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The Benefits of Educational Attainment for U.S. Adult Mortality: Are they Contingent on the Broader Environment?

Jennifer Karas Montez[1] · **Kaitlyn Barnes**[2]

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Abstract The growing recognition that educational attainment is one of the strongest preventive factors for adult health and longevity has fueled an interest in educational attainment as a population health strategy. However, less attention has been given to identifying social, economic, and behavioral resources that may moderate the health and longevity benefits of education. We draw on theories of resource substitution and multiplication to examine the extent to which the education–mortality association is contingent on other resources (marriage, employment, income, healthy lifestyles). We use data on adults aged 30–84 in the 1997–2006 National Health Interview Survey Linked Mortality File and estimate discrete-time event history models stratified by gender ($N = 146{,}558$; deaths $= 10{,}399$). We find that the mortality benefits of education are generally largest for adults—especially women—who have other resources such as employment and marriage, supporting the theory of resource multiplication. Nonetheless, our results also imply that other resources can potentially attenuate the mortality disadvantages (advantages) associated with low (high) levels of education. The findings suggest that efforts to improve population health and longevity by raising education levels should be augmented with strategies that assure widespread access to social, economic, and behavioral resources.

Keywords Education · Gradient · Mortality · Gender · NHIS-LMF

✉ Jennifer Karas Montez
jmontez@maxwell.syr.edu

Kaitlyn Barnes
kaitlyn.barnes@cwru.edu

[1] Department of Sociology and Aging Studies Institute, Syracuse University, 314 Lyman Hall, Syracuse, NY 13244, USA

[2] Department of Sociology, Case Western Reserve University, 226 Mather Memorial Building, Cleveland, OH 44106, USA

Introduction

Educational attainment is one of the strongest preventive factors in social epidemiology. The growing recognition of its importance for mortality has fueled an interest in raising education levels as a population health strategy. Nonetheless, this preventive strategy may be necessary but insufficient. While education is strongly associated with lower mortality among the U.S. population, its mortality benefits are not shared equally across population subgroups. For instance, the benefits tend to be smaller for women (e.g., Montez et al. 2009; Ross et al. 2012), blacks, Hispanics, and non-U.S.-born adults (e.g., Goldman et al. 2006; McKinnon and Hummer 2007; Turra and Goldman 2007). The benefits are smaller in part because stratification systems and discrimination hinder some individuals from fully converting their education into other salubrious resources such as employment and healthy lifestyles. This implies that the mortality benefits of education for individuals are moderated by other resources that individuals possess. More generally, it implies that the mortality benefits at the population level are contingent on the availability of other resources within the broader environment.

Drawing on theories of resource substitution and multiplication (Ross and Mirwosky 2006), this study examines the extent to which several key resources—marriage, employment, income, healthy lifestyles—moderate the mortality benefits of educational attainment among U.S. adults. We find that the benefits are contingent on several of these resources, especially for women. In general, the mortality benefits of education are largest for adults who possess other resources, such as employment and marriage, supporting the theory of resource multiplication. Nonetheless, by examining the mortality benefits of education in combination with other resources, our results also imply that those resources can potentially attenuate, or even erase, the mortality disadvantages (advantages) associated with low (high) levels of education. Taken together, the findings can be used to augment an education-as-prevention strategy into a more comprehensive and robust population health strategy.

Educational Attainment and Adult Mortality

The inverse association between educational attainment and U.S. adult mortality is pervasive, enduring, and strengthening (e.g., Hummer and Lariscy 2011; Meara et al. 2008). Indeed, education has become one of the strongest predictors of mortality in recent decades. For example, during the 1980s and 1990s, gaps in U.S. life expectancy at age 25 widened across education levels while they shrunk between men and women and between whites and blacks (Meara et al. 2008). The strength and pervasiveness of the association across time, place, and population subgroups have led some scholars to consider educational attainment a fundamental cause of mortality disparities (Masters et al. 2015), and others to advocate that the standard dimensions of demographic analyses—age and sex—be extended to include education (Lutz et al. 1998).

Why is an individual's educational attainment such a strong predictor of their mortality risk? Education can influence mortality though myriad ways, or a "massive multiplicity of connections" (Lutfey and Freese 2005). Compared to their less-educated peers, higher-educated adults can more easily garner material resources, such as income and wealth, which can be used to purchase nutritious foods, gym memberships, and homes in safe neighborhoods (Mirowsky and Ross 2003). Higher-educated adults are not only more likely to be employed, they are more likely to hold jobs that are stable, fulfilling, and require creative thinking, which benefits health (Mirowsky and Ross 2007). Schooling also enhances social-psychological resources. For instance, higher-educated adults are more likely to have salubrious social ties, such as stable marriages, which can provide emotional and instrumental support and encourage healthy behaviors (Umberson and Montez 2010). Higher-educated adults are less likely to encounter marital, parental, and financial strains (Lantz et al. 2005), which can deteriorate health. Schooling may also enhance a sense of control, in part by teaching individuals how to read, analyze, synthesize, and develop the confidence to tackle complex problems (Mirowsky and Ross 2003). Schooling also enhances general cognitive ability, which partly explains why higher-educated adults are less likely to engage in risky behaviors and more likely to engage in preventive behaviors (Cutler and Lleras-Muney 2010). These adults are more likely to exercise, avoid tobacco, drink alcohol in moderation, and maintain a healthy body weight (Pampel et al. 2010). In addition to the myriad ways that education can indirectly shape mortality (the above list is not exhaustive) it may also directly shape it. For example, the cognitive challenges encountered in school can significantly enhance brain structure and function (Rosenberg-Lee et al. 2011).

The above discussion presumes that education has a causal effect on mortality; however, the association may be more complex than that. For instance, the association may also reflect truncated educational attainment among individuals who experienced poor health in childhood (e.g., Haas et al. 2011) and thus have an elevated risk of death. It may also partly reflect social and psychological traits or genetic endowments that influence both education and mortality (e.g., Behrman et al. 2011). While these complexities should not be ignored, a growing literature using innovative econometric, epidemiologic, and meta-analytic methods indicates that a substantial part of the association reflects a causal influence of education on mortality (e.g., Baker et al. 2011; Glied and Lleras-Muney 2008; Lleras-Muney 2005; Smith 2004). Consistent with these latter studies, we assume here that a non-trivial part of the association is causal, from education to mortality.

Given that educational attainment appears to have substantial benefits for health and longevity at the individual level, does it also have important benefits at the population level? Several studies have explored this question, often contrasting the health benefits of large-scale investments in education to other social, economic, and medical investments. Woolf et al. (2007) estimated that during 1996–2002, giving U.S. adults at least 1 year of college would have averted roughly eight times as many deaths as had been averted by medical advances during that period. Another study compared the effectiveness of education expenditures against other public expenditures (e.g., environment and housing, welfare, health, hospitals) at the

U.S. state level, and concluded that "…the most promising sectors for public investment to improve health are higher education and primary and secondary education" (Dunn et al. 2005, p. 773). Almost half a century ago, Auster et al. (1969) reported that the rate of return on higher schooling outlays for improving health exceeded the rate of return on higher medical care outlays. Studies like these have helped fuel an interest in education policy as a powerful and cost-effective strategy for improving population health in developed (e.g., House et al. 2008; Montez and Hayward 2014) and developing (Curtin and Nelson 1999; United Nations n.d.) countries.

