Reassessing the Shape of the Relationship Between Education and Health*

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Abstract

This article questions the common description of the relationship between education and adult health as following a linear gradient. Instead, results of multivariate regression analyses of data from the National Health Interview Survey Disability Survey (NHIS-D) show that the relationship between education and five key measures of adult health is usually nonlinear, with the strength of the relationship significantly weakening above 12 years of schooling. An exception is the relationship between education and self-reported health, which does not flatten out at higher education levels. Subgroup analyses show that the relationship is also relatively more linear for men than women. The methodological implication is that researchers must account for this nonlinearity when assessing the links between education and health. The theoretical implication is that primary and high school education are uniquely important for health promotion.

Reassessing the Shape of the Relationship Between Education and Health

The positive correlation between education and adult health is one of the most robust relationships in the social and demographic sciences. Studies consistently find across numerous datasets and a broad range of measures of health and longevity that, for both men and women and for most racial/ethnic groups, those with higher levels of education live longer and enjoy better health on average than those with lower education levels (Cutler and Lleras-Muney 2006; Grossman and Kaestner 1997; Mirowsky and Ross 2003; Preston and Taubman 1994). In the United States, differences in health by education level range up to 7 years or more in life expectancy and up to 12 years or more in the age at which disabling health problems first onset (Molla, Madans, and Wagener 2004, table 5). Mounting evidence suggests that these differences are even larger today than they were one or two decades ago, at least among older adults (Goesling forthcoming; Schoeni et al. 2005).

Researchers often describe this relationship as following a linear gradient, such that the marginal effect on health of an additional year of schooling is roughly similar across all levels of education—that is, that the effect of an additional year of primary schooling is comparable in size to the effect of an additional year of secondary or tertiary schooling. This assumption implies that the health benefits of education extend far beyond remedial education to also include high school, university, or even post-graduate education. For example, a recent study of Swedish men even suggests that Swedes with PhDs live longer than those with "higher tertiary" degrees—a group that includes physicians, engineers, and lawyers (Erikson 2001). However, few studies have systemically tested this assumption with data for the U.S. population, and much other theory and research gives reason to believe that the relationship between education and health is instead nonlinear.

In this article I add to research on the relationship between education and health by reexamining the basic shape of this relationship. In particular, I want to determine whether the relationship is in fact linear, or whether the effect of education is instead more concentrated at certain periods of a individual's educational career. I compare the hypothesis of a linear relationship with two nonlinear alternatives and test these hypotheses with data from a large nationwide health survey of the U.S. population. Because there are large differences in both health and education between men and women, I also examine whether the shape of the relationship varies by gender.

Although I sometimes refer to the association between education and health in terms of the "effect" of education on health, readers should not take the term too literally, because at least part of the association likely reflects the spurious effects of unmeasured third factors such as family social background, childhood health problems, or genetic traits. However, as I explain below, recent studies demonstrate that such unmeasured third factors cannot totally or primarily explain the strength of association, so at least part of the relationship must reflect a causal effect.

Background and Significance

Determining the basic shape of the relationship between education and health is important for two main reasons. One is to establish how to best measure the education effect in studies of health and longevity. To date, many studies have measured education using a simple linear indicator of the number of years of formal schooling completed, reflecting the assumption of a linear gradient. But this approach will yield misleading results if the effects of education are instead nonlinear.

Note that this measurement issue has implications for the health literature beyond the subset of studies focusing specifically on the relationship between education and health. In typical regression analyses, the bias introduced by misspecifying the shape of the relationship between predictor and outcome variables plagues the parameters estimates associated with all of the variables in the model, not just the estimates associated with the misspecified variable (Wooldridge 2006, pp. 98-99). This means that the proper measurement of the effect of education concerns not only those studies focusing mainly on education but also the many additional studies that include education as a secondary variable of interest or control variable.

More broadly, determining the shape of the relationship is also important to further knowledge of the possible mechanisms or pathways by which education improves health. Recent studies have made progress in establishing that at least part of the relationship reflects a causal effect of education on subsequent health rather than the spurious effect of unmeasured third factors like family social background, childhood health conditions, or genetic traits. For example, drawing on decennial census data for several U.S. birth cohorts, Lleras-Muney (2005) shows that the association between education and adult mortality risk persists when estimating the association with the seemingly exogenous variation in education levels produced by changes in compulsory schooling laws. Likewise, Hayward and Gorman (2004, table 4) find in data from the

National Longitudinal Study of Older Men (NLS) that the relationship between education and adult mortality persists after adjusting for a broad range of childhood social and economic conditions, including family socioeconomic position, family living arrangements, mother's work status, and parents' nativity. However, although these studies help establish causality, still uncertain are the specific mechanisms or pathways by which the process works.

