

Article

Educational differences in the compression of disability incidence in the United States

Chi-Tsun Chiu^{a,*}, Mark D. Hayward^b, Angelique Chan^{c,d}, David B. Matchar^{c,e}^a Institute of European and American Studies, Academia Sinica, No. 128, Sec. 2, Academia Rd., Nangang Dist., Taipei City 115, Taiwan^b Population Research Center and Department of Sociology, University of Texas at Austin, 305 E. 23rd Street, Stop G1800, Austin, TX, USA^c Duke-National University of Singapore Graduate Medical School, Program in Health Services and Systems Research, 8 College Road, Singapore^d National University of Singapore, Department of Sociology, Faculty of Arts and Social Sciences, AS1#03-06, 11 Arts Link, Singapore^e Duke University School of Medicine, Department of Medicine, 201 Trent Dr, Durham, NC, USA

ARTICLE INFO

Keywords:

Education
Compression

Disability

Compression of disability incidence

Mortality

ABSTRACT

Objective: To examine educational differences in the compression of disability incidence in the United States.**Method:** We use the Health and Retirement Study and techniques of microsimulation and bootstrap to estimate the distribution of mortality and disability incidence for major education groups.**Results:** Higher education is associated with a right shift in the age distributions of both mortality and disability incidence, and more compressed distributions above the modal ages ($p < 0.05$). Our study also points to gender differences in the association between education and compression of mortality and disability incidence ($p < 0.05$).**Discussion:** To our knowledge, no prior studies have examined educational difference in compression of disability incidence and conducted formal tests for statistical significance. Educational differences in life span variation in mortality correspond closely with life span variation in disability incidence. One long-range implication of this work is growing inequality in life-span variation in disability incidence given trends in educational differences in life-span variation in mortality.

Introduction

Studies regarding education as a fundamental cause of health disparities (Link & Phelan, 1995; Phelan & Link, 2005) have produced a wealth of evidence showing that more-educated people enjoy longer lives (Braveman, Cubbin, Egerter, Williams & Pamuk, 2010; Crimmins & Saito, 2001; Manton, Stallard, & Corder, 1997), delayed disability incidence (Jagger, Matthews, Melzer, Matthews & Brayne, 2007; Latham, 2012; Melzer, Izmirlian, Leveille & Guralnik, 2001) and shorter periods of disability (Crimmins & Saito, 2001) compared to their less-educated counterparts. This pattern in educational inequality in adult health and mortality has been documented for a number of high-income countries in North America, East Asia and Europe (Saito, Chan, Malhotra & Matchar, 2012; Sasson, 2016; van Raalte et al., 2011). The bulk of research on this issue has largely evaluated educational health disparities in terms of mean differences across the education groups, e.g., educational inequality in life expectancy, disabled life expectancy, or the expected age of disability incidence. Recent research on mortality

compression, however, highlights another form of inequality in population health, the variation in lifespan health experiences (Brown, Hayward, Montez, Hummer, Chiu & Hidajat, 2012; Sasson, 2016). Persons with greater educational attainment not only have a later expected age of death but they also exhibit greater compression of mortality (i.e., less variation), with deaths more concentrated in the upper end of the age range compared to persons with low levels of education (Brown et al., 2012; Sasson, 2016; van Raalte et al., 2011).

Here, we extend work on lifespan variation to assess inequality in the compression of disability incidence. Our overarching question is whether higher levels of educational attainment are associated with the incidence of disability being more concentrated at later ages in the upper tail of the age distribution – a pattern documented for adult mortality. Do higher levels of education not only postpone the average age of disability incidence but also reduce the uncertainty in the timing of disability incidence? Disability and mortality are far from isomorphic concepts and the links between them are sometimes blurred (Cantu, Hayward, Hummer & Chiu, 2013; Crimmins, Hayward, & Saito, 1994;

* Corresponding author.