Educational Attainment and Other Adult Resources: Resource Substitution or Multiplication?

Given the compelling evidence about education's benefits for health and longevity highlighted above, investing in educational systems and raising education levels may appear to be a silver bullet for improving population health and longevity. Indeed, education is "among the most important preventive factors in social epidemiology" (Schnittker 2007, p. 222). Nonetheless, it is important to understand the extent to which the benefits of investing in educational systems and raising education levels for improving population health and longevity are contingent on broader social, economic, political, and epidemiological contexts. These broader contexts may limit or expand the opportunities individuals have to translate their educational attainment into health and longevity. For example, education may have a marginal effect on health within epidemiological environments where it is unknown how to avoid disease; in sociopolitical contexts with strong social and economic safety nets; or during economic booms when good jobs and opportunities for a living wage are plentiful, or during economic downturns when these resources are scarce. Such contingencies are often overlooked when estimating the benefits of educational attainment for boosting population health. However, the contingent nature of these benefits is at the core of fundamental cause theory (FCT: Phelan and Link 2005). A core principle of FCT is that education has the greatest potential to "purchase" health within contexts that contain the material and intellectual resources to avoid disease and premature death. Individuals with more schooling are best-positioned to acquire these resources and glean the health and mortality benefits.

The main aim of this study is to elucidate the extent to which the mortality benefits of education in the contemporary U.S. context are moderated by other resources, such as employment, income, social ties, and healthy lifestyles. These resources are typically conceptualized as mediators of the education–mortality association: individuals with more years of schooling have lower mortality risk in part because schooling increases access to these resources. However, in some situations mediators also act as moderators (Mirwosky 2012; Ross et al. 2001). As one illustration, Ross and Mirowsky (2011) found that the association between parents' education and an individual's health was partly mediated by the individuals' education; however, achieving more education attenuated the health disadvantages of having low-educated parents. In other words, educational attainment acted as both a mediator and moderator of the association between parental education and adult health.

If mediators can also act as moderators, then can the availability of employment, income, social ties, and healthy lifestyles (i.e., resources thought to mediate the education–mortality association) in the broader environment moderate the population health benefits of rising education levels? Could secular declines in marriage, stagnating employment opportunities, and a bifurcating labor market offset the population health benefits of rising education levels? Could boosting employment opportunities or ensuring a living wage for all workers accentuate the population health benefits? Could these resources erase the health risks associated with low education? Addressing questions such as these is critical for understanding the extent to which the benefits of investing in educational systems and raising education levels for population health and longevity are contingent on the broader environment.

To address our main aim, we draw on the theories of resource substitution and resource multiplication (Ross and Mirwosky 2006, 2010; Ross et al. 2012). Our conceptual framework is illustrated in Fig. 1 using employment as an example resource. Employment is a well-established mediator of the education–mortality association, but it may also act as a moderator. Panel A in Fig. 1 illustrates a potential context in which the mortality benefits of education *are not* moderated by employment: each year of education provides the same mortality risk reduction regardless of employment status. Panels B and C illustrate two potential contexts in which employment modifies the mortality benefits of education. First, the theory of resource substitution asserts that the benefits of education are larger for adults who are disadvantaged in other resources. This occurs because adults who are *advantaged* in other resources are less reliant on education and can substitute other

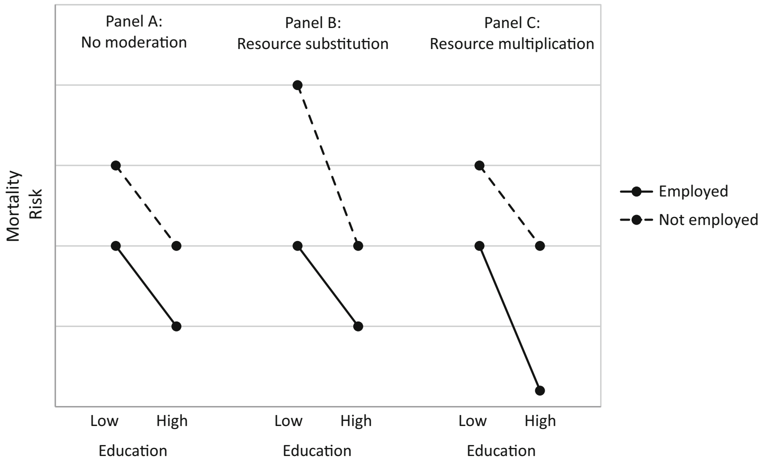

Fig. 1 Illustration of resource substitution and multiplication using employment as an example resource

resources for low levels of education. This theory is depicted in panel B. It shows a potential scenario in which the mortality benefits of additional years of education are larger for non-employed adults, and hence mortality inequalities are widest among the low-educated. Second, the theory of resource multiplication proposes instead that the mortality benefits of education are larger for employed adults because advantages multiply in their effects on mortality. The theory of resource multiplication is illustrated in panel C, where inequalities are widest among high-educated individuals.

Social, Economic, and Behavioral Resources

While many moderators of the education–mortality association may exist, we focus on five resources: marriage, employment, income, and healthy lifestyles (specifically, not smoking and not being obese). In addition to education, these resources are among the most important social, economic, and behavioral resources for living long and healthy lives. A large body of research documents that, on average, married adults have better health and lower mortality than unmarried adults, partly due to financial economies of scale, social support, and behavior regulation among spouses (e.g., Umberson and Montez 2010; Waite and Gallagher 2000). It is also well-established that employed adults have a substantial mortality advantage (Krueger and Burgard 2011). Employment increases access to material (e.g., income, medical insurance) and non-material (e.g., social networks, sense of purpose) goods that individuals can garner to enhance health and longevity. A healthy lifestyle is also protective. One that entails avoiding tobacco and maintaining a healthy weight is particularly important for lowering mortality (Mokdad et al. 2004).