Evidence of a linear relationship has been used to support claims that education serves primarily as a proxy for an individual's rank or social standing. For example, Marmot (2004, pp. 75-78) cites evidence of a roughly linear relationship between education and mortality risk to support his provocative and influential "status syndrome" hypothesis, which holds that social rank or standing has become a prime determinant of health and longevity in contemporary rich societies.

Marmot's (2004) hypothesis hinges especially on the persistence of the relationship between education and health at very high levels of education—for example, at more than 12 or 16 years of schooling completed. He argues that although differences in material living conditions or other common health-risk factors might explain a finding of better health among college graduates than among people with very low levels of education, such differences cannot explain a finding of better health among people with doctor's or lawyer's degrees than among those with somewhat lower post-graduate or college degrees, because there are scant differences in common health-risk behaviors among the highest education groups, and because few people in these groups suffer from poor material living conditions. For Marmot, then, evidence of a persistent relationship between education and health across the entire range of education levels suggests the presence of other factors at work, and he focuses on the possible deleterious effects of low social rank or standing.

However, other theory and research questions these assumptions and instead suggests that the effects of education are more concentrated at certain points of an individual's educational career. For example, much developmental theory and research suggests that educational experiences occurring relatively in early in the life course are most important in determining later adult outcomes, because childhood experiences form the foundation on which all later physiological, cognitive, and socioemotional development is built (Knudsen et al. 2006). Early educational experiences also teach the basic reading and comprehension skills that later aid basic health-promoting activities such as reading the nutritional information on food labels, finding and utilizing basic health care services, following a doctor's prescribed treatment regimen, and understanding the risks posed by unhealthy behaviors such as cigarette smoking, drug abuse, and heavy drinking (Mirowsky and Ross 2003). Moreover, the failure to complete very minimum levels of education often has with severe economic consequences, because most job opportunities in industrialized societies now require the completion of at least secondary education. For these reasons, one might expect the effect of education on health to be strongest for primary or early secondary schooling and then diminish for later high school and especially college education.

Yet other research predicts the opposite pattern of a strengthening effect of education on health at higher levels of education. For example, the findings of Goldman and Smith (2002) suggest that, given today's highly complex health services and technologies, the more complex skills and knowledge students obtain only in higher levels of schooling are becoming increasingly important for health promotion. As examples they cite the complex treatment regimens now used to manage diseases like HIV and diabetes, and show in both observational and experimental data that highly educated individuals are more successful in managing these diseases than people with lower levels of education.

Moreover, higher education also coincides with a period in the life course in which individuals begin making more independent decisions about the adoption of health-risk behaviors such as cigarette smoking and drug use, and research shows that such decisions have important and long-standing consequences for behavioral patterns extending throughout adulthood. For example, Merline et al. (2004, table 3) show in data from the national Monitoring the Future Study that the odds of cigarette smoking at age 35 are *42 times higher* for individuals who smoked daily during their senior year of high school than for individuals who had never smoked by the time of their senior year. They found similar results for a range of health-risk behaviors, including heavy drinking, marijuana use, cocaine use, and the misuse of prescription drugs. These findings suggest that educational experiences occurring in adolescence and early adulthood might have particularly important consequences for adult health and health behaviors.

Finally, it is also likely that all of these processes interact with other social and demographic factors such as race/ethnicity and gender. For example, with respect to gender, prior research shows large and important gender differences in educational achievement and attainment (Buchmann and DiPrete 2006; DiPrete and Buchmann 2006), in rates of mortality, disability, and limitation in physical functioning (Case and Paxson 2005), and in important health-risk behaviors like cigarette smoking, poor diet and body mass, and low physical activity (Umberson 1992). Given these differences, it is likely that the shape of the relationship between education and adult health varies by gender as well.

Recent Evidence

Recent empirical studies of the shape of the relationship has focused mostly on the issue of so-called "credentialing" or "sheepskin" effects. These effects refer to the possible additional health benefits of selected educational credentials such as a high school degree or a college degree in addition to the benefits associated with completing an additional year of schooling. The logic behind such effects derives from "signaling" theory in economics (Spence 1973) and credentialing theory in sociology (Berg 1970; Collins 1979). To date, studies have found little evidence of credentialing effects in the relationship running from education to health (Ross and Mirowsky 1999), but this does discount the possibility that the overall relationship between education and health is in some way nonlinear.

Other evidence comes from Erikson's (2001) study of mortality rates among Swedish adults. As noted above, this study suggests that the relationship between education and adult mortality risk persists through the highest levels of education levels. Specifically, Erikson found a significantly lower six-year mortality rate among Swedish men with Ph.D.'s than among with men with slightly lower post-graduate degrees. However, he also found evidence of a more curvilinear relationship among women, with the strength of the relationship diminishing at higher levels of education.