E-mail addresses: ctchiu@gate.sinica.edu.tw (C.-T. Chiu), mhayward@prc.utexas.edu (M.D. Hayward), angelique.chan@duke-nus.edu.sg (A. Chan), david.matchar@duke-nus.edu.sg (D.B. Matchar).<https://doi.org/10.1016/j.ssmph.2018.100347>

Received 2 May 2018; Received in revised form 25 December 2018; Accepted 26 December 2018

2352-8273/ © 2018 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Crimmins & Saito, 2001; Hayward & Heron, 1999). Nonetheless, there are reasons to suggest that educational inequality in the variation in disability incidence should parallel educational inequality in mortality compression. For example, hypothetically, greater variation in disability incidence at lower levels of education points to an increasing proportion of premature disability from injuries and other exogenous causes as well as disability accruing from earlier life adverse conditions that jeopardize individuals' health in midlife. In contrast, persons with advanced education face fewer risks of work-related injuries and have health behaviors and life course social advantages that delay pathophysiological and aging processes leading to disability.

Brown and his colleagues (2012) argued in their study of educational inequality of mortality compression that educational attainment affects later life health by shaping exposure to multiple health risks and by providing access to material and non-material resources that allow persons to "...maximize their potential for a long and health life over time and in multiple socio-environmental and socio-epidemiological contexts" (2012, p. 821). Research points to well-educated persons having a vast array of resources that help them accrue health advantages compared to less educated persons – fewer deleterious health behaviors, greater psychosocial resources and a sense of control, more income that improves life choices and intrinsically rewarding jobs, access to information about medical technologies, and less exposure to chronic and acute stressors (Cutler & Lleras-Muney, 2006, 2010a; Mirowsky & Ross, 1989; Ross & Mirowsky, 1995). Perhaps most importantly with respect to life span variation in health events, educational attainment, by marshaling the array of resources, provides the means to gain greater control over their environment and maximize potential for a healthy life. Well-educated persons have not only more resources than less educated persons but well-educated persons have greater control in deploying those resources. In comparison, less educated persons not only have fewer resources but they have less control over their environment. This introduces uncertainty into their lives which at the population level is likely to be reflected in greater heterogeneity in disability and mortality compared to well-educated persons. In a very real sense, educational attainment not only decreases health risks but it also decreases uncertainty in those risks across multiple life domains (Hayward, Hummer, & Sasson, 2015).

The compression of morbidity paradigm was introduced in 1980 (Fries, 1980) to describe the reduction in cumulative lifetime morbidity through primary prevention. The basic idea is that "the age at first appearance of symptoms of aging and chronic disease could increase more rapidly than life expectancy" (Fries, Bruce, & Chakravarty, 2011). Expressed in terms of disability incidence, the expected age of disability incidence should increase faster than life expectancy, thereby compressing cumulative lifetime disability (Fries et al., 2011). Applying this idea to educational inequality, the central tendency of age of disability incidence (measured as the modal age at disability incidence) should differ more across educational groups than the expected age of mortality (also measured as the modal age at death). We move beyond this issue, however, by also introducing the idea of the degree of homogeneity in the age span of disability incidence. Our overarching hypothesis is that with greater resources and a later age of disability incidence comes greater homogeneity and certainty. Conversely, those with few resources ought to face greater risk (and an early age of incidence) and greater uncertainty.

Our analytic approach draws on research that has examined the compression of mortality (Cheung & Robine, 2007; Cheung, Robine, & Caselli, 2008; Cheung, Robine, Tu & Caselli, 2005). Two major parameters are used to characterize the lifespan distribution of disability incidence for gender-education groups: the modal age (M) of the distribution and the compression of the distribution above the modal age ($SD(M+)$). Fig. 1 uses these parameters to display a heuristic scenario based on the hypotheses laid out above. Note that for the less educated population, the modal age at death is T_1 , modal age at disability incidence is t_1 ; standard deviation above the mode of distribution of

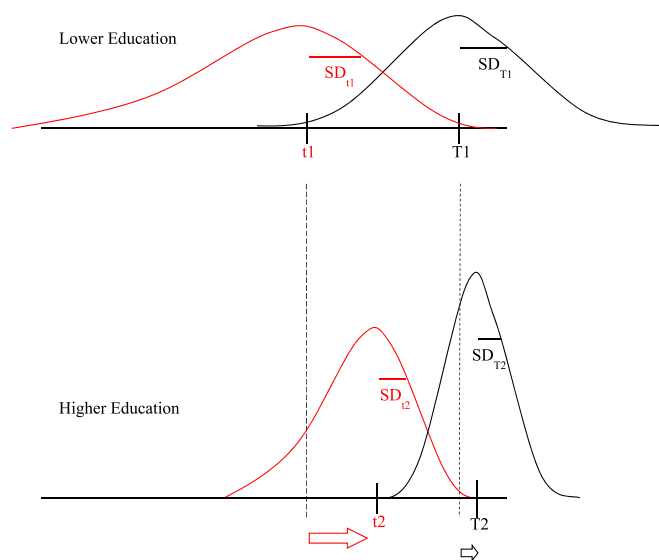


Fig. 1. Hypothetical scenario of compression of disability incidence.