The few prior studies examining whether specific resources can substitute for, or multiply with, education to influence health and longevity find that some of them do.[1] For instance, Denney (2014) found that higher-educated adults had a disproportionately lower suicide risk in married-couple households than did their lower-educated peers, regardless of children. Education and marriage may have a synergistic effect because the education of each spouse matters for health and mortality (Brown et al. 2014; Montez et al. 2009) and high (low) educated individuals tend to marry high (low) educated spouses (Schwartz and Mare 2005). The benefits of education may also depend on employment and income. These resources could substitute for low education by buffering against social isolation, family strains, and other risks correlated with low education. Instead, (a lack of) resources could accentuate educational (dis)advantages. For instance, the physical functioning of low-educated adults appears to be especially harmed by adverse economic circumstances (Mirowsky and Ross 2003). Also, high-educated adults may benefit more from resources such as employment because they are more likely to hold jobs with creative work and high wages (Ross and Mirwosky 2006). Lastly,

[1] Given our aims, we focus on studies that examined interactions between education and social, economic, and behavioral resources, rather than interactions between two non-education resources, such as employment and children (e.g., Montez et al. 2015), employment and family households (e.g., Denney 2014), and employment, marriage, and children (e.g., Verbrugge 1983).

some studies find that health behaviors may moderate education's benefits. Pampel and Rogers (2004) reported that morbidity (but not mortality) of low-educated adults was disproportionately harmed by smoking. They speculated that smoking exacerbates health problems caused by adverse socioeconomic conditions. Other scholars have posited that unhealthy lifestyles are most damaging for *advantaged* adults because they have the most to lose given their greater potential for good health (Blaxter 1990). We build on these studies by expanding the set of resources as well as the outcome, all-cause mortality.

Another reason that we examine these five resources is that they could potentially be made more or less available through social and economic policies, such as minimum wage laws, work-family policies, nutrition labels, and tobacco control. Thus, our findings are policy-relevant. For instance, if we find that the mortality benefits of education are diluted by non-employment then expanding employment opportunities may be one way to ensure that the population health benefits of rising education levels are realized to their fullest potential. These resources have also undergone dramatic trends in recent decades. For instance, since the 1970s the prevalence of marriage has declined while employment rates have risen among women (Montez et al. 2014), smoking rates have declined for most demographic groups except low-educated white women (Escobedo and Peddicord 1996), and obesity rates have increased (Flegal et al. 2002).

Gender and the Education–Mortality Association

The strength of the association between education and U.S. adult mortality may differ between men and women. In the seminal study by Kitagawa and Hauser (1973), education was more protective for women's than men's mortality. Several recent studies find that education is more protective for men (e.g., Ross et al. 2012), although the gender difference is modest and limited to certain portions of the education distribution (Montez et al. 2009; Zajacova and Hummer 2009). In contrast, a few studies find no gender difference in education's association with mortality (McDonough et al. 1999; Zajacova 2006). The mixed findings among recent studies may partly reflect the ways that education is operationalized. Studies using categorical measures tend to find gender differences in education's effect on mortality, while studies using a linear measure often do not.[2]

Gender differences in the importance of education for mortality may reflect socially structured differences between men and women in access to other resources—regardless of educational attainment—as well as opportunity structures for translating education into these resources. For example, compared with women, men have historically been more likely to be employed regardless of educational attainment, and better able to translate their education into employment and higher earnings (Ross and Mirwosky 2006). Another explanation points to health-related behaviors. As Nathanson and Lopez (1987) proposed decades ago, education appears to have a stronger effect on men's mortality by reducing risky behaviors,

[2] While education's benefits for longevity appear to be greater among men than women, its benefits for health appear to be greater among women (Ross and Mirwosky 2006; Ross et al. 2012).

particularly smoking, which are disproportionately prevalent among low-educated men (Montez et al. 2009; Ross et al. 2012). Corroborating this finding, a recent study by Denney et al. (2010) showed that smoking plays a much larger role in mediating the education–mortality association among U.S. men than women. For all of these reasons, we conduct our analysis separately for women and men.

Study Aims

As stated above, the main aim of this study is to examine the extent to which the benefits of education for adult mortality are moderated by other social, economic, and behavioral resources. If the benefits are not contingent on these resources then ensuring widespread access to high-quality education may be a singularly effective "preventive strategy" for reducing mortality rates and disparities. If the benefits are contingent, then ensuring access to these resources may be an important complementary strategy.

This study also provides insights into whether specific resources can potentially attenuate, or even erase, the mortality disadvantages (advantages) of low (high) levels of education. For instance, can employment compensate for not obtaining a college degree? Can avoiding tobacco compensate for not obtaining a high school credential? Can smoking eliminate the mortality benefits of a graduate education? The insights gleaned from answering questions such as these can be used to develop a population health strategy that combines an education-as-prevention strategy with broader social and economic strategies. The findings also offer insights into specific strategies and policy levers that may be used to reduce mortality rates and disparities among U.S. adults.

Data and Methods

Data

The data come from the public-use National Health Interview Survey Linked Mortality File (NHIS-LMF) downloaded from the Minnesota Population Center (2012). The NHIS-LMF links non-institutionalized adults in the 1986–2004 annual, cross-sectional waves of the NHIS with death records in the National Death Index through December 31, 2006. The link is mainly based on a probabilistic matching algorithm, which correctly classifies the vital status of 98.5 % of eligible survey records (NCHS 2009). In 1997, the NHIS began annually collecting information on several variables of interest in this study (e.g., smoking). Thus, we use the 1997–2004 NHIS surveys and vital status information through 2006.

Analytic Sample

The analytic sample includes U.S.-born, non-Hispanic white and black adults aged 30–84 years. In the 1997–2004 NHIS, just 1.8 % of adults are missing information on country of birth, race, ethnicity, or education (no adults are missing data on age); we exclude these individuals from our sample. Consistent with prior studies (e.g., Brown et al. 2012; Meara et al. 2008; Montez and Zajacova 2013), we also exclude Hispanic adults and respondents born outside of the United States due to data concerns. For these groups the vital status matching process is of significantly lower quality than it is for non-Hispanic and U.S.-born adults (Lariscy 2011), and the quality may correlate with education level. In addition, we want to minimize the chance that respondents obtained their education abroad because this introduces uncertainty in the education measure, and because education obtained abroad does not necessarily provide the same health benefits as education obtained domestically (e.g., Walton et al. 2009).

Mortality

The NHIS-LMF contains an indicator of whether a respondent died from any cause during the mortality follow-up. Our analytic sample includes 5047 deaths among women and 5352 deaths among men occurring during 1997–2006. For all analyses, the dependent variable is the annual log-odds of death.

Educational Attainment

Educational attainment is measured as a five-category variable that includes 0–11 years; high school credential; some college (includes adults with an associate's degree and adults who attended college but did not receive a bachelor's degree); bachelor's degree; and post-graduate degree (includes adults with a master's, doctoral, or professional degree). We chose a categorical measure over a continuous one based on prior studies that have found the association between education and mortality in the United States is better described by a non-linear than a linear functional form, in many cases exhibiting discontinuities when credentials are attained (Backlund et al. 1999; Everett et al. 2013; Hayward et al. 2015; Montez et al. 2012). We chose the five categories of education because they are significant predictors of mortality (e.g., Rogers et al. 2010) and preliminary analyses revealed that splitting the categories further created cells too sparse to reliably estimate interaction terms in the models described below.

