The Role of Social and Health-Related Characteristics in Determining Survivorship Among the U.S. Oldest Old

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Abstract

Despite increasing numbers of people reaching old age, little is known about the social, behavioral and health-related factors that play an important role in determining survivorship into oldest-old age (85 and older) among those who have survived to old age (65 and older). In this paper, we address the question of how socioeconomic and demographic characteristics, health status and health behaviors are associated with oldest-old mortality and survivorship among people who have survived to old age. We use data from the 1990-91 National Health Interview Survey's Health Promotion and Disease Prevention Supplement and the mortality follow-up through 2002. Our results indicate that activity limitation and exercise status, in combination with education, play an important role in survival into old age (between 65 and 85) but have a smaller effect on survival among the oldest-old population (85 and older).

Introduction

Large declines in U.S. mortality rates in the past century have translated into sizable increases in the survival of Americans at all ages. Particularly important were the improvements in mortality at older ages. For example, the probability of a 65-year-old surviving to age 85 doubled between 1970 and 2005, from about 0.2 in 1970 to about 0.4 in 2005 (Bell and Miller 2005). Declines in mortality rates at older ages have been reported in most developed countries, with significant declines since the 1970s observed among those 80 or older (Kannisto 1994; Kannisto 1997; Vaupel 1997). Despite the increasing number of people reaching old age, little is known about the social, behavioral and health-related factors that play an important role in determining survivorship into oldest-old age (85 or more years) among those who have survived to old age (65 or more years).

Research on longevity among the oldest-old has typically utilized national level studies of mortality and survivorship based on vital statistics records (Christensen et al. 2009; Rau et al. 2008). Nonetheless, individual-level factors play a crucial role in understanding the health dynamics of the oldest-old population, particularly in survivorship. In this paper, we address how socioeconomic and demographic characteristics, health status and health behaviors are associated with oldest-old mortality and survivorship among people who have survived to old age.

Background

There is ample evidence in the literature documenting differences in health outcomes by socioeconomic status (SES), such that those with higher SES have better health and tend to live longer. The evidence for a direct relationship between SES and health is consistent across three of the most common measures of SES: income (Kawachi and Kennedy 1999; Smith and Kington 1997), education (Beckett 2000; Ross and Wu 1995) and occupation (Marmot et al. 1991). In addition, the SES differentials in health have been reported to differ over the life cycle. Some research shows that SES inequalities in health are larger in middle age (Hayward et al. 2000; Kunst and Mackenbach 1994) and appear to decline at older ages (Crimmins 2005; Crimmins, Hayward and Seeman 2004). However, the particular mechanisms leading to reductions in health inequalities by SES at old age are not well understood.

In addition, there is an interaction between education and activity limitation at old age that leads to important differences in survivorship. Crimmins and Saito (2001) show that among black and white men and women in 1990, there was at least a 10-year difference in healthy life expectancy at age 30 between people with a college education and those with less than high school. This education difference declined with age but the gap remained quite large even at age 65, at least four and six years difference in life expectancy for whites and blacks, respectively. In addition, recent evidence suggests there were significant increases in disability rates among people aged 60 to 69 during the 1990s, but a slightly lower prevalence among 70- to 79-year-olds in recent years (Seeman et al. 2010).

Physical activity has also been shown to have a strong association with a variety of health outcomes, including mortality. For example, there is evidence leisure-time physical activity is associated with declines in the risk of developing coronary heart disease (Wannamethee and Shaper 2002) and noninsulin dependent diabetes (Helmrich et al. 1991; Manson et al. 1992), reductions in the hazard of death (Schnohr, Scharling and Jensen 2003), and increases in both total life expectancy and cardiovascular disease–free life expectancy (Franco et al. 2005). There is also an interaction between physical activity and disability. Relative to those who engage in low leisure-time physical activity (nonoccupational), people with moderate activity are less likely to become disabled, more likely to recover from disability and live more years free of disability (Nusselder et al. 2008; Van Den Brink et al. 2005).

Health inequalities observed in old age are the result of competing forces acting differentially over the life cycle. On the one hand, health differentials experienced in early life and adulthood shape the health status of those who will eventually reach old age. For instance, there is evidence showing significant differences in the prevalence of mortality-related diseases among middle-aged people but not among old individuals (Crimmins 2005) suggesting that mortality removes from the population those individuals with fatal conditions in mid-life. That is, those who reach old age represent a highly selective group both with regard to their health and sociodemographic characteristics. On the other hand, more and more people are reaching very old age (Christensen et al. 2009), suggesting that individuals are increasingly able to overcome a set of life course adversities and thereby increase their survivorship. In this paper, we focus on how SES, activity limitation and exercise status are linked to mortality and survivorship among people who have already survived to old age (65 years old).

Data and Measures

We analyze data from the 1990 and 1991 National Health Interview Survey: Health Promotion and Disease Prevention Supplements, a nationally representative sample of noninstitutionalized U.S. adults 18 or older who took part in in-person interviews. Individual data from the supplements were linked to prospective mortality data from the National Death Index (NDI), with follow-up through December 2002. The analytic sample is restricted to 16,521 adults 65 and older, with 8,522 deaths recorded during follow-up (51.6 percent).