Mirowsky and Ross's (2003) comprehensive study of the links between education and health among U.S. adults also shows evidence of diminishing effects of education on health at higher levels of schooling, including for measures of self-reported health (p. 37), limitation in physical functioning (p. 40), vitality and emotional well-being (p. 43), and diagnoses of serious chronic diseases (p. 46). They based their analyses primarily on data from the 1995 survey of Aging, Status, and Sense of Control (ASOC), a national telephone survey of U.S. households. In related work, Ross and Mirowsky (1999, p. 451) note that "health's association with years of schooling is essentially linear, although perhaps not entirely," and that simple bivariate plots of the relationship between years of schooling and health "suggest a leveling off of physical functioning and perceived health at the master's degree level" (p. 451). They caution that their findings are limited by the relatively small sample size of their ASOC study, but in the present study I can overcome this limitation by using data for a larger study sample.

Data and Methods

Data and Study Sample

The data are from Phase I of the National Health Interview Survey Disability Survey (NHIS-D), conducted in 1994 and 1995 as a supplement to the "core" survey of the annual National Health Interview Survey (NHIS). The sample consists of the members of a nationally representative sample of U.S. households selected using a multistage clustered sampling design. Data were collected for all members of selected households, through self-reports for respondents ages 17 and older and through proxy response for children and for adults not present at the time of the interview. I used the NHIS-D instead of a more recent wave of the NHIS, first, because the NHIS-D includes a broader range of health measures than the standard core survey of the NHIS and, second, because in 1997 the NHIS switched to a new degree-based measure of educational attainment that does not permit an assessment of the shape of the relationship between years of schooling and adult health.

The NHIS-D includes detailed information on health, education, and other demographic characteristics for a total of 205,560 respondents, but I limited the analysis to the 32,701 respondents ages 60 and older, because most of the health problems measured in the survey are relatively uncommon among younger adults. Simultaneity bias—the bias caused by the relationship between education and health at least partly reflecting the impact of childhood health problems on subsequent educational attainment—is also a greater concern when among younger adults, because most of the health problems reported among adults ages 40 and younger are concentrated among those with very low levels of education, and it is likely that most of these problems were not caused by a lack of education but by preexisting health conditions from childhood. I excluded an additional 378 respondents with missing education data and 200 respondents with missing data on the measure of self-reported health status (described below), resulting in a final analytic sample of 32,123 adults ages 60 and older.

To account for the survey's complex sampling design, I used survey sample weights throughout the analysis. The weights include adjustments for nonresponse and the probability of selection as well as a post-stratification adjustment for gender, age, and race/ethnicity. I adjusted standard errors to account for the stratification and clustering employed in the sampling design using the survey estimation commands in Stata statistical software (StataCorp 2005).

Measures

Health is a multidimensional concept encompassing both physical and mental factors. Because there is no single best measure of health, I examine the shape of the relationship between education and five different health outcomes: disability in activities of daily living (ADLs); disability in instrumental activities of daily living (IADLs); limitation in physical functioning; self-reported health status; and mental health.

For the measure of ADL disability, respondents were first asked whether they receive help from another person or use special equipment in performing any of the following six activities: bathing or showering; dressing; eating; getting in and out of bed or chairs; toileting; and getting around inside the home. Respondents who answered no to this set of questions were then asked if they have any difficulty in performing these activities. I counted as disabled anyone receiving help from another person, using special equipment, or having difficulty in performing a given activity, and summed the items to form a single scale ranging from 0 for respondents with no reported disability to 6 for respondents with a reported disability in all six activities.

Respondents were asked a similar set of questions about disability in performing IADLs. For this measure, respondents were asked if they receive help from another person or have difficulty in performing the following six activities: preparing meals; shopping for personal items; managing money; using the telephone; doing heavy housework (e.g., scrubbing floors or washing windows); and doing light housework (e.g., doing dishes or taking out the trash). I summed these items to create a measure of IADL disability ranging from 0 to 6.

For the measure of limitation in physical functioning, respondents were asked if they had difficulty in performing the following eight activities: lifting something as heavy as 10 pounds; walking up 10 steps; walking a quarter of a mile; standing for about 20 minutes; bending down from a standing position; reaching up over the head; using fingers to grasp; and holding a pen or pencil. I summed these items to create a measure of functional limitation ranging from 0 to 8.

For the measure of self-reported health status, respondents were asked to assess their own health on a five-point scale ranging from “poor” to “excellent.” Self-reported health status is one of the most commonly used health indicators in social scientific survey research, and studies have consistently shown such measures to have high test-retest reliability (Lundberg and Manderbacka 1996) and to strongly predict mortality risk and other health outcomes (Benjamins et al. 2004; Idler and Benyamini 1997).

Finally, for the mental health measure, respondents were asked seven yes or no questions relating to different aspects of mental and emotional health. Questions included whether respondents are frequently depressed; whether they have trouble making or keeping friendships; whether they have a lot of trouble getting along with other people in social settings; whether they have trouble concentrating long enough to complete everyday tasks; whether they have any serious difficulty coping with day-to-day stressors; whether they are frequently confused, disoriented, or forgetful; and whether they have any phobias or unusually strong fears. I summed these items to create a scale ranging from 0 for respondents with no reported mental or emotional health issues to 7 for respondents reporting all seven issues.