Social, Economic, and Behavioral Resources

We include five social, economic, and behavioral resources that may moderate the education–mortality association: marriage, employment, income, not smoking, and not being obese. We dichotomized each resource indicator to ensure we had sufficient cell sizes to reliably estimate mortality risk for all combinations of education and the indicators. This decision was based on preliminary analyses in which we first created detailed categories for each indicator and then cross-tabulated them with the five levels of education in order to calculate the number of deaths in each cell. Some cells had very few deaths. For these indicators, we then collapsed the categories in a meaningful way so that each cell contains a minimum of 30 deaths. As an example, our initial measure of the family income-to-poverty ratio contained four categories (0–0.99, 1.00–1.99, 2.00–2.99, 3.00 and higher). The cross-tabulation of this detailed measure with the five levels of education revealed that it provided just 12, 22, 22, and 99 deaths in each income category, respectively, among women with a post-graduate degree. Thus, we dichotomized the measure into 0–1.99 versus 2.00 and higher for all analyses. Given our focus on educational attainment, collapsing the indicators was preferred over collapsing education levels.

We include one indicator of psychosocial resources. *Legal marital status* identifies adults who were married at the time of interview. The NHIS does not include other measures of social ties or networks.[3] We include two measures of economic resources. *Employment status* identifies respondents who were employed full or part time at interview. *Income* indicates a family income-to-poverty ratio of 2 or greater. For ease, we refer to the income groups as poor and non-poor. We include two measures of healthy lifestyles. *Smoking* distinguishes respondents who never smoked from those who ever smoked (i.e., current or former smokers). *Obese* identifies respondents who had a body mass index of 30 or higher. A few respondents were missing values for one or more indicators. We imputed these values using IVEware multiple imputation software (Raghunathan et al. 2002).

Methods

We first built a person-year file that aged non-Hispanic whites and blacks aged 30–84 years at interview by 1 year beginning with their 1997–2004 NHIS interview until their year of death or 2006 if they survived. We set the upper age limit at 84 years for several reasons: the 1997–2004 NHIS top-codes age at 85 years, the mortality matches are not as reliable among women over 85 (Ingram et al. 2008), and the non-institutional sample excludes nursing home residents who are predominately older white women. For the person-year data structure, this means that respondents "age out" of the mortality follow-up once they reach 85 years of age (see also Montez and Zajacova 2013). The final sample contains 146,558 respondents who contributed 898,498 person-years and 10,399 deaths.

The first part of the analysis examines the extent to which the association between education and mortality is moderated by the five social, economic, and behavioral resources. We estimate a series of discrete-time event history models using logistic regression.[4] For men and for women, we estimate separate models for

[3] Some studies of working-age adults have used the NHIS household roster to identify the presence of minor children (e.g., Denney 2014; Montez et al. 2015). We do not include this information due to the age range of our sample, with very few respondents over the age of 60 living with minor children. Moreover, like many studies, both Denney (2014) and Montez et al (2015) find that marriage has a much stronger moderating effect on mortality than do children in the household.

[4] We chose a discrete-time method because the public-use NHIS-LMF only provides quarter and year of death. More importantly, we chose logistic regression over Cox proportional hazards models—two common methods of survival analysis—because we wanted to estimate probabilities of death from the covariates. In Cox models, the baseline hazard rate is unspecified and absorbs the intercept term; thus, the models do not provide a direct estimate of the model intercept which is needed to estimate probabilities of death (Box-Steffensmeier and Jones 2004). The use of logistic regression to estimate log-odds and probabilities of death from a person-time data structure is a common method in survival analysis (see Allison 1995). We conducted preliminary analyses (available on request) to ensure our model estimates are comparable to the National Center for Health Statistics.

each resource. Each model includes education, the resource, the education-by-resource interaction, age, race, and the remaining four resources. This model allows us to examine whether the education–mortality association is moderated by each resource, and it ensures that the association is net of the other four resources. As an example, the model for marital status is shown below, where $\boldsymbol{\beta_r x_r}$ denotes a vector containing the four remaining resources (employment, income, smoking, obesity) and $\boldsymbol{\beta_c x_c}$ denotes a vector containing the covariates (age, race).

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \sum_{j=1}^{4} \beta_j\,\text{Education}_j + \beta_5\,\text{Married} + \sum_{j=1}^{4} \beta_{j1}\text{Education}_j\,\text{Married} + \boldsymbol{\beta_r x_r} + \boldsymbol{\beta_c x_c}$$

The omitted reference group for educational attainment is less than high school. The theory of resource substitution is supported if the coefficients for the interaction terms are significant and increasingly positive with each education level. Resource multiplication is supported if the coefficients are significant and increasingly negative. To account for selection of healthy adults into employment, the model for employment also adjusts for health-related work limitations. All adults in the NHIS were asked whether they were limited in the kind or amount of work they can do because of a physical, mental or emotional problem. The three responses categories include no, yes, or unable to work.

We assess whether the model including the interaction between education and each resource is a better fit to the data than a model including only the main effects by comparing the Akaike information criterion (AIC) and Bayesian information criterion (BIC) between the two models. We use both criteria because AIC runs the risk of choosing too big a model while BIC runs the risk of choosing too small a model (Dziak et al. 2012). We consider the interaction model to be preferred if it contains a statistically significant interaction term and has a smaller AIC and BIC. All models were estimated with SAS Version 9.3 using PROC SURVEYLOGISTIC. The models were weighted by the eligibility-adjusted sample weights and accounted for the complex sample design of the NHIS-LMF. The model coefficients were then analyzed with PROC MIANALYZE to account for the multiple imputation procedure.

The second part of the analysis provides insights into whether social, economic, and behavioral resources can potentially attenuate, or even erase, the mortality disadvantage of low levels of education; and whether a lack of these resources can attenuate, or even erase, the mortality advantage of high levels of education. To address this question, we plot the probability of death, and 95 percent confidence intervals, for each education–resource combination estimated from the models above.

Results

Descriptive characteristics of the sample by gender and education are provided in Table 1. The association between education and each resource is in the expected direction. For example, 30 % of women without a high school credential were

Table 1 Demographic characteristics of U.S.-born, non-Hispanic white and black adults aged 30–84 by educational attainment, NHIS-LMF 1997–2006

