N_L)}
\]

where \( M_L \) and \( \lambda^N_L \) are as defined above. The fraction of all deaths attributable to smoking in a given age-sex-education group is a weighted average of the attributable fractions for lung cancer and for all other causes of death:

\[
A = \frac{A_LD_L + A_OD_O}{D}
\]

where \( A_L \) and \( A_O \) are as defined above, \( D_L \) is the number of lung cancer deaths, \( D_O \) is the number of deaths from all other causes, and \( D \) is the total number of deaths. Finally, the contribution of smoking to the educational gap in mortality among adults 55-64 is calculated based on the reduction in the size of the educational gap in mortality after smoking-attributable deaths are removed (6).

Indirect methods usually attribute a greater fraction of deaths to smoking than survey-based smoking prevalence methods (17). However, indirect methods have advantages, since they account for the cumulative nature of the relationship between cigarette smoking and mortality. Smoking typically begins in adolescence or early adulthood, but the health effects are not observed until later life. The indirect method, which focuses on the observable consequences of
smoking rather than self-reports of behavior, provides a more accurate assessment of the cumulative damage from smoking in a population (9).

Results

Table 1 presents sociodemographic characteristics of those in the NHIS sample aged 55-64 in 1997-2003 and 2005-2011. In 2005-2011, those aged 55-64 were less likely to be non-Hispanic white than the same age group 10 years prior: 76.5% were non-Hispanic white in 2005-2011, compared with 79% in 1997-2003. Hispanics increased from 7.5% of this age group in 1997-2003 to 8.5% in 2005-2011. During this period, the percentage of adults aged 55-64 who were married declined from 72% to 69%, the percent never married increased from 4% to 6%, and the percent cohabiting rose from 2.8% to 3.5%. Educational attainment for this age group increased as well. 81% had at least a high school diploma and 25% had at least a bachelor’s degree in 1997-2003 and this rose to 87% and 31%, respectively, in 2005-2011. The percent with some college education rose from 24% in 1997-2003 to 27% in the later period. 9.5% had incomes below the federal poverty line in the early period, declining to 8.6% by the later period.

In 2005-2011, the death rate for men without a high school diploma was 40% higher than that of high school graduates and 2.5 times as high as that of college graduates. Among women, it was 60% higher than that of high school graduates and 2.7 times as high as that of college graduates (Figure 1). Between 1997-2003 and 2005-2011, all-cause death rates for adults aged 55-64 declined for both men and women. The death rate decreased by 10% for men, from 1180 to 1065 per 100,000, and by 9% for women, from 708 to 643. However, these aggregate trends obscure large differences in the trends by education. Among those without a high school education, the death rate rose by 6% among men and 13% among women between the early and the late period. The death rate for high school graduates declined by 3% among men and 5%
among women, while the death rate for college graduates declined by 22% for men and 23% for women. The death rate for those with some college education declined by 12% among men and 15% among women. As a result, the gap in mortality in this age group between college graduates and those without a high school education widened from 749 deaths per 100,000 to 1,017 among men and from 441 per 100,000 to 689 among women. The gap between college graduates and high school graduates grew as well.

The fraction of deaths due to cigarette smoking among adults aged 55-64 is shown by education and period in Figure 2. In both the early and late period and among both men and women, higher education is associated with a smaller smoking-attributable fraction. Among men in the early period, 28% of deaths among those without a high school education, 17% among high school graduates and those with some college education, and 10% among college graduates were due to smoking. By 2005-2011, the decline in the attributable fraction is larger for college graduates, which led to a widening gap in smoking-attributable deaths. Among women, the attributable fraction for those without a high school education increased from 12% to 16% between the early and later periods, while for college graduates it remained constant at 4%. The gap in smoking related mortality between college graduates and those without a high school education grows from 18 percentage points to 20 among men and from 7 percentage points to 12 among women.

The results in Table 2 demonstrate the contribution of smoking to the gap in mortality between college graduates and the other education groups in each period. Among both men and women and in each period, smoking makes a larger contribution to the mortality gap among men than among women. 47% of the difference in mortality between men without a high school education and college graduate men is due to smoking during the 1997-2003 period. Smoking
explains 31% of the advantage of college graduate men and men with a high school diploma or
men with some college. Among women, smoking makes a smaller contribution to educational
differences in mortality, explaining 21% of the gap between college graduate women and women
without a high school diploma, 15% of the gap between college graduates and high school
graduates, and 19% of the gap between college graduates and women with some college
education.

The increase in educational gaps in smoking-related mortality between the early and late
period (shown in Figure 2) contributed to rising educational gaps in all-cause mortality. Figure 3
presents the contribution of cigarette smoking to widening educational gaps in mortality between
1997-2003 and 2005-2011. Results for those with some college education are not shown, since
there is no significant change over time in their mortality gap with college graduates. Among
men, smoking explains 14% of the increase in the gap between those without a high school
diploma and college graduates, and 21% of that between high school and college graduates.
Among women, smoking is responsible for 30% of the increase in the former gap and 8% of the
increase in the latter gap. The fraction of the change due to “other factors” represents the
expected size of the increase in the absence of changes in smoking.