We measure health status in terms of functional limitation and exercise status. Individuals are considered to have functional limitations if they require assistance performing personal care needs either because they are unable to perform these tasks themselves or because they are limited in performing these tasks. Exercise status is a dichotomous variable that distinguishes between those who do not exercise (exercise = 0) and those who engaged in any of the following activities in the two weeks prior to the survey: walk, jog, golf, play tennis, garden, aerobics, bowl, bike or swim (exercise = 1). We use education as our measure of socioeconomic status and categorize it into three groups: less than high school (less than 12 years of schooling), high school (12 years) and college or more (13 or more years).

Methods

We use three analytic approaches. First, we characterize the functional health and health behavior profiles of individuals by socioeconomic and demographic characteristics (e.g. sex, age and education). In this step, we present bivariate associations of functional health and health behaviors by socioeconomic and demographic variables. Second, we estimate the association of functional limitation, exercise, and socioeconomic and demographic variables with the risk of death by fitting separate longitudinal Poisson log-linear models (proportional hazard model) to people age 65 through 85 and 85 through 105. This approach allows us to look at the differential effect of socioeconomic status and health behaviors on mortality and survivorship to old age (65 to 85 years) and oldest-old age (85 years or older). Sample data are weighted in all analyses to represent the noninstitutionalized U.S. adult population.

Preliminary analyses indicate significant sex differences in the links between the independent variables and mortality; we thus fitted separate models by sex. The first model explores socioeconomic differences in mortality for the two age groups. We then fit a second model adding activity limitation to investigate its association with mortality. A third model restricts the analysis to individuals who reported no activity limitation to further assess the hazard of death by exercise status. Results from these models are shown in Appendix A (Tables A.1 and A.2).

Using the coefficient estimates from the Poisson models, we then estimate mortality rates by socioeconomic and demographic characteristics and used those rates to construct life tables. We use standard demographic techniques in the construction of life tables (Preston, Heuveline and Guillot 2001). Because the Poisson models are fitted to two separate age groups, 65 through 85 and 85 through 105, the life tables provide temporary life expectancies (TLE) between those ages. That is, it gives us the average number of years someone is expected to live between ages 65 and 85 and 85 and 105, respectively.[1] We then examine the difference in TLE between people with college education and those with less than high school education by activity limitation and exercise status. This approach allows us to assess whether there is a differential effect of activity limitation and exercise status on socioeconomic differences in TLE before and after age 85.

Results

Baseline characteristics of the study sample are shown in Table 1. The sample contains a large number of oldest-old individuals; about one-fifth of the sample is 80 or older at baseline (about 1,018 men and 2,506 women). The majority of the sample has less than a college education and nearly half did not complete high school. For both men and women, about one-third of the sample reported having activity limitations. Although there are more deaths among women, relative to the initial sample size, men die in greater proportions. About 57 percent of men die during the follow-up period, while the corresponding figure for women is about 48 percent.

TABLE 1
Sample Characteristics at Baseline: NHIS 1990-91

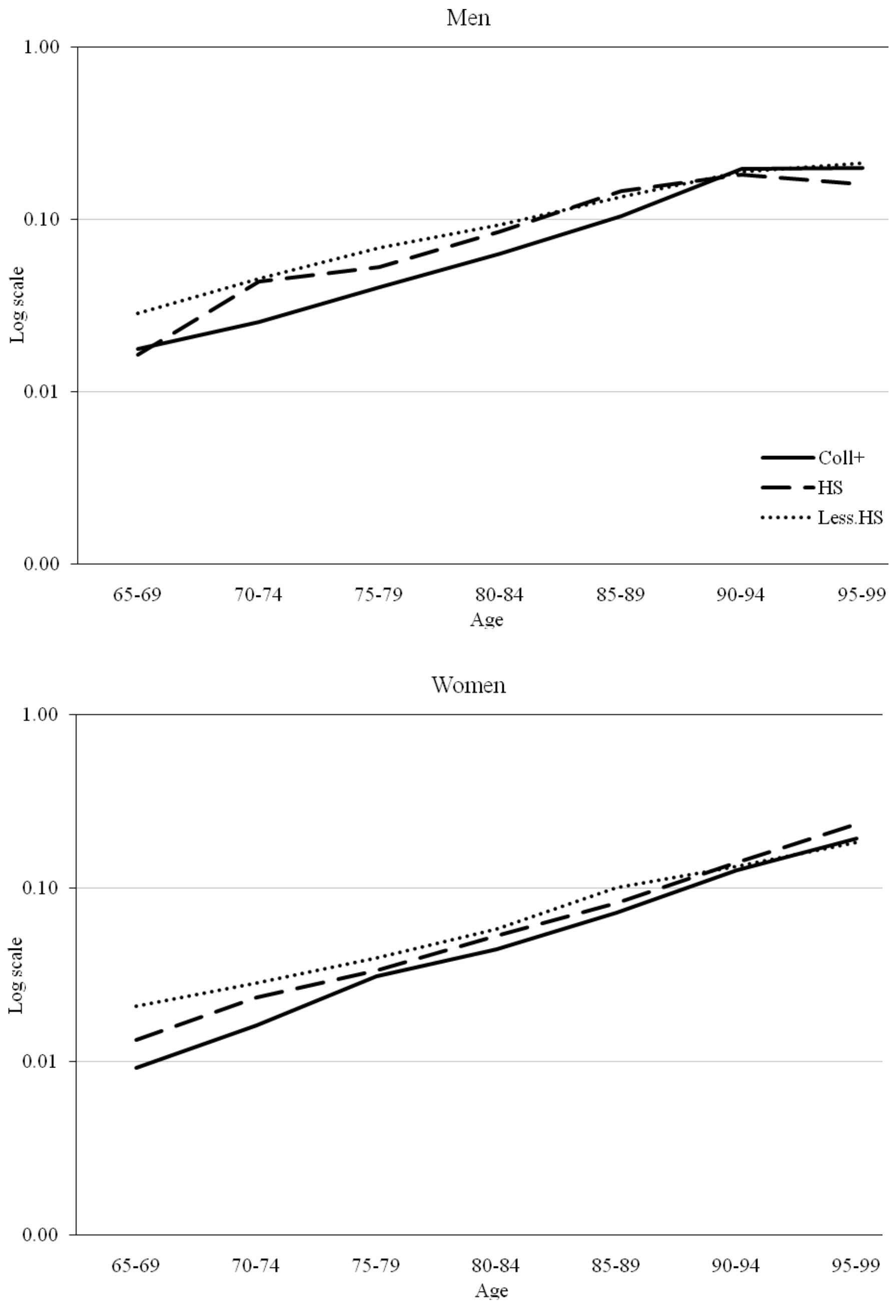
Characteristics	**Women**		**Men**	
	N	**%**	**N**	**%**
Age				
65-69	3,053	(28.8)	2,024	(34.6)
70-74	2,778	(26.2)	1,705	(29.2)
75-79	2,282	(21.5)	1,097	(18.8)
80-84	1,520	(14.3)	703	(12.0)
85-89	747	(7.0)	242	(4.1)
90-94	203	(1.9)	60	(1.0)
95-+	36	(0.3)	13	(0.2)
Education				
Less High School	4,245	(40.0)	2,160	(37.0)
High School	3,713	(35.0)	1,885	(32.3)
College+	2,661	(25.1)	1,799	(30.8)
Activity Limitation				
No	6,522		3,722	
Yes	4,097		2,122	
Exerciser Status*				
No	2,520		1,120	
Yes	4,002		2,602	
Sample Size	10,619		5,844	
Deaths	5,154		3,368	
Person-Years	100544.5		51167.25	