	Women										Men									
	0–11 Years		High school		Some college		Bachelor's degree		Post-graduate		0–11 Years		High school		Some college		Bachelor's degree		Post-graduate	
	%	#D[a]	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D
Marital status[b]																				
Married	46.2	354	64.4	641	64.3	346	70.0	112	66.5	53	63.3	720	68.2	928	70.2	585	73.3	268	78.4	189
Not married	53.8	1245	35.6	1296	35.7	695	30.0	203	33.5	102	36.7	885	31.8	837	29.8	590	26.7	219	21.6	131
Employment status																				
Employed	30.3	136	56.0	321	67.2	245	72.3	87	76.8	48	47.0	228	73.7	472	80.2	404	84.1	192	82.5	128
Not employed	69.7	1463	44.0	1616	32.8	796	27.7	228	23.2	107	53.0	1377	26.3	1293	19.8	771	15.9	295	17.5	192
Family income[c]																				
Not poor	41.0	449	68.9	964	78.1	583	89.4	228	92.3	121	53.7	634	77.3	1123	84.9	830	92.1	403	93.4	274
Poor	59.0	1150	31.1	973	21.9	458	10.6	87	7.7	34	46.3	971	22.7	642	15.1	345	7.9	84	6.6	46
Smoking status[d]																				
Never smoked	44.7	661	50.9	814	53.0	399	65.3	143	68.1	73	23.1	261	35.7	386	42.4	243	58.1	148	63.1	121
Ever smoked	55.3	938	49.1	1123	47.0	642	34.7	172	31.9	82	76.9	1344	64.3	1379	57.6	932	41.9	339	36.9	199
Obesity status																				
Not obese	67.8	1131	74.6	1442	75.4	778	83.3	255	85.1	125	72.3	1237	73.7	1378	73.7	902	80.9	402	82.0	251
Obese	32.2	468	25.4	495	24.6	263	16.7	60	14.9	30	27.7	368	26.3	387	26.3	273	19.1	85	18.0	69
Race																				
White	77.4	1144	87.2	1649	87.0	860	91.6	269	92.3	132	80.6	1165	87.4	1494	88.6	987	94.1	451	95.6	298
Black	22.6	455	12.8	288	13.0	181	8.4	46	7.7	23	19.4	440	12.6	271	11.4	188	5.9	36	4.4	22

Table 1 continued

	Women										Men									
	0–11 Years		High school		Some college		Bachelor's degree		Post-graduate		0–11 Years		High school		Some college		Bachelor's degree		Post-graduate	
	%	#D[a]	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D	%	#D
Age (average years)	60.2		54.2		49.9		47.5		50.2		57.8		51.0		49.5		49.0		53.0	
Total number of deaths		1599		1937		1041		315		155		1605		1765		1175		487		320

[a] *#D* number of deaths

[b] *Not married* includes never married, divorced, separated, and widowed

[c] *Poor* refers to a family income-to-poverty ratio <2.0. The threshold is set at 2.0 rather than the standard poverty threshold of 1.0 to ensure that cell sizes in the table were large enough for reliable mortality estimates

[d] *Ever smoked* includes current and former smokers

employed compared to 56 % of women with a high school credential, 67 % of women with some college, 72 % of women with bachelor's degrees, and 77 % of women with post-graduate degrees. The table also shows that the number of deaths within each gender–education–resource combination is sufficiently large for robust mortality estimates.

Of interest for the second aim of this study are individuals on the "off-diagonals"—that is, low-educated individuals who have these resources and high-educated individuals who do not. Indeed, despite the strong correlation between education and each resource, many low-educated adults had these resources. Among women without a high school credential, 46 % were married, 30 % were employed, 41 % were non-poor, 45 % had never smoked, and 68 % were not obese. In contrast, many high-educated adults did not have these resources. Among men with a post-graduate degree, 22 % were not married, 18 % were not employed, 7 % were poor, 37 % had ever smoked, and 18 % were obese.

Educational Attainment and Women's Mortality

To assess the extent to which the five resources moderate the education–mortality association among women, we estimate several models in Table 2. Model 1 estimates the association between education and the log-odds of death, controlling for age and race. Compared to women with 0–11 years of education, the odds of death were 29 % $[100(e^{-0.344}-1)]$ lower among women with a high school credential, 38 % lower among women with some college education, 55 % lower among women with a bachelor's degree, and 64 % lower among women with a post-graduate degree; the comparisons are significant at $p < 0.001$. After adjusting for the five resources in model 2, the log-odds coefficients are attenuated by 36–50 % but remain significant at $p < 0.001$. Consistent with our hypotheses, these resources explain a substantial portion of the education–mortality association but other resources (e.g., psychological, cognitive) and direct effects are also important.

Models 3–7 examine the extent to which the education–mortality association is moderated by the five resources. Each model includes an interaction between education and one resource, while controlling for age, race, and the other four resources. In all five models the interaction is statistically significant and the AIC is smaller than one obtained from an ancillary model without the interaction, suggesting that these resources condition the effects of education on women's mortality.

Three patterns emerged from the results in Table 2. First, the mortality benefits of increasingly higher levels of education are significantly greater among women who were employed (model 3) or not poor (model 4), supporting the theory of resource multiplication. This conclusion is based on the negative coefficients for the education-by-resource interactions which generally become larger with each level of education. The findings are clearly illustrated in Fig. 2. It displays the probability of death and 95 % confidence intervals estimated from the five models.[5] For instance, the annual probability of death among women who were poor ranged from

[5] Probabilities are estimated for non-Hispanic white women aged 60 with no work limitations.

Table 2 Coefficients predicting the log-odds of death among non-Hispanic white and black women aged 30–84 years

	1	2	3	4	5	6	7
Intercept	−9.244***	−7.717***	−7.744***	−7.576***	−7.746***	−7.698***	−7.828***
Age	0.083***	0.070***	0.069***	0.071***	0.069***	0.070***	0.070***
White	−0.377***	−0.277***	−0.280***	−0.270***	−0.280***	−0.278***	−0.282***
Education (REF: 0–11 years)							
High school ("HS")	−0.344***	−0.171***	−0.114*	−0.064	−0.146**	−0.206***	−0.001
Some college ("SC")	−0.472***	−0.269***	−0.266***	−0.196***	−0.151*	−0.308***	−0.106
Bachelor's degree ("BD")	−0.808***	−0.509***	−0.330***	−0.316***	−0.379*	−0.611***	−0.395*
Post-graduate ("PG")	−1.025***	−0.656***	−0.625***	−0.417***	−0.242	−0.772***	−0.255
Married			−0.202**				
Education × married							
HS × married			−0.155†				
SC × married			−0.040				
BD × married			−0.383**				
PG × married			−0.106				
Employed				−0.317**			
Education × employed							
HS × employed				−0.265*			
SC × employed				−0.198			
BD × employed				−0.395*			
PG × employed				−0.545**			
Not poor[a]					−0.147*		
Education × not poor							
HS × not poor					−0.093		
SC × not poor					−0.242*		
BD × not poor					−0.235		

Table 2 continued

	1	2	3	4	5	6	7
PG × not poor					−0.584*		
Never smoked						−0.698***	
Education × never smoked							
HS × never smoked						0.087	
SC × never smoked						0.101	
BD × never smoked						0.240†	
PG × never smoked						0.256	
Not obese							0.137*
Education × not obese							
HS × not obese							−0.235**
SC × not obese							−0.224*
BD × not obese							0.160
PG × obese							−0.513*
All covariates[b]		√	√	√	√	√	√
AIC (model shown)	34,536,844	33,788,177	33,787,872	33,208,121	33,785,579	33,792,186	33,786,874
AIC (main effects model)[c]	34,536,844	33,788,177	33,795,888	33,215,609	33,795,888	33,795,888	33,795,888