disability incidence is SD_{t1} , and standard deviation above the mode of distribution of death at SD_{T1} . For the higher educated group, the modal age at death is T_2 , the modal age at disability incidence is t_2 ; the standard deviation above the mode of distribution of disability incidence is SD_{t2} , and the standard deviation above the mode of distribution of death is SD_{T2} .

In this figure the higher educated group is designated to have a later modal age at death ($T_2 > T_1$) compared to the less educated group and that mortality is more concentrated at the upper tail of the age distribution also ($SD_{T2} < SD_{T1}$). The higher educated group also has a later modal age at disability incidence ($t_2 > t_1$), and the inequality in the modal age at disability incidence is greater than the inequality in the modal age at death ($T_2 - T_1 < t_2 - t_1$). Inequality in the variation of disability incidence is greater than the inequality in the variation in mortality ($SD_{t2} < SD_{t1}$) which shows the compression of disability incidence comes with increased education. We note, however, that the figure is only a representation of our core hypotheses, and that it is also feasible that higher level of educational attainment does not necessarily result in greater certainty. This will depend on the degree to which educational attainment is able to postpone the incidence of disability relative to mortality.

Methods

Data

The data source for this study is the Health and Retirement Study (HRS), a biennial survey which began in 1992 and is available up until 2012 (Health & Retirement Study, 2016). Although the sample is drawn from the civilian non-institutionalized population, the longitudinal design followed respondents as they entered institutions and died. Overall, the HRS is representative of the U.S. non-institutional population aged 50 years and older, and their spouses. This study makes use of eight observational waves (1998, 2000, 2002, 2004, 2006, 2008, 2010, and 2012) from Rand file (v.o) (Rand, 2016) to identify changes in disability across waves, and mortality incidence for the U.S. population age 50 and over.

The HRS is linked to a National Death Index and also identifies additional deaths via follow-up interviews from family members. Disability is measured by difficulties with activities of daily living (ADL), and a composite measure for ADL is used in this study. The ADL measure includes five items: dressing, bathing, eating, bedding and walking. An individual is considered to have an ADL disability (i.e., to be disabled) if he/she had difficulties performing at least one of the five ADL activities; otherwise, he/she is not considered to be disabled. In HRS, an ADL summary variable,

RwADLA (where “w” refers to wave number), including the five necessary ADL items, is already provided in the HRS RAND data file, so this study uses this summary ADL variable. This study defines persons as disabled if they have one or more ADL items. For persons who never reported becoming disabled but were institutionalized, we do not assign them as disabled because they reported they did not have any ADL item.

Educational attainment at the time of the baseline interview was reported as years of formal schooling for respondents. In the data, those falling into the low-level category have less than high school graduation (0–11 years), those in the mid-level category achieved high school graduation (12 years), while those in the high-level category have at least some college education (13+ years). Even though previous studies by Zajacova and her colleagues have shown the difference between high school and General Education Development (GED) diploma in terms of health (Zajacova, 2012; Zajacova & Everett, 2014; Zajacova, Hummer, & Rogers, 2012), their studies focus on working aged adults whose birth cohorts, compared to older persons, differ not only in their health but also in the frame of history that defines the value of education for good health. Besides, we do not have sufficient events to use a refined measure of educational attainment that focuses on GED given the type of analysis we are doing in the study. The way we categorize educational attainment is consistent with the best fitting form identified by Montez, Hummer, and Hayward (2012).