Discussion

This study examined the contribution of cigarette smoking to educational differences in
mortality trends of the 55-64 age group during a recent period. Recent trends in the mortality
experience of adults aged 55-64 have important implications for the survival of these adults at 65
and over, the point at which they enter Medicare (18). The results of the current study
demonstrate that while mortality has declined for this population as a whole, there are growing
educational gaps in survival, driven largely by declines in mortality among those with a college
education combined with stagnant or increasing mortality among those with a high school education or less. These results are consistent with studies demonstrating widening educational不同ials in life expectancy during the 1990s, especially the worsening mortality experience for those with less than a high school education (5). The results also confirm the role played by cigarette smoking (6), which contributes to the growing gaps between educational groups. As these adults enter Medicare, they will do so with wider socioeconomic differences in health and survival than in previous decades.

Smoking emerges as an important determinant both of educational differences in mortality and as a cause of widening differentials between 1997 and 2011. Among both men and women, smoking plays an important role in educational gaps in mortality, explaining 47% of the gap between college graduates and those without a high school diploma among men and 21% among women. Among men, college graduates have seen large declines in smoking-related mortality, while those with a high school education or less have maintained relatively high levels of mortality due to smoking (15-25%). Among women, college graduates have maintained low levels of smoking-related mortality (4%), while those with less education have seen increases during the 2000s. These trends reflect growing educational differences in smoking behavior over the past several decades. While college educated men and women have seen rapid declines in smoking since the 1970s, those with a high school education or less have made less progress in reducing smoking (19). Indeed, white women without a high school education do not appear to have seen any decline in smoking since 1970 (6). Women, however, never reached the peak smoking prevalence of men (20), which can help to explain why smoking makes a greater contribution to educational differences among men than among women.
Diverging trends in cigarette smoking have been an important issue for researchers examining diverging mortality outcomes by education (6, 7). Although there are debates surrounding the magnitude of health care costs surrounding smoking-related conditions, it is clear that Medicare pays a high fraction of these costs (21).

Limitations

The primary limitation of the analysis is the potential shift in the composition of educational categories over time. The average educational level of middle-aged adults has grown over time, even between the two periods in this study, and a college education has become increasingly necessary for many middle-class jobs (7). Between 1997-2003 and 2005-2011 the fraction of adults aged 55-64 without a high school diploma declined from 19% to 13%. The declining size of this population increases the selectivity of individuals in this education group, suggesting that the remaining 13% may be disadvantaged in other ways that relate to health. This has led some researchers to claim that observations of worsening health among those without a high school education partially reflect changing composition of this group (22, 23). A fully comprehensive analysis of widening health differentials by education should account for compositional effects, and how selective processes might relate to smoking.

Conclusion

American adults experience higher mortality rates than their counterparts in other high income countries (1). Indeed, even the wealthiest and most well-educated Americans experience rates of chronic conditions similar to those of lower status individuals in the UK (24). This gap also partially reflects historically high levels of smoking in the US (16). Although rates of cigarette smoking have fallen in the US since the mid-20th century, trends have been uneven by education; while smoking remains high for those without a high school education, it has fallen to
very low levels among college graduates (11). This widening disparity in smoking is reflected in
a widening disparity in mortality risk, a trend that has continued in recent years. The Healthy
People 2020 goals have emphasized narrowing socioeconomic inequalities in health and
longevity for several decades, yet the health gap between high SES individuals and low SES
individuals has continued to grow, even among middle-aged adults.
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>n</strong></td>
<td>51,160</td>
<td>119,938</td>
</tr>
<tr>
<td><strong>Sex (%)</strong></td>
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<tr>
<td>Male</td>
<td>48.1 (0.13)</td>
<td>48.2 (0.10)</td>
</tr>
<tr>
<td>Female</td>
<td>51.9 (0.13)</td>
<td>51.8 (0.10)</td>
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<td><strong>Race/Ethnicity (%)</strong></td>
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<td>Non-Hispanic white</td>
<td>79.1 (0.11)**</td>
<td>76.5 (0.09)</td>
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<td>Non-Hispanic black</td>
<td>9.5 (0.08)**</td>
<td>10.2 (0.06)</td>
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<tr>
<td>Non-Hispanic other</td>
<td>4.0 (0.05)**</td>
<td>4.8 (0.04)</td>
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<tr>
<td>Hispanic</td>
<td>7.5 (0.07)**</td>
<td>8.5 (0.06)</td>
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<td><strong>Marital Status (%)</strong></td>
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<tr>
<td>Married</td>
<td>72.3 (0.12)**</td>
<td>69.3 (0.09)</td>
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<tr>
<td>Divorced/Separated</td>
<td>13.6 (0.09)**</td>
<td>16.0 (0.07)</td>
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<td>7.2 (0.07)**</td>
<td>5.6 (0.05)</td>
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<tr>
<td>Never Married</td>
<td>4.2 (0.05)**</td>
<td>5.7 (0.05)</td>
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<tr>
<td>Cohabiting</td>
<td>2.8 (0.04)**</td>
<td>3.5 (0.04)</td>
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<td><strong>Education (%)</strong></td>
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<td></td>
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<tr>
<td>Less than High School</td>
<td>19.2 (0.10)**</td>
<td>12.8 (0.07)</td>
</tr>
<tr>
<td>High School Graduate</td>
<td>31.7 (0.12)**</td>
<td>29.4 (0.09)</td>
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<tr>
<td>Some College</td>
<td>24.3 (0.11)**</td>
<td>27.3 (0.09)</td>
</tr>
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<td>College Degree</td>
<td>24.9 (0.11)**</td>
<td>30.5 (0.09)</td>
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<tr>
<td><strong>Family Income (%)</strong></td>
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<tr>
<td>Below Poverty Line - Low</td>
<td>9.5 (0.08)**</td>
<td>8.6 (0.06)</td>
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<tr>
<td>100%-399% of PL - Middle</td>
<td>43.2 (0.13)**</td>
<td>41.5 (0.10)</td>
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<td>400%+ of PL - High</td>
<td>47.3 (0.13)**</td>
<td>50.0 (0.10)</td>
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</table>