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, † $p < 0.10$ (two-tailed tests)

[a] Non-poor is defined as having a family income-to-poverty ratio of 2.0 or higher

[b] Models 2–7 adjust for the other four resources not included in the education-by-resource interaction

[c] *AIC* Akaike information criterion. Smaller AIC values for the models that include the education-by-resource interaction terms (shown in table) compared to models that include only main effects of education and the resource (not shown but available on request) indicate that the interaction model is a better fit to the data

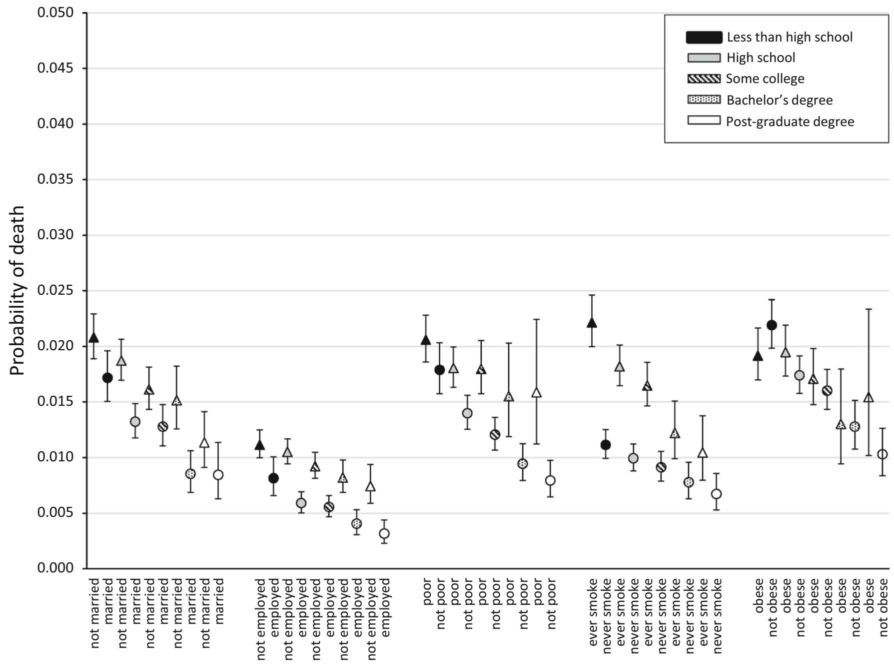

Fig. 2 Annual probability of death among non-Hispanic white women aged 60 years by education level, NHIS-LMF 1997–2006. Estimates were obtained from logistic regression models in Table 2

0.021 for women without a high school credential (black triangle) to 0.016 for women with a post-graduate degree (white triangle). Because the confidence intervals for these two groups overlap, the difference is not statistically significant at $\alpha = 0.05$. The probability of death among women who were *not poor* ranged from 0.018 for women without a high school credential (black circle) to 0.008 for women with a post-graduate degree (white circle)—a reduction which is highly significant and twice as large as the reduction among poor women.

In contrast to the pattern for employment and income, where the mortality benefits of education were greater for advantaged women, the pattern for smoking in model 6 shows that the mortality benefits of education were greater for disadvantaged women, supporting the theory of resource substitution. The mortality benefits of education are greater for women who ever smoked because the combination of low education and smoking greatly exacerbates the risk of death. The probability of death among women who ever smoked ranged from 0.022 for women without a high school credential to 0.010 for women with a post-graduate degree, a drop of 0.012. In contrast, the probability of death among women who never smoked declined from 0.011 to 0.007 (a drop of just 0.004). Lastly, while not as striking as the patterns for employment, income, and smoking, the patterns for marriage in model 3 and obesity in model 7 show that the mortality benefits of education were generally (but not always) greater among women who were married or not obese.

Using Fig. 2, we address our second aim which is to glean insights into whether the five resources can potentially attenuate the mortality disadvantage (advantage) of low (high) education. In general the patterns imply that these resources can indeed attenuate, and sometimes erase, the mortality advantages and disadvantages associated with educational attainment. For example, married women without a high school credential had a similar probability of death (0.017) as unmarried women with a high school credential (0.019). The findings imply that, *ceteris paribus*, unmarried women without a high school credential experience a similar mortality reduction through either a high school credential or marriage. The patterns for income are similar. For instance, the probability of death among women without a high school credential who were not poor is similar to the probability of death among women with a high school credential or some college but who were poor.

The patterns for employment and smoking are particularly striking. Employed women had mortality rates that were similar to or less than non-employed women, *regardless of educational attainment.* For example, the probability of death among women without a high school credential who were employed (0.008) is similar to the probability of death among women with a post-graduate degree who were not employed (0.007). Recall that the employment models adjust for health-related ability to work in order to account for health-selection into employment. As a striking illustration of the deleterious effects of smoking, the figure shows that women who achieved a post-graduate degree but had ever smoked had a similar probability of death as women who did not graduate high school but never smoked. Smoking essentially erased the mortality benefits of higher education. Lastly, in contrast to the other four resources, the patterns for obesity are not as pronounced.

Educational Attainment and Men's Mortality

Compared to men with 0–11 years of education, the odds of death were 27 % [$100(e^{-0.308}-1)$] lower among men with a high school credential, 32 % lower among men with some college, 52 % lower among men with a bachelor's degree, and 59 % lower among men with a post-graduate degree; the comparisons are significant at $p < 0.001$. After adjusting for the five resources in model 2, the log-odds coefficients are attenuated by 43–58 % but remain significant at $p < 0.001$.

Educational attainment and these resources combine to shape mortality somewhat differently for men compared to women. First, while each of the five resources moderated the effect of education on women's mortality, just two of these resources—marriage and employment—conditioned the effect of education on men's mortality. Only model 3 (for marriage) and model 4 (for employment) contain significant education-by-resource interaction terms and they support the theory of resource multiplication. Figure 3 illustrates the findings. Married men and employed men generally received more mortality benefits from their education than did their unmarried or non-employed counterparts.