Methodology

Transition probabilities estimated from multinomial logistic regression:

$$\ln\left(\frac{p_{ij}}{p_{ii}}\right) = \beta_{0ij} + \beta_{1ij} \cdot \text{age}, \text{ by gender and education}$$

where p_{ij} is the transition probability from the current state i to state j ($i \neq j$), β_{0ij} is the intercept, β_{1ij} is the coefficient for age at the beginning of the observation interval. Then, the estimated transition probabilities are used to produce a microsimulation of disability changes and mortality for a hypothetical cohort of individuals. There are total of six transitions (see Fig. 2). Through microsimulation, the life histories of each member of the population could be simulated in order to calculate compression of disability incidence. For example, to simulate the disability and mortality experiences of a million-person cohort of high education American women aged 50 years, an initial health status (either disabled or not disabled) for each American woman at age 50 is randomly assigned based on the information from the input data set. Then, each life history is simulated according to the transition probabilities obtained from multinomial logistic regression from equation above, and repeating this for every American woman in the cohort. Therefore, each history has “not disabled” and/or “disabled” states at different ages until death occurs. The life histories allow us to accumulate all age-specific simulated transitions by different kinds of transitions. Age distributions of all six transitions (see Fig. 2), including transitions from a disabled or not disabled state to death, could be obtained by educational group, providing the means to calculate the

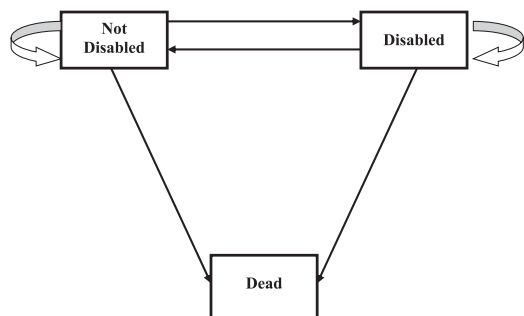


Fig. 2. Health transitions between not disabled, disabled and dead.

modes and standard deviations above the mode. In the study, disability incidence is based on a Markov model where transitions are bi-directional and individuals may experience multiple changes in disability status in the life histories. To assure stable estimates, we simulated a million-person cohort as opposed to a standard life table cohort of one hundred thousand. Our interests are the transition of disability incidence (from not disabled to disabled state) and death. The distribution of the ages at incidence (disability incidence or death) can be summarized by a central value and by an indicator of dispersion (to measure the degree of compression). The central value is measured following the formula by Kannisto (2001) based on the modal age (M), with M obtained via interpolation:

$$M = x + \frac{d(x) - d(x-1)}{[d(x) - d(x-1)] + [d(x) - d(x+1)]}$$

where $d(x)$ is the number of disability incidences or life table deaths at age x , $d(x-1)$ is the number of disability incidences or life table deaths at age $x-1$, and $d(x+1)$ is the number of disability incidences or life table deaths at age $x+1$. We also measure compression via the SD above the modal age ($SD(M+)$) following the idea of Kannisto (2001) and the formula of Cheung et al. (2005):

$$SD(M+) = \sqrt{\frac{\sum_{i=1}^n (x - M)^2}{n}}$$

where $\sum_{i=1}^n (x - M)^2$ represents the sum of the squared positive deviations from the modal age, and n represents the number of age intervals above the mode. A bootstrapping technique was adopted to obtain standard errors for the life table functions. Bootstrapping generates repeated estimates of the life table functions by randomly drawing a series of bootstrap samples from the analytic samples. The bootstrap method is a data resampling method which is used to derive variance estimates when analytic methods are unavailable (Efron, 1987; Efron & Tibshirani, 1986). The bootstrap method used here has been implemented in recent demographic studies (Cai, Hayward, Saito, Lubitz, Hagedorn & Crimmins, 2010; Cai & Lubitz, 2007). It considers the sampling design elements such as stratification and multi-stage clustering in large-scale and complex surveys, such as the HRS surveys in this study. Suppose that there are certain amount of strata in the survey and there are n_i PSUs (Primary Sampling Units) in stratum i . The bootstrap method draws samples from $n_i - 1$ PSUs with replacement within stratum i . The original sampling weight w_j for each PSU $_j$ drawn within stratum i would be re-calculated as $\frac{n_i}{n_i - 1} \cdot m_j \cdot w_j$, where m_j was the number of times the PSU $_j$ was sampled. Then, disability and mortality rates and the multistate life tables are calculated based on the bootstrap sample. Repeat this approach for 300 times and distributions of the life table functions would be obtained, which allows us to estimate sampling variability. This study combines this information with the original estimates to construct confidence intervals, allowing for statistical tests of the parameters across the gender-education groups.

Please note that an incidence in our paper refers to a Markov process, where the event of becoming disabled only depends on being in the “not disabled” state at the beginning of the age interval. No prior history is considered in our analysis. All events regardless of whether a person has experienced a prior event are included in the numerator of the rate.