* Among those who have no activity limitation.
Source: Pooled NHIS 1990 and 1991.

Bivariate Results

Figure 1 shows crude age-specific mortality rates by sex and education estimated from the data. The computation of mortality rates is carried out using the NHIS follow up in 2002 to estimate the person-years lived by age, sex and level of education for the period of study, and then taking the ratio of deaths over person-years lived. This graph shows that mortality rates are fairly similar between the two lowest education groups (less than high school and high school) and the survival advantage of college-educated individuals decreases with age. The differences in mortality rates by level of education are almost negligible by age 75 for both men and women. This result highlights the decreasing education differential in survival by age.

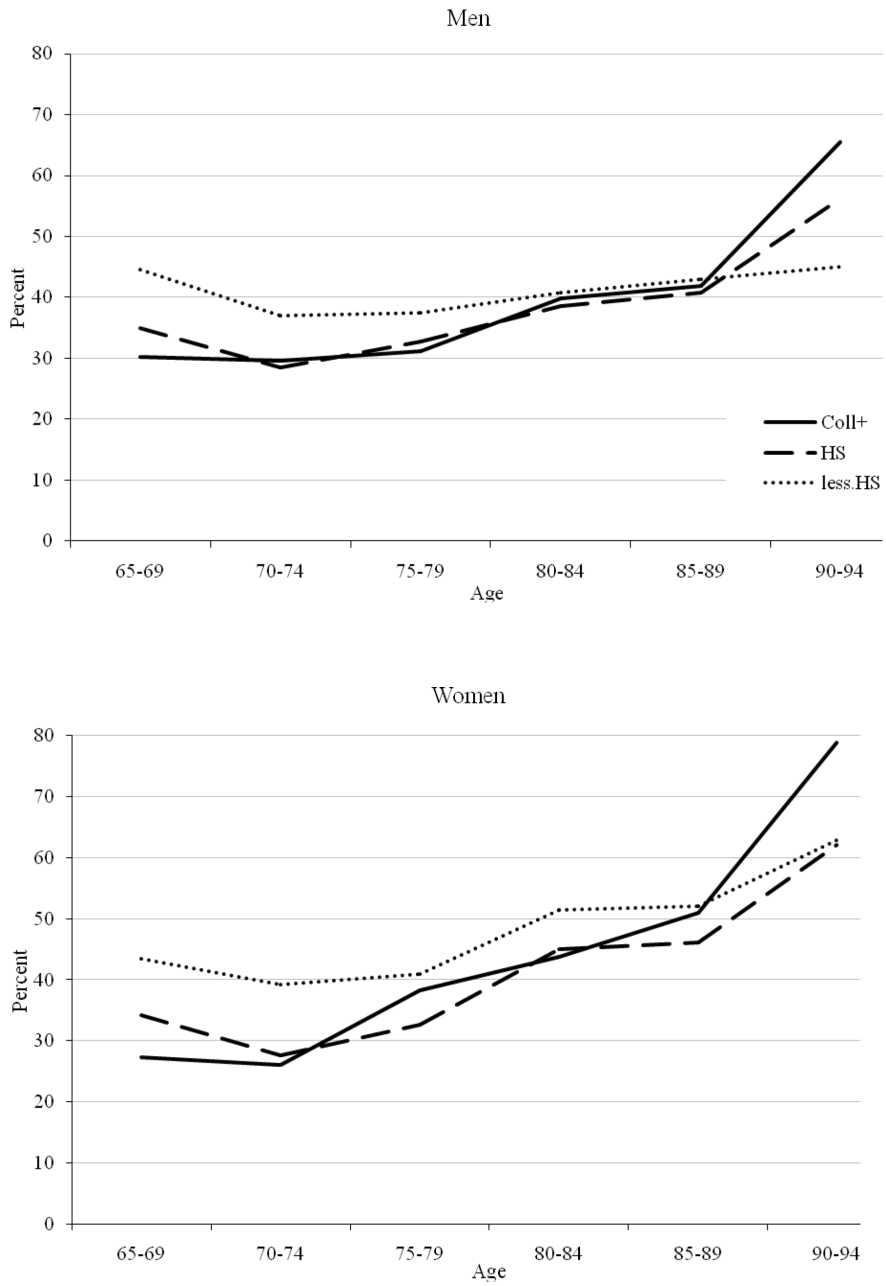
Figure 1
Crude Age-Specific Mortality Rates by Sex and Level of Education (Log Scale)