The mortality of married men was similar to or less than unmarried men, regardless of educational attainment. One implication is that raising education levels in the context of weakening structural supports for marriage may be countervailing forces for lowering men's (and women's) mortality. We also find that even though

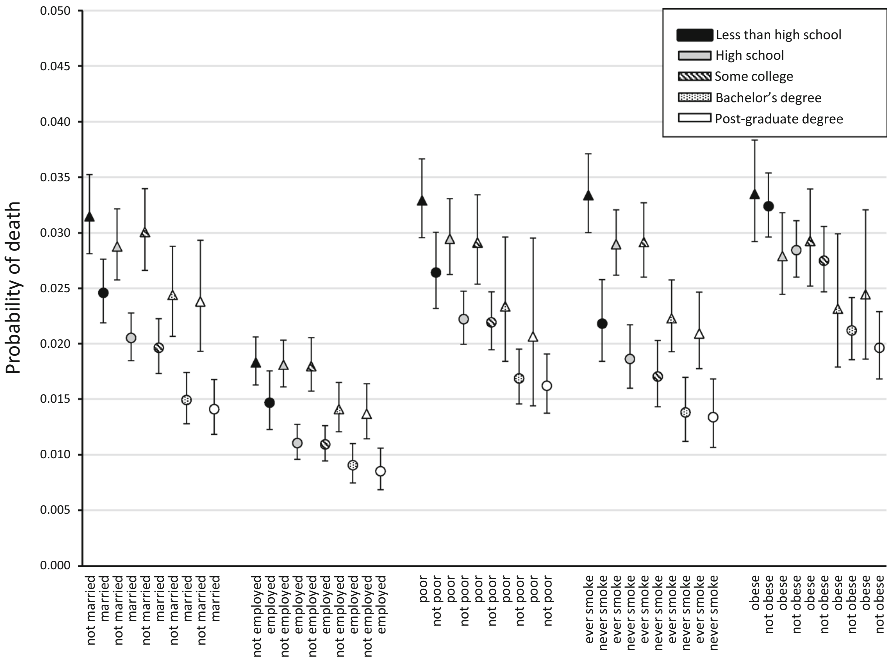

Fig. 3 Annual probability of death among non-Hispanic white men aged 60 years by education level, NHIS-LMF 1997–2006. Estimates were obtained from logistic regression models in Table 3

income, smoking, and obesity did not moderate the effects of education on men's mortality, different education–resource combinations have similar mortality risk. For example, as shown in Fig. 3, men who achieved a post-graduate degree but had ever smoked had a similar probability of death (0.021) as men who did not graduate high school but never smoked (0.022). On one hand, this suggests that smoking can erase the mortality benefits of a post-graduate degree. On the other hand, *ceteris paribus*, preventing smoking among low-educated men might have similar mortality benefits as obtaining a post-graduate education with no change to smoking behavior.

Discussion

The growing recognition of the importance of educational attainment for the health and longevity of individuals and populations has fueled an interest in education as a population health strategy. But, is raising education levels sufficient for improving population health? Or are other social, economic, and behavioral resources needed to realize the full benefits of this strategy? Can other resources compensate for low education or dilute the benefits of high education? By addressing such questions, this study contributes to scientific understanding of the efficacy of "education policy as health policy" and ways to realize the full benefits of this approach (House et al. 2008; Montez and Hayward 2014).

Consistent with extant research, we found a strong inverse association between educational attainment and adult mortality risk. To the extent that the association is causal, education substantially lowered mortality risk. However, the degree to which it lowered mortality was contingent on an individual's social, economic, and behavioral resources—especially employment, marriage, and income (for women). The mortality benefits of education were enhanced when individuals translated their educational advantage into these resources: conversely, the benefits were attenuated when individuals did not. The patterns for employment, marriage, and income (for women) support the theory of resource multiplication, which proposes that the mortality benefits of education and other resources are synergistic. Moreover, the patterns illustrate a case where mediators also act as moderators and, in this case, exacerbate inequalities (see also Mirwosky 2012; Ross et al. 2001). Specifically, because individuals with fewer resources were the same individuals whose mortality benefited less from their own education, mortality inequalities widened as education levels increased.

The mortality benefits of education were significantly enhanced when individuals were employed and/or married. The reasons are likely two-fold. First, employment and marriage generally provide access to material (e.g., income) and non-material (e.g., social support) goods which enhance health and longevity. Second, the health-promoting qualities of these goods tend to increase with education. Compared to their lower-educated peers, higher-educated adults are more likely to have jobs that entail creative work and high wages, and they are more likely to marry higher-educated spouses. To be clear, education was also associated with lower mortality for adults who were not employed or married, as it provides access to myriad other resources. Nonetheless, employment and marriage appear to be particularly important engines for converting education into a lower risk of death.

Another noteworthy finding is that the synergistic benefits of education alongside other resources were most evident among women. This may reflect structural differences in the lives of men and women, which disproportionately disadvantage low-educated women. For instance, low-educated women are more likely than their male peers to be single parents, unemployed, and, partly as a result, more likely to live in poverty and report high depressive symptoms (Thurston et al. 2005). Furthermore, the social and economic resources available to low-educated women may be only marginally salubrious. When employed, low-educated women are more likely than their male peers to have tedious, low-wage jobs (Ross and Mirwosky 2006); and compared to their married male peers, they are more likely to have a low-educated spouse (Brown et al. 2014). Partly because low-educated women are markedly disadvantaged in other resources, increasingly higher levels of education are associated with stronger gains in both the quantity and quality of resources for women than they are for men, such that gender gaps in these resources converge among higher-educated adults.

Only for smoking did we find evidence for resource substitution. The combination of low education and having ever smoked was particularly deleterious for women. This finding has been reported previously, with some scholars speculating that it reflects pathophysiological sex differences (Huxley and Woodward 2011). Smoking may also exacerbate underlying health problems created by the myriad disadvantages disproportionately experienced by low-educated women, as explained above.

Another important contribution of our study is its illustration that different configurations of education and other resources (e.g., the "off-diagonals") had similar risks of death. In other words, education is not destiny. For instance, unmarried men with a post-graduate degree had a similar risk of death as married men without a high school credential (controlling for the other resources). Women with a post-graduate degree who ever smoked had a similar risk of death as women without a high school credential who never smoked (controlling for the other resources). These results may be interpreted optimistically, as they suggest that other resources might be able to compensate for low education in terms of lowering mortality risk. A less optimistic interpretation is that the mortality benefits of education are diluted when those resources are not available.

Implications

Our findings do not discount the importance of education for adult mortality risk; on the contrary, they underscore it. Adults with higher levels of education were substantially more likely to be employed, married, not poor, not obese, and never have smoked; and partly as a result they were significantly less likely to die. Education inheres in individuals the capacity to coalesce a healthy lifestyle, develop and maintain supportive social relationships, avoid financial hardship, seek and understand information about how to avoid disease, and so on, all of which reduces the risk of poor health and early death (Mirowsky and Ross 1998, 2003).

At the same time, our findings imply that the mortality benefits of education are moderated by the broader environment, at least for the context and cohorts we examined. The benefits appear to be greatest in environments where individuals can translate their education into other health-enhancing resources, in particular, employment, marriage, and income (for women). Our results corroborate a recent study finding that more-educated adults experienced greater benefits from marriage than did less-educated adults in protecting against suicide, regardless of children in the household (Denney 2014). While this multiplicative process can enhance the health and longevity of advantaged individuals, our study reveals that it can also exacerbate inequalities within the population. In essence, our results (similar to others (e.g., Denney 2014)) highlight that the importance of an individual's educational attainment for mortality risk is embedded within larger social processes. Thus, efforts to understand the extent to which raising education levels can improve population health should consider the availability of other resources within the environment and how they are distributed across education levels.