Source: National Health Interview Survey 1997–2009
Notes: Standard errors in parentheses
* p<0.05  ** p<0.01 – Tests for statistical difference between the early and the late period
Figure 1: All-cause death rate (per 100,000) among adults aged 55-64 by education: 1997-2003 and 2005-2011

(a) Men

Source: Author’s calculations from restricted use NHIS Linked Mortality Files 1997-2009
Notes: Bars denote 95% confidence intervals

(b) Women

Source: Author’s calculations from restricted use NHIS Linked Mortality Files 1997-2009
Notes: Bars denote 95% confidence intervals
Figure 2: Fraction of Deaths Attributable to Smoking by Education among Adults 55-64 1997-2003 and 2005-2011

(a) Men

(b) Women

Source: Author’s calculations from restricted use NHIS Linked Mortality Files 1997-2009

Notes: Bars denote 95% confidence intervals. Smoking-attributable mortality estimated using an indirect method based on the statistical relationship between lung cancer mortality and mortality from all other causes of death (Fenelon and Preston 2012).
Table 2: Contribution of Smoking to Educational Gaps in Mortality among Adults aged 55-64: 1997-2003 and 2005-2011

<table>
<thead>
<tr>
<th></th>
<th>Observed Gap¹ (A)</th>
<th>Gap in the Absence of Smoking¹ (B)</th>
<th>Fraction of Gap due to Smoking² (A)-(B)/(A)</th>
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<tbody>
<tr>
<td><strong>1997/2003</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than High School vs. College</td>
<td>749</td>
<td>399</td>
<td>47%</td>
</tr>
<tr>
<td>High School vs. College</td>
<td>405</td>
<td>278</td>
<td>31%</td>
</tr>
<tr>
<td>Some College vs. College</td>
<td>403</td>
<td>276</td>
<td>31%</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than High School vs. College</td>
<td>441</td>
<td>348</td>
<td>21%</td>
</tr>
<tr>
<td>High School vs. College</td>
<td>195</td>
<td>166</td>
<td>15%</td>
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<tr>
<td>Some College vs. College</td>
<td>134</td>
<td>108</td>
<td>19%</td>
</tr>
<tr>
<td><strong>2005/2011</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than High School vs. College</td>
<td>1,017</td>
<td>630</td>
<td>38%</td>
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<tr>
<td>High School vs. College</td>
<td>547</td>
<td>390</td>
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<tr>
<td>Some College vs. College</td>
<td>436</td>
<td>355</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
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<tr>
<td>Less than High School vs. College</td>
<td>689</td>
<td>522</td>
<td>24%</td>
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<tr>
<td>High School vs. College</td>
<td>281</td>
<td>244</td>
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<tr>
<td>Some College vs. College</td>
<td>195</td>
<td>177</td>
<td>9%</td>
</tr>
</tbody>
</table>

¹Advantage of college graduates in deaths per 100,000 population
²The percent of the observed educational gap that is explained by the educational gap in mortality attributable to smoking

Source: Author’s calculations from restricted use NHIS Linked Mortality Files 1997-2009
Figure 3: Contribution of Smoking to Widening Educational Gaps in Mortality 1997-2003 – 2005-2011

Source: Author’s calculations from restricted use NHIS Linked Mortality Files 1997-2009
Abbreviations: LTHS=Less Than High School education. HS=High School graduate
References