Mortality selection plays an important role in describing patterns in health outcomes observed among surviving individuals at older ages. For example, health outcomes associated with mortality are likely to show a similar age trend as what we observe for crude mortality rates.

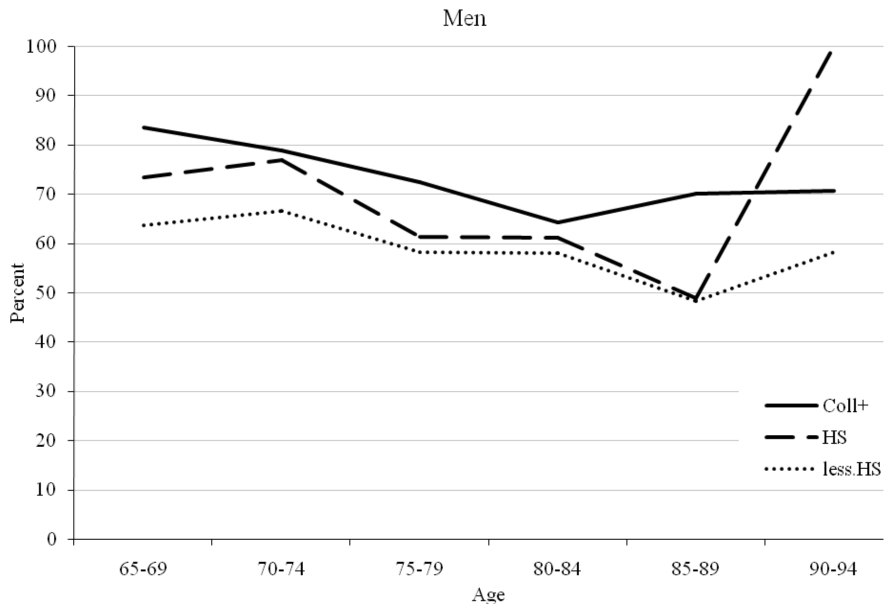
However, for outcomes not directly associated with mortality, the pattern observed among surviving individuals may be quite different. Figure 2, for example, shows the prevalence of individuals who reported having an activity limitation by age, sex and level of education. This graphs shows there are very small differences in the prevalence of activity limitation at older ages by level of education. That is, among the oldest old (approximately 80 and older), having a lower level of education does not necessarily translate into a higher likelihood of activity limitation. This pattern may reflect mortality selection by level of education.

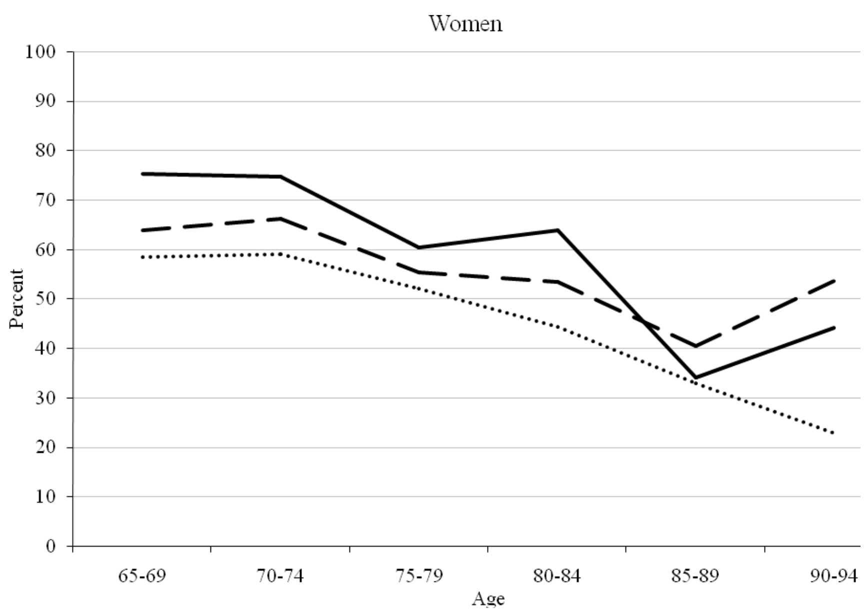
Figure 2
Percent of Population Who Had an Activity Limitation by Age, Sex and Level of Education



On the other hand, when we look at the proportion of people who engage in physical exercise in the two weeks prior to the interview among those who have no activity limitation, the pattern is quite different (Figure 3). For both men and women, the proportion of exercisers declines with age but there remains a considerably higher proportion of exercisers among the college educated compared to the other education groups, a difference that continues into the oldest ages. However, the proportion of exercisers among people age 90 to 94 is based on very small numbers, which may lead to unstable results that should be interpreted with caution.