Our findings also imply that providing structural supports for stable and supportive marriages and unions, as well as expanding access to employment, could boost the health and longevity gains from rising levels of education. Likewise, trends such as shrinking employment opportunities for low-skill labor, and diminishing supports for salubrious marriages and unions, may be countervailing forces against rising education in terms of lowering mortality. These scenarios are not unrealistic. For example, increasing financial insecurity (Smock et al. 2005) and recent welfare-to-work policies (Cherlin and Fomby 2005) have deterred low-income individuals away from marriage, while the great recession has had a major impact on employment. All that said, we caution that our results do not suggest that promoting marriage for everyone at all costs would be an effective or desirable strategy. While marriage is, *on average*, associated with good health, the benefits are heterogeneous across population subgroups, with some research indicating that marriage promotion efforts could potentially harm the health of some women if those efforts do not also enhance marital stability (Williams et al. 2008). Overall, our results imply that, if the goal is to improve population health, raising education levels may be a powerful strategy combined with expanding access to other social, economic, and behavioral resources. These findings corroborate Woolf et al (2007, p. 681) who stated, "…..the amelioration of education-associated excess mortality requires more extensive social change than simply ensuring that all adults complete college or even eliminating educational disparities."

Limitations

A few limitations of the study should be noted. First, information on the five resources was collected once at the time of survey. Thus, we did not have life course exposures to these resources which may have provided additional insights. We also did not have information on other potentially relevant factors such as parity, social networks, and sense of control. Another consideration is that, given the relatively short mortality follow-up, we did not explore potential period and cohort effects. Our results may also differ by age groups; however, we could not replicate the analysis for age subgroups because many of the education-by-resource cells became too small or empty.[6] Also important to note is that the analyses do not represent true counterfactuals. For instance, when we propose that, *ceteris paribus*, other resources may be able to compensate for low levels of education, this interpretation is based on observational data that can only approximate a counterfactual by adjusting for key confounders.

Another consideration is that positive selection into higher education and other resources may have contributed to our results. Aside from an indicator of health-related ability to work, the NHIS-LMF does not contain sufficient information to assess selection. While we cannot rule out selection, we do not believe this to be a major limitation for our study. First, the significant association between employment and mortality persisted after controlling for ability to work. Moreover, the

[6] To glean some insights into whether our results were robust across age groups, in ancillary analyses we estimated the models in Tables 2 and 3 for two broad groups (ages 30–64 and 65–84) using a continuous measure of education. This measure is not ideal because several studies have found the education–mortality association among U.S. adults is non-linear (Backlund et al. 1999; Everett et al. 2013; Hayward et al. 2015; Montez et al. 2012). However, we had to use the linear measure because the categorical measure created sparse education-by-resource cells in the age-stratified analyses. The analyses generally corroborate our main findings. The mortality benefits of education were largest for adults with other resources such as marriage and employment, supporting the theory of resource multiplication, with stronger support for the younger than older age group as anticipated.

Table 3 Coefficients predicting the log-odds of death among non-Hispanic white and black men aged 30–84 years

	1	2	3	4	5	6	7
Intercept	−8.825***	−7.240***	−7.304***	−7.192***	−7.267***	−7.241***	−7.246***
Age	0.084***	0.069***	0.069***	0.072***	0.069***	0.069***	0.069***
White	−0.398***	−0.274***	−0.280***	−0.269***	−0.277***	−0.274***	−0.274***
Education (REF: 0–11 years)							
High school ("HS")	−0.308***	−0.145***	−0.091	−0.011	−0.096	−0.146**	−−0.179*
Some college ("SC")	−0.381***	−0.160***	−0.044	−0.017	−0.094	−0.136**	−0.134*
Bachelor's degree ("BD")	−0.743***	−0.423***	−0.260**	−0.264***	−0.367*	−0.415***	−0.366**
Post-graduate ("PG")	−0.889***	−0.475***	−0.274*	−0.293***	−0.447*	−0.475***	−0.308*
Married			−0.253***				
Education × married							
HS × married			−0.092				
SC × married			−0.185*				
BD × married			−0.246*				
PG × married			−0.294*				
Employed				−0.224**			
Education × employed							
HS × employed				−0.275**			
SC × employed				−0.281**			
BD × employed				−0.223			
PG × employed				−0.256†			
Not poor[a]					−0.210**		
Education × not poor							
HS × not poor					−0.093		
SC × not poor					−0.113		
BD × not poor					−0.095		

Table 3 continued

	1	2	3	4	5	6	7
PG × not poor					−0.064		
Never smoked						−0.439***	
Education × never smoked							
HS × never smoked						−0.009	
SC × never smoked						−0.116	
BD × never smoked						−0.045	
PG × never smoked						−0.023	
Not obese							−0.028
Education × not obese							
HS × not obese							0.044
SC × not obese							−0.035
BD × not obese							−0.071
PG × obese							−0.208
All covariates[b]		√	√	√	√	√	√
AIC (model shown)	202,827,575	39,827,917	39,817,282	39,273,770	39,822,791	39,823,727	39,822,388
AIC (main effects model)[c]	202,827,575	39,827,917	39,825,135	39,282,398	39,825,135	39,825,135	39,825,135

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, † $p < 0.10$ (two-tailed tests)

[a] Non-poor is defined as having a family income-to-poverty ratio of 2.0 or higher

[b] Models 2–7 adjust for the other four resources not included in the education-by-resource interaction

[c] *AIC* Akaike information criterion. Smaller AIC values for the models that include the education-by-resource interaction terms (shown in table) compared to the models that include only main effects of education and the resource (not shown but available on request) indicate that the interaction model is a better fit to the data

health and longevity benefits of resources such as marriage (Murray 2000), employment (Frech and Damaske 2012), and education (see review in Montez and Friedman 2015) persist when adjusting for selection.

Future studies may want to evaluate how race, ethnicity, and immigration structure these processes. Our sample contains few deaths among college-educated blacks so race-stratified analyses were not possible. In addition, we focused on U.S.-born, non-Hispanic whites and blacks to increase our confidence that the results reflected the effects of education rather than biases introduced by the mortality matching process (which is much lower quality for immigrants and Hispanics) and unmeasured social processes (e.g., country where education was obtained, return migration)—complexities that mainly concern the low-educated. While our sample limits generalizability, its benefits for addressing our aims greatly outweigh the costs. Separate studies of Hispanic and immigrant populations which can account for the complexities are warranted, particularly given the growing size of these populations.

Conclusions

The rise in education levels during the last half century has likely contributed to enhanced population well-being, health, and longevity. Like numerous other studies, we find that education is inversely associated with lower mortality risk; however, we add to those studies by illustrating that the benefits of education for lowering mortality are moderated by the presence of other social, economic, and behavioral resources. The mortality benefits of education for individuals are enhanced when education is converted into these resources. More generally, the results imply that the mortality benefits at the population level are contingent on the availability of these resources within the broader environment. Efforts to improve population health and longevity by raising education levels should be augmented with strategies that assure widespread access to social, economic, and behavioral resources.

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