To check the robustness of my results, I also performed the analysis using dichotomous versions of each health measure. For the measure of self-reported health, the dichotomous indicator compared respondents reporting "fair" or "poor" health with those reporting "good," "very good," or "excellent" health. For the other four health measures, the dichotomous indicators compared respondents reporting any disability, functional limitation, or mental health problem with those reporting no disability, limitation, or problem. Results were similar.

I measured education using a self-report of the highest level of formal schooling completed. Response categories range from "0 years" to "18 or more years" in one-year increments. I also included a limited set of demographic control variables for race (coded black, white, and other), gender, and age.

Statistical Analysis

To determine the shape of the relationship between education and health, I used two complimentary methods: quadratic regression models and piecewise linear spline regression models. For the quadratic models, I first estimated a simple linear regression of health on a quadric function of educational attainment:

$$h_i = \alpha + \beta_1 e_i + \beta_2 e_i^2 + \mathbf{x}_i \boldsymbol{\delta} + u_i \quad , \qquad (1)$$

where h is the value of the selected health measure for the ith individual, e is years of schooling, $\mathbf{x}$ is a row vector of control variables, $\boldsymbol{\delta}$ is a column vector of coefficients, and u is an error term. Because I coded the health measures with higher values representing worse health, I expect a negative coefficient for the linear education term (β_1), indicating that health improves with higher levels of education. The main results of the analysis then hinge on the coefficient β_2. The value of this coefficient indicates whether the shape of the relationship between education and health is linear ($\beta_2 = 0$), curvilinear with the strength of the relationship declining at higher levels of education ($\beta_2 > 0$), or curvilinear with the strength of the relationship increasing at higher levels of education ($\beta_2 < 0$). I base my main conclusions on the direction of this coefficient.

If the shape of the relationship is linear, then the coefficient β_1 represents the marginal effect on health of an additional year of education. But if the relationship is nonlinear, then the marginal effect of an additional year of education varies by level of education, and I compute the marginal effect as follows:

$$\Delta h = \beta_1 + \beta_2\left[(e+1)^2 - e^2\right] \quad . \qquad (2)$$

One problem with this model is that the skewed distributions of my health variables (described below) threaten two standard linear regression assumptions. One is the assumption of normally distributed errors, and the other is the assumption of equal error variance across levels of the independent variables. I avoid the bias associated with skewed error distributions because the central limit theorem renders this assumption unnecessary in the context of large sample sizes (Wooldridge 2006, ch. 5). I addressed the problem of unequal error variance by reporting and calculating significance tests with robust standard errors (Wooldridge 2006, ch. 8). Researchers often address such problems by switching to alternative nonlinear models like poisson regression or ordered logistic regression (Long 1997), but one of the top goals of this analysis is to test for a linear relationship between education and health, and it is impossible to test for a linear relationship with nonlinear models.

To test the robustness of my results to an alternative modeling strategy, I also estimated a piecewise linear spline regression that allows the strength of the relationship between education and health to vary across different parts of the education distribution (Zeng and Xie 2004, p. 1093):

$$h_i = \alpha + \beta_1 s_1(e_i) + \beta_2 s_2(e_i) + \beta_3 s_3(e_i) + \mathbf{x}_i \boldsymbol{\delta} + u_i \quad , \tag{3}$$

where:

$$s_1(e_i) = \begin{cases} e & e \le 12 \\ 12 & e > 12, \end{cases}$$

$$s_2(e_i) = \begin{cases} 0 & e \le 12 \\ e-12 & 12 < e \le 16 \\ 4 & e > 16, \end{cases}$$

$$s_3(e_i) = \begin{cases} 0 & e \le 16 \\ e-16 & e > 16. \end{cases}$$

The spline function works by estimating a separate coefficient for each of three different education groups: 0-12 years; 12-16 years; and 17 or 18+ years. The resulting coefficients denote the health improvement associated with an additional year of schooling for the first 12 years of schooling (β_1), for years 12 through 16 (β_2), and for years 17 and above (β_3). I chose the cut-off points, or "knots," at 12 and 16 years of education to roughly correspond with the assignment of major educational credentials. Note that although this specification allows the strength of the relationship between education and health to vary across groups, it assumes a linear relationship within each group.

Finally, to determine whether the shape of the relationship between education and health varies by gender, I estimated separate models for men and women. Samples sizes were too small to examine possible differences by race/ethnicity.

Results

Table 1 reports basic descriptive statistics for the total study sample. The average age of the sample is roughly 71 years, and the average education level is just under 11 years. Approximately 86 percent of the sample is white and 58 percent is female.