Figure 3
Percent of Population Who Exercise Among Those Who Have no Activity Limitation by Age, Sex and Level of Education





Results From Poisson Models

Analysis by Level of Education

We fitted two separate regression models longitudinally for people age 65 to 85 and for individuals age 85 to 105 stratified by gender. Figure 4 shows the percent increase in the risk of death for individuals with less than high school education relative to those with college education for these two age groups for men and women, respectively. This graph provides important evidence that socioeconomic differentials in mortality decrease in old age and that they are much larger before age 85. By the time men reach age 85, the mortality differences by education have vanished. The pattern is similar for women, but education differences in mortality prevail into oldest age.

Figure 4
Results from a Poisson model including education by age and gender:
A) Percent increase in the relative risk of death for people with less than high school relative to college-educated individuals, and
B) Difference in temporary life expectancy between people with college education and more and those with less than high school.

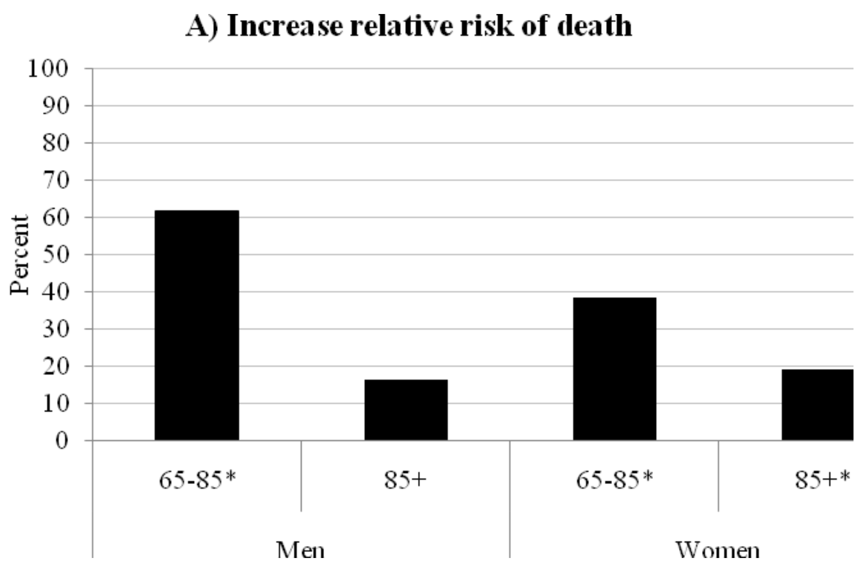
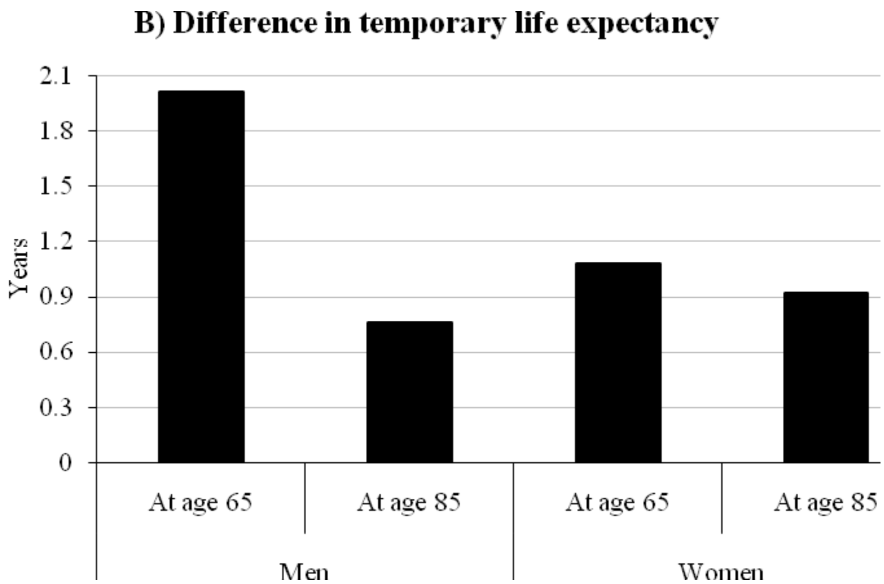