TABLE 1 ABOUT HERE ------ Descriptive statistics

The means for several of the health measures are low because the majority of respondents report having no disability, functional limitation, or mental or emotional health problem. Additional descriptive analyses (not reported, but available upon request) show that more than 80 percent of respondents report having no type of IADL disability, and more than 90 percent report having no type of ADL disability. About 68 percent of respondents report no limitation in physical functioning, and 86 percent report no mental or emotional health problems. These figures are comparable to those reported in other recent studies of the elderly population (Freedman et al. 2004). I discussed how these skewed distributions threaten standard linear regression assumptions in the methods section above.

Table 2 shows a more detailed description of the distribution of educational attainment. Because the NHIS collects data for such a large sample of respondents, the study sample includes at least 100 respondents at each level of education, including nearly 1,500 respondents with less than five years of schooling and more than 4,400 respondents with 16 or more years of schooling. These figures confirm that the data include enough respondents at each level of education to accurately measure the strength of the relationship between education and health across the entire range of the education distribution.

TABLE 2 ABOUT HERE ------ Education distribution

Table 3 reports the quadratic regression results. To save space, I report coefficients for the linear and squared education variables but not for the demographic control variables included these models. The results corroborate the well-known finding of a strong association between education and health. Because I coded the health variables with higher values representing worse health, the negative coefficients for the linear education variable denote a significant association between higher levels of education and improved health. This finding holds across all five health indicators.

TABLE 3 ABOUT HERE ----- Quadratic regression results

To get a better sense of the magnitude of the effects, one can compare the coefficients for the linear education variable with the means for the health measures reported earlier in table 1. The linear coefficients imply that each additional year of education comes with at most a 10 percent decline in the mean number of reported ADL disabilities (i.e., .0320/.32 = .10), a 14 percent decline in the mean number of reported IALD disabilities, an 8 percent decline in the mean number of reported functional limitations, and a 12 percent decline in the mean number of reported mental or emotional health problems. There is no easy metric with which to interpret the results for self-reported health, but in additional analyses I estimated a comparable model with a dichotomous version of this measure and found that each additional year of education comes with a 2 percentage point decline in the probability of reporting fair or poor health as opposed to good, very good, or excellent health.

These calculations assume that the effects of education hold constant across the entire education distribution. However, the results in table 3 also show strong evidence that the shape of the relationship is in fact nonlinear. I described earlier how a number of factors predict that the effects of education are strongest early in a person's educational career and then diminish with higher levels of schooling. The positive coefficients for four of the five squared education variables strongly support this claim. These coefficients imply that the relationship between education and health is strongest at lower levels of education and then weakens with each additional year of schooling.

To illustrate, consider the variable effects of education on the measure of ADL disability. The results in table 3 imply that the marginal effect of an additional year of schooling on the number of reported ADL disabilities narrows from -.0248 for the difference between 4 and 5 years of education, to -.0184 for the difference between 11 and 12 years, to -.0056 for the difference between 16 and 17 years (see equation 2 above). Put another way, the marginal effect is more than four times greater for the difference from 4 to 5 years than for the difference from 16 to 17 years. Similar patterns hold for the measures of IADL disability, functional limitation, and mental and emotional health.

An exception is the relationship between education and self-reported health. Results for this measure show the opposite pattern of a strengthening relationship at progressively higher levels of education. For self-reported health, the marginal effect of an additional year of schooling is roughly twice as great for the difference from 16 to 17 years of schooling than for the difference from 4 to 5 years. I discuss why the results for self-reported health might differ in the discussion section below.

Table 4 reports results of the piecewise linear spline regressions. The quadratic regression models capture the curvilinear relationship between education and health by allowing the linear effect to vary at different levels of schooling. Instead, the linear spline regressions capture the nonlinearity by estimating the strength of the relationship separately for three different education groups. For example, the results for ADL disability show that each additional year of schooling comes with a .0193 decline in the number of reported disabilities for the first 12 years of schooling, a .0072 decline in the number of reported disabilities for years 13 through 16, and a .0142 decline in the number of reported disabilities for any additional years of schooling.

TABLE 4 ABOUT HERE ------ spline regression models

The results of these models further support the hypothesis of stronger educational effects at lower levels of schooling. All five coefficients for the lowest education group are statistically significant at the .001 level, but only three of five coefficients are significant at this level for the middle education group, and only one coefficient is statistically significant for the highest education group. These findings suggest that the relationship between education and health is strongest below 12 years of education and then diminishes among high school and especially college graduates. Only the results for self-reported health status again show evidence of a significant relationship across all education levels.

It is possible that I biased the spline regression models in favor of finding stronger effects at lower education levels by including a greater number of respondents and more variation in education levels in the lowest education group than in the two higher groups. The lowest education group ranges from 0 to 12 years of education and includes roughly 72 percent of the total study sample, whereas the middle group ranges from 13 to 16 years and includes about 21 percent of the sample, and the top group ranges from 17 to 18+ years of education and includes about 6 percent of the sample. To address this possible source of bias, I checked the sensitivity of the results to several other coding schemes, including the subdivision of the lowest education group into two groups at 9 years of education, the exclusion of respondents with less than 9 years of education from the study sample, and the adjustment of the top group to begin at 14 or 15 years of education instead of 16 years. Results were similar.

Table 5 examines possible gender differences. This table reports results of quadric regression models estimated separately by gender. Earlier I described how prior research shows large and important gender differences in both health and education. The results in table 4 suggest that the shape of the relationship between education and health varies by gender as well. For women, the coefficient for the squared education variable is positive and significant for the measures of disability and functional limitation, positive but nonsignificant for the measure of mental and emotional health, and negative and significant for the measure of self-reported health. These results are generally consistent with the findings for the total study sample, showing a diminishing effect of education for most health outcomes. For men, however, the coefficient for the squared education term is positive for four of the five health outcomes, but only for the measure of IADL disability does the coefficient reach statistical significance at the five percent level. The results for self-reported health are similar for both men and women.

TABLE 5 ABOUT HERE ----- Quadratic regressions, by gender

To better illustrate the magnitude of these gender differences, figure 1 plots a range of predicted values of IADL disability by education level and gender. I calculated these values from the gender-specific quadratic regression models reported in table 5. Consistent with the results of prior research, the results show sizeable gender differences in levels of reported IADL disability, with women reporting greater disability than men at all levels of education. Moreover, new findings show gender differences in the shape of the relationship between education and health, such that the relationship is more linear among men and more curvilinear among women. For both men and women, the strength of the relationship levels off after roughly 12 years of education. Gender differences in the shape of the relationship mean that average differences in health between men and women are generally smaller among those with higher education levels.

FIGURE 1 ABOUT HERE ----- IADL disability, by ed and gender

Discussion and Conclusion

The results of this study question the common description of the relationship between education and adult health as a linear gradient. Instead, results of both quadratic regression models and piecewise linear spline regression models show that the relationship between education and five key measures of adult health is usually nonlinear, with the strength of the relationship diminishing at higher levels of education. The results support the well-known finding that education is strongly predictive of adult health, but also add to this finding by showing that educational effects are relatively strongest below 12 years of education and then diminish among high school and especially college graduates. I find no evidence of a linear "gradient" in health.

An exception is the relationship between education and self-reported health. For this measure I find the opposite pattern of a strengthening relationship at higher levels of education. This finding implies that college graduates report feeling significantly better about their health even though they report levels of disability and physical limitation similar to those with somewhat lower levels of education. A full assessment of the reasons for this finding awaits future research, but one likely explanation is that self-reported health status assesses different dimensions of health. Unlike measures of disability or limitation in physical functioning, which assess an individual's ability to perform specific tasks like doing housework or walking a quarter of a mile, self-reported health measures tap into broader and more abstract dimensions of health, including not only physical condition but also mental and emotional health as well as life satisfaction and general happiness. Studies show that college graduates report feeling happiest and most satisfied with life (Firebaugh and Tach 2005), and this may partly explain why they also report feeling better about their health.

I also find evidence of possible gender differences in the relationship between education and health, such that the shape of the relationship is somewhat more linear among men and more curvilinear among women. Put another way, this finding implies that, compared with the marginal effect on health of an additional year of primary education, the effect of an additional year of secondary or tertiary education is relatively greater for men than women. What accounts for this difference? One hypothesis I can rule out involves gender differences in the economic returns to education. It is possible that men enjoy relatively greater health returns to higher education because they also enjoy relatively greater economic returns. However, this argument does not square with evidence that the economic premium associated with higher education is in fact relatively greater for women, and that the female advantage in the economic returns to higher education has grown in recent years (DiPrete and Buchmann 2006). This means that gender differences in the shape of the relationship between education and health cannot totally or primarily reflect gender differences in the economic returns to education, and that researchers interested in explaining these differences should thus look more to other possible explanations, such as gender differences in either social supports or health-promoting behaviors.

These results have two main implications. First, the general robustness of the results across several health measures and alternative modeling strategies highlights the importance of measuring the curvilinear association between education and health in future studies of health and longevity. In this study I captured the nonlinearity using simple linear regression but measuring education with either a quadratic function or a piecewise linear spline function. Both strategies produced similar results. Other options include measuring education as a categorical variable or using an alternative nonlinear model like order logistic regression or poisson regression that accounts for the nonlinearity in the relationship between education and health in a more general way.