Figure 4
continued



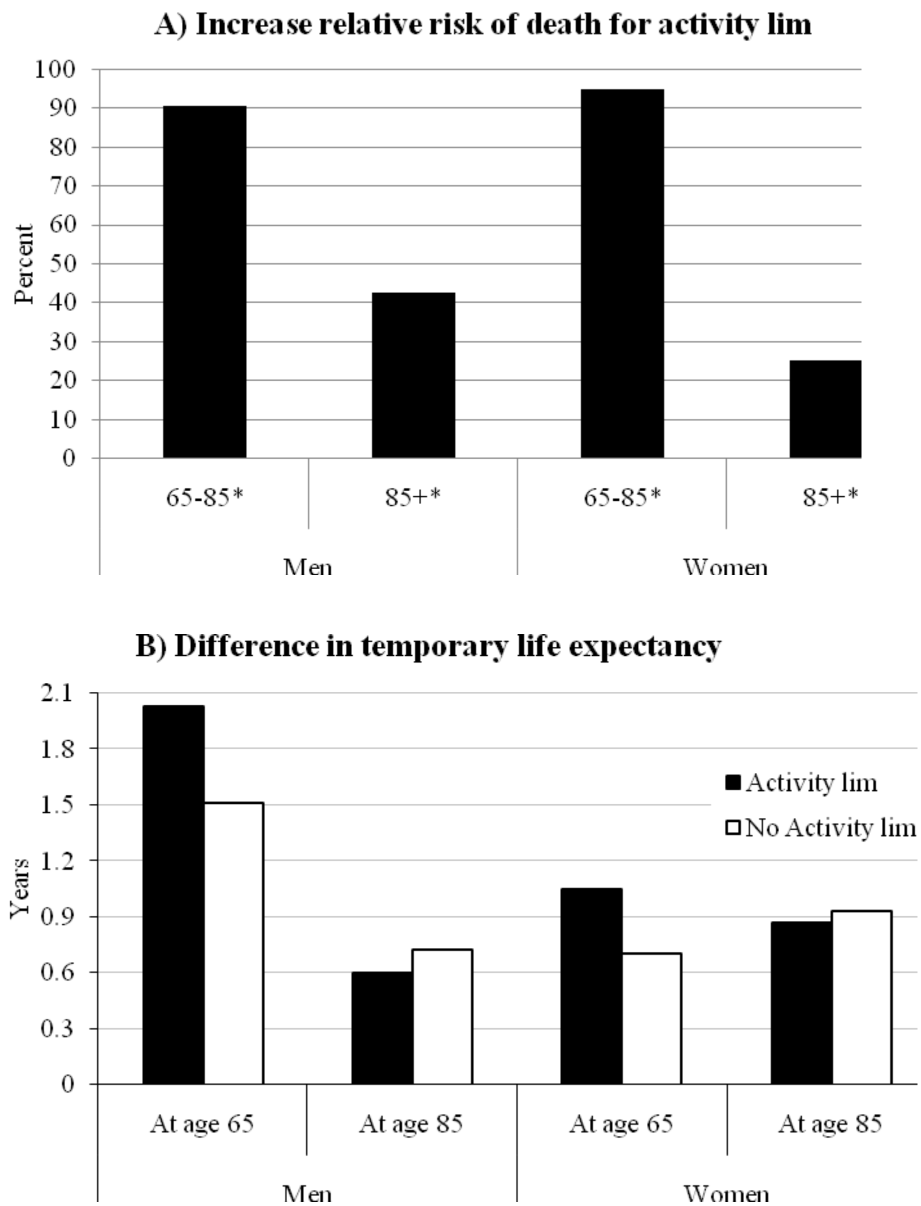
* P<0.001.
Note: The bars correspond to the difference between college education or more and less than high school in the corresponding measure. Temporary life expectancy at age 65 corresponds to the age range 65 to 85, while the corresponding range for temporary life expectancy at age 85 is 85 to 105.

The socioeconomic differentials in mortality translate into important differences in temporary life expectancy (TLE) (Figure 4, Panel B). Between ages 65 and 85, men with college education are expected to live about two years longer than their counterparts with less than high school. At older ages, however, the educational differences in TLE reduce to less than one year. For women, the socioeconomic differences in TLE are less pronounced between the old and the oldest old. There is a slightly higher socioeconomic differential between ages 65 and 85, but the gap remains fairly constant at about one year in favor of those with college education or more.

Analysis by Level of Education and Activity Limitation

In this section, we study the association among education, activity limitation, and the hazard of death for men and women. We use a similar procedure as before, fitting two models for people age 65 to 85 and those older than 85 by sex. The results are shown in Figure 5. Panel A shows the percent increase in the risk of death for individuals with activity limitation for these two age groups for men and women. We see that having activity limitation has by far a greater impact than socioeconomic status on one's survival into old age. Particularly large is the increased hazard of death among people younger than 85. Mortality differentials by activity limitation reduce dramatically with age, more so among women, although the differential remains highly significant even at the oldest ages for both men and women.

Figure 5
Results from a Poisson model including education and activity limitation by gender:
A) Percent increase in the relative risk of death for people with activity limitation, and
B) Difference in temporary life expectancy between people with college education or more and those with less than high school by activity limitation.