Second, the results also have broader implications for current understandings of the mechanisms or pathways linking education and health. In particular, the finding of possible diminishing returns of education to health offers little support for theories of the deleterious effects of education as a general marker of social standing and instead supports theories highlighting the special importance of basic levels of education in shaping later adult outcomes. Explanations of the relationship between education and health should thus focus relatively less on the reasons for possible differences in health among people with very high levels of education and instead focus more on the reasons for the larger and more fundamental differences in health between people with very low levels of education and those with at least a high school degree. Especially important is determining what students gains from very basic levels of education that seems to promote health and longevity later in adulthood. Possible examples include basic reading and comprehension skills that later aid basic health-promoting activities; some minimum protection from the severe economic consequences associated with school dropout and low educational attainment; and, more generally, a solid base of physiological, cognitive, and socioemotional development on which later adolescent and adult development is built. The challenge for future research is to determine more precisely how these different factors operate and interact to produce the large and persistent disparities in health observed at later stages of the life course.

Future research should also seek to replicate these findings with additional measures of health, including especially all-cause and cause-specific mortality. My finding of a curvilinear relationship between education and health runs somewhat counter to other recent evidence of a linear relationship between education and risk of adult mortality, including Erikson's (2001) finding of differences in mortality rates among highly educated Swedish men. However, it is unclear whether the difference in our results stems more from the different study sample or from my focus on measures of health instead of mortality. My results are similar to Erikson's in showing a relatively more curvilinear relationship among women than men.

Finally, future studies should also look for differences in the shape of the relationship between other population subgroups, especially groups defined race/ethnicity. The sample size of the NHIS-D was not large enough to test for racial/ethnic differences, but Goldman et al. (2006) show evidence of a relatively flat relationship between education and both health and health behaviors among Hispanics, and Ferraro and Farmer (2005) report similar evidence of among African Americans. Documenting and understanding such differences is yet another way to further refine knowledge of pathways or mechanisms through which education might lead to better health.

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Table 1. Descriptive Statistics: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.

Variable	Mean	SD	Min.	Max.
Health				
ADL Disability	.32	1.08	0	6
IADL Disability	.62	1.34	0	6
Functional Limitations	1.37	2.08	0	8
Self-Reported Health Status	3.29	1.11	1	5
Mental Health	.31	.82	0	7
Education	10.97	3.61	0	18
Age	71.37	7.89	60	99
Female	.58	----	0	1
Race				
Black	.12	----	0	1
Other	.02	----	0	1
White	.86	----	0	1
Unweighted N	32,123			

Notes: Data are weighted. See text for description of measures.

Table 2. Distribution of Educational Attainment: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.

Years of Schooling	Unweighted N	Percent
0	357	1.11
1	107	.33
2	221	.69
3	373	1.16
4	435	1.35
5	515	1.60
6	875	2.72
7	963	3.00
8	2,939	9.15
9	1,486	4.63
10	1,835	5.71
11	1,566	4.88
12	11,593	36.09
13	1,544	4.81
14	2,138	6.66
15	740	2.30
16	2,436	7.58
17	501	1.56
18+	1,499	4.67
Total	32,123	100.00

Note: See text for description of measure.

Table 3. Selected Coefficients from Ordinary Least Squares (OLS) Regressions of Five Selected Health Measures on Quadratic Function of Educational Attainment: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.

Independent Variable	Activities of Daily Living	Instrumental Activities of Daily Living	Functional Limitations	Self-Reported Health Status	Mental Health
Education	-.0320***	-.0847***	-.1113***	-.0397***	-.0362***
	(.0063)	(.0092)	(.0134)	(.0088)	(.0078)
Education × Education	.0008**	.0024***	.0016**	-.0020***	.0008*
	(.0003)	(.0004)	(.0006)	(.0004)	(.0003)

Note: Numbers in parentheses are standard errors and have been adjusted for the clustering and stratification employed in the NHIS-D sampling design using the survey estimation commands in Stata statistical software (StataCorp 2005). Models include additional controls for gender, race, and age, and were estimated separately for each health outcome. Education is measured as self-reported number of years of formal schooling completed.

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed tests)

Table 4. Selected Coefficients from Piecewise Linear Spline Regressions of Five Selected Health Measures on Educational Attainment: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.

Independent Variable	Activities of Daily Living	Instrumental Activities of Daily Living	Functional Limitations	Self-Reported Health Status	Mental Health
Education:					
0-12 years	-.0193***	-.0474***	-.0939***	-.0752***	-.0266***
	(.0026)	(.0036)	(.0053)	(.0035)	(.0027)
12-15 years	-.0072	-.0119*	-.0638***	-.1044***	-.0118***
	(.0037)	(.0048)	(.0080)	(.0060)	(.0030)
16+ years	-.0142	-.0086	.0116	-.0442**	.0076
	(.0097)	(.0127)	(.0224)	(.0165)	(.0086)

Note: Numbers in parentheses are standard errors and have been adjusted for the clustering and stratification employed in the NHIS-D sampling design using the survey estimation commands in Stata statistical software (StataCorp 2005). Models include additional controls for gender, race, and age, and were estimated separately for each health outcome. Education is measured as self-reported number of years of formal schooling completed.

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed tests)

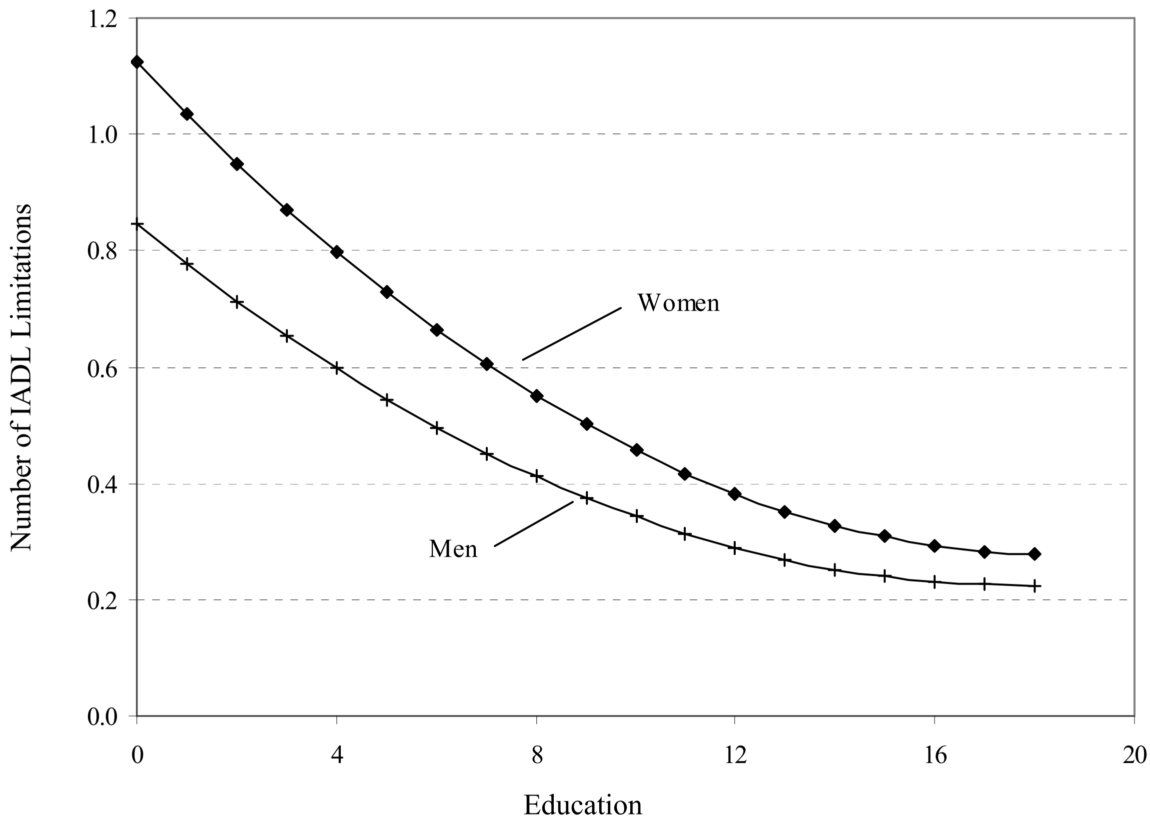
Table 5. Selected Coefficients from Ordinary Least Squares (OLS) Regressions of Five Selected Health Measures on Quadratic Function of Educational Attainment, by Gender: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.

Subgroup	Independent Variable	Activities of Daily Living	Instrumental Activities of Daily Living	Functional Limitations	Self-Reported Health Status	Mental Health
Women	Education	-.0437*** (.0096)	-.0914*** (.0136)	-.1296*** (.0202)	-.0438*** (.0113)	-.0437*** (.0122)
	Education × Education	.0013** (.0004)	.0025*** (.0006)	.0018* (.0009)	-.0020*** (.0005)	.0008 (.0005)
Men	Education	-.0165* (.0077)	-.0699*** (.0117)	-.0752*** (.0174)	-.0341** (.0124)	-.0218** (.0071)
	Education × Education	.0001 (.0003)	.0020*** (.0005)	.0005 (.0007)	-.0021*** (.0005)	.0005 (.0003)

Note: Numbers in parentheses are standard errors and have been adjusted for the clustering and stratification employed in the NHIS-D sampling design using the survey estimation commands in Stata statistical software (StataCorp 2005). Models include additional controls for race and age, and were estimated separately by gender and for each health outcome. Education is measured as self-reported number of years of formal schooling completed.

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed tests)

Figure 1. Predicted Number of Limitations in Instrumental Activities of Daily Living (IADLs) by Education Level and Gender: 1994-1995 National Health Interview Survey Disability Survey (NHIS-D), Respondents Ages 60 and Older.



Note: Predicted values calculated from ordinary least squares (OLS) regression model shown in table 4 Education is measured as self-reported years of formal schooling completed. See text for details.