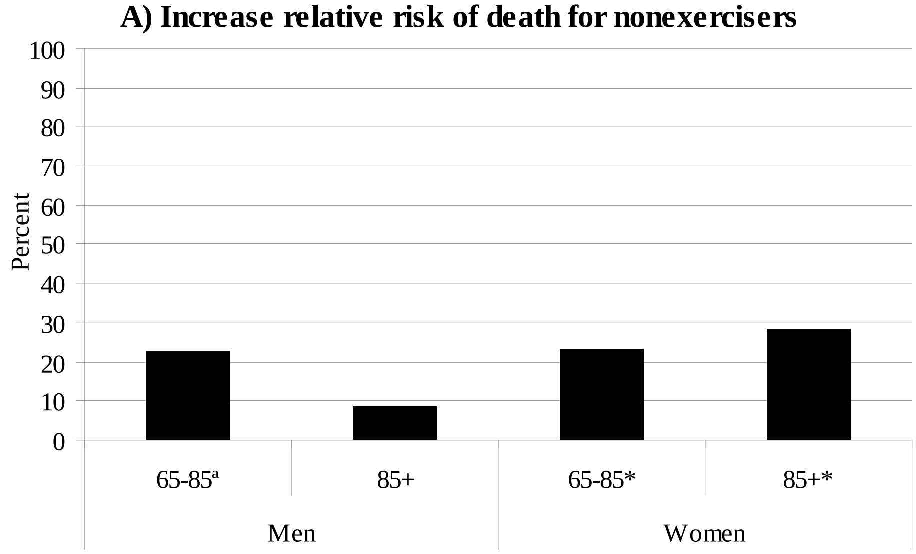
* P<0.001.
Note: The bars correspond to the difference between college education or more and less than high school in the corresponding measure. Temporary life expectancy at age 65 corresponds to the age range 65 to 85, while the corresponding range for temporary life expectancy at age 85 is 85 to 105.

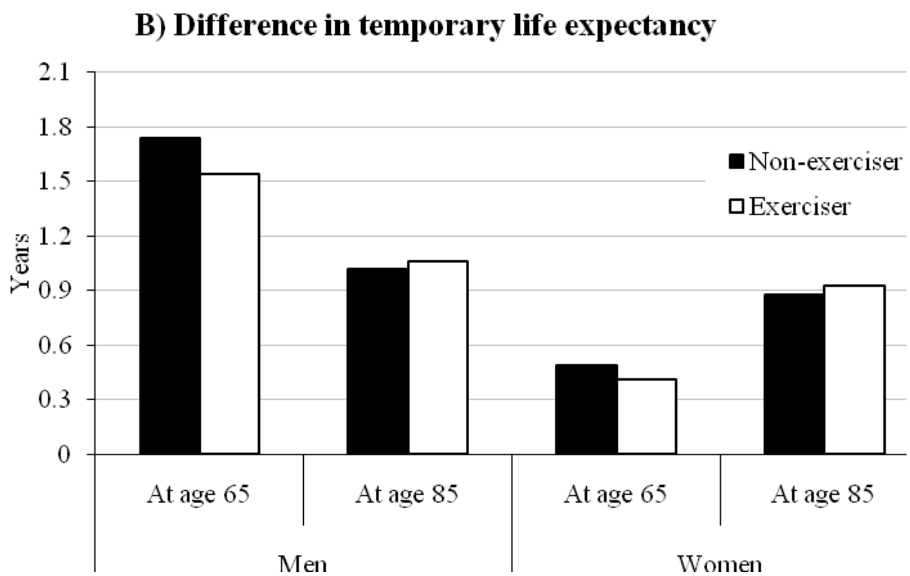
Using the results from the Poisson model, we constructed life tables to assess the effect of education and activity limitation on life expectancy. We estimated the difference in TLE between ages 65 and 85 and 85 and 105 between people with college education or more and those with less than high school by activity limitation (Figure 5, Panel B). The results reveal that educational differences in TLE are larger among people who have an activity limitation between ages 65 and 85. For oldest ages, however, the educational gap in TLE is reduced and is very similar between those with and without activity limitation. That is, educational level can make a sizable difference in one's survival when having activity limitations between ages 65 and 85. Men with activity limitation and college education or more can expect to live about two more years between ages 65 and 85 relative to their counterparts with less than high school. The difference for women is about one year. In addition, the educational difference in TLE is still large for men who have no activity limitation between ages 65 and 85 (1.5 years) but quite small for women (0.7 years). At older ages, however, the educational gap in life expectancy has been reduced to less than one year. The SES gap in TLE is about the same magnitude between those with and without activity limitation between ages 85 and 105, which suggests that SES differences seem to permeate into old age.

Analysis by Level of Education and Exercise Status Among People With no Activity Limitation

We further analyze the association of exercise status with the hazard of death among people who have no activity limitation (Figure 6). We excluded from this analysis individuals who reported having an activity limitation as they are likely less capable of engaging in physical exercise. Nonexercisers experience an increased risk of death, though there is a stronger association with mortality among women than men, particularly at older ages (Figure 6, Panel A). For men, lack of exercise has a significant effect in raising mortality risk between ages 65 and 85, but it appears to have no effect at oldest ages. For women, this effect significantly associates with mortality at all ages with a larger magnitude between ages 85 and 105.

Figure 6
Results from a Poisson model including education and exercise status among people who have no activity limitation by gender:
A) Percent increase in the relative risk of death for nonexercisers, and
B) Difference in temporary life expectancy between people with college education or more and those with less than high school by exercise status.





* $p<0.001$, [a]$p<0.05$.
Note: Temporary life expectancy at age 65 corresponds to the age range 65 to 85, while the corresponding range for temporary life expectancy at age 85 is 85 to 105.

Using these results, we constructed life tables to assess the effect of education and exercise status on TLE (Figure 6, Panel B). The educational gaps in TLE are larger for men than women for both ages 65 and 85 and declines with age among men but increases among women. For example, the educational difference in TLE among men declines from 1.7 years at age 65 to one year at age 85 but increases from 0.4 to one year among women, respectively. It appears that at age 85, the socioeconomic differences in TLE are about the same magnitude for both men and women regardless of exercise status. That is, the educational advantage seems to extend to old age for this selective sample of individuals who have no activity limitation.

Discussion

Our results show that activity limitation and exercise status play an important role in survival into old age. For example, men with activity limitation have about two times higher hazard of death between ages 65 and 85, compared to those with no limitations. This translates into sizable differences in TLE by level of education. Men with activity limitation and college education or more can expect to live about two more years between ages 65 and 85 relative to their counterparts with less than high school. Among men with no activity limitation, the difference in TLE is about 1.5 years in favor of those with college education or more. Having an activity limitation continues to increase the likelihood of death after age 85, but its effect on SES differences in life expectancy is quite small. Crimmins and Saito (2001) also found higher life expectancy by activity limitation (healthy life expectancy) at age 65 for people with college or more. However, compared to Crimmins and Saito, our results show that most of the SES differences in life expectancy by activity limitation happen before age 85.

In addition, exercise status also has an effect on mortality with a stronger effect before age 85. For nonexercisers with no activity limitation, those with college or more can expect to live about two more years between ages 65 and 85 than their counterparts with less than high school. Between ages 85 and 105, the difference narrows to about one year in favor of those with college education. Our results are consistent with previous research showing that physical activity is an important factor in increasing disability-free life expectancy between ages 50 and 80 (Nusselder et al. 2008). However, our results indicate that after age 85, the effect is quite small.

Our study has some limitations. We do not have time-varying information on activity limitation and exercise status over the period of study. We thus assume that people remain in the same status they reported at baseline. In this regard, the differences in life expectancy reported here represent the case in which the prevalence of activity limitation and exercise status remained constant between 1990 and 2002. On the other hand, an important advantage of our study is that we use a large nationally representative sample of the noninstitutionalized U.S. population. Thus, a major strength of this study is the ability to examine national differences in survival in a highly selective population, those reaching the old and oldest-old ages.

Future work should consider the inclusion of time-varying covariates to better understand the dynamics of the association between health, health behaviors and socioeconomic status at older ages.

Endnotes

[1] Standard demographic methods have a special way of estimating person-years lived (${}_nL_x$) in the open-ended interval in a life table by assuming that those who survive to the last age group are exposed to a constant mortality rate until the last group member dies (Preston et al. 2001). We modify this assumption and estimated person-years lived in the last age group (80 to 84 and 100 to 104) assuming that constant mortality rates apply for five years, rather than indefinitely until the last member of the age group dies. More formally, ${}_nL_x$ is estimated as: $l_x\left[\frac{1-e^{-5\,{}_nM_x}}{{}_nM_x}\right]$, for x=80,100 and n=5, where l_x represents the life table survivors at age x, and ${}_nM_x$ represents the mortality rates between ages x and $x+n$.

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Appendix A
Results From Poisson Models Fitted Longitudinally for Ages 65 Through 85 and 85 Through 105

Table A.1
Relative Risks of Death for Men From Poisson Models Fitted Longitudinally: Ages 65 Through 85 and 85 Through 105

Covariates	Model 1		Model 2		Model 3[a]	
	Ages 65 Through 85					
Age (ref=65-69)						
70-74	1.85	***	1.90	***	2.43	***
75-79	2.60	***	2.71	***	3.61	***
80-84	3.90	***	4.11	***	5.90	***
Education (ref=Coll+)						
Less HS	1.63	***	1.53	***	1.60	***
HS	1.39	***	1.38	***	1.34	***
Activity Limitation	---		1.91	***	---	
Nonexercisers (ref=exercisers)	---		---		1.23	**
	Ages 85 Through 105					
Age (ref=85-89)						
90-94	1.49	***	1.48	***	1.62	***
95-99	1.54	***	1.46	***	2.23	***
100-104	1.12	***	0.95	***	2.36	**
Education (ref=Coll+)						
Less HS	1.17		1.14		1.24	*
HS	1.22	*	1.24	*	1.33	*
Activity Limitation	---		1.43	***	---	
Nonexercisers (ref=exercisers)	---		---		1.09	

a This model is fitted to people who have no activity limitation.
*** p<0.000, **p<0.01, *p<0.05

Table A. 2
Relative Risks of Death for Women from Poisson Models Fitted Longitudinally: Ages 65 Through 85 and 85 Through 105

Covariates	Model 1		Model 2		Model 3[a]	
	Ages 65 Through 85					
Age (ref=65-69)						
70-74	1.60	***	1.62	***	1.49	***
75-79	2.44	***	2.51	***	2.78	***
80-84	3.65	***	3.69	***	4.66	***
Education (ref=Coll+)						
Less HS	1.39	***	1.29	***	1.19	*
HS	1.21	**	1.19	**	1.15	
Activity Limitation	---		1.95	***	---	
Nonexercisers (ref=exercisers)	---		---		1.23	***
	Ages 85 Through 105					
Age (ref=85-89)						
90-94	1.53	***	1.51	***	1.51	***
95-99	2.25	***	2.18	***	2.34	***
100-104	2.19	***	2.10	***	2.92	***
Education (ref=Coll+)						
Less HS	1.19	**	1.19	**	1.19	*
HS	1.13		1.14	*	1.14	
Activity Limitation	---		1.25	***	---	
Nonexercisers (ref=exercisers)	---		---		1.28	

a This model is fitted to people who have no activity limitation.
*** p<0.000, **p<0.01, *p<0.05