Results

Figs. 3 and 4 show that education fundamentally affects the location of the life table death (dx) curves for both men and women in the United States. Clear educational gradients on death are shown, and higher education is associated with a right shift in the distribution of the number of deaths at the mode. In each figure, the black line is less than the high school graduation level (0–11 years), the red line is high school graduation level (12 years), and the green line is some college and above (13+ years). Fig. 5 displayed that more survivors were

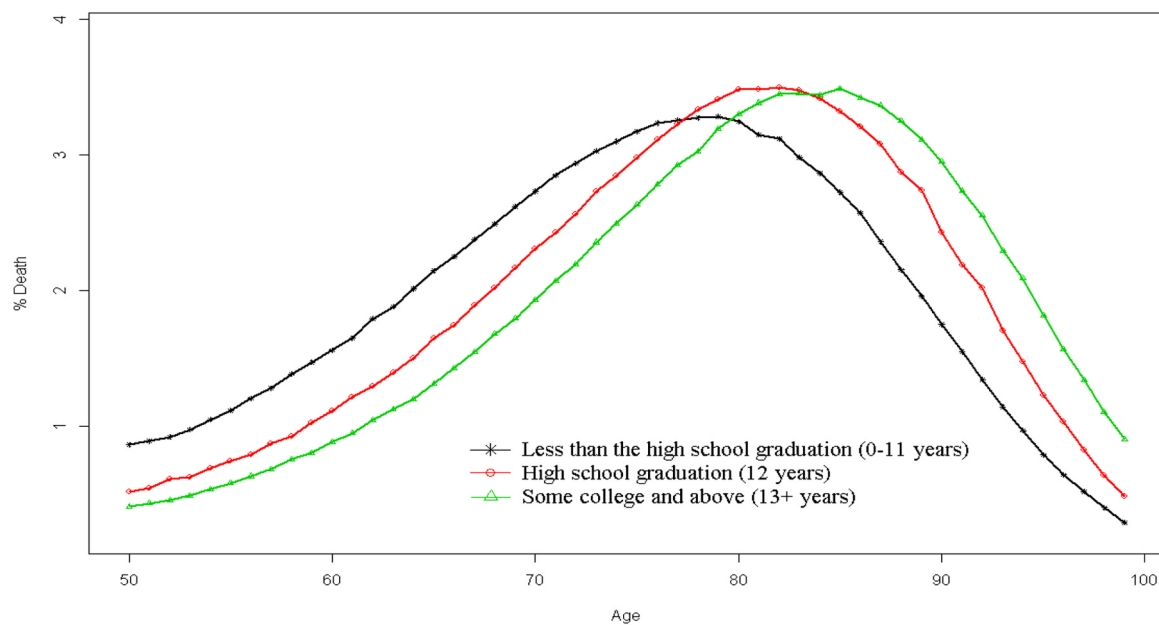


Fig. 3. Age-specific percentage of life table deaths from simulation models for older American men aged 50 and above by education.

among those with higher education. People who had higher education had higher modal age at death, and their survival curves become more rectangular compared to those with lower levels of education. Comparing men and women, women are found to have a higher modal age at death, and less variation above the mode than do men.

Figs. 6 and 7 display the modal age at disability incidence (M) and the standard deviation above the modal age at disability incidence ($SD(M+)$). Those with 0–11 years of education have different patterns than do the other two education groups. The modal age at disability incidence is much younger and variation above the mode is larger compared to those of other two education groups. People with high school graduation (12 years) are more similar to those with some college and above education (13+ years) in terms of the shape of distribution and the location of modal age.

Figs. 8 and 9 show the results of compression of disability incidence for men and women separately. The graphs exhibit that, with increasing education, people experience greater longevity, mortality compression,

and later disability incidence, and these are along with compression of disability incidence, i.e., a smaller variation in ages of disability incidence above the mode. Gender differences by education are shown here. The educational differences in compression of disability incidence are more profound for women than men.

The numerical results for modal age at death show that men with less than a high school graduation level of education ($M=79.2$, $CI=77.6-80.8$) have a mode about three years lower than men with high school graduation ($M=82.3$, $CI=80.9-83.8$) ($p < 0.05$), who also have a mode about three years lower than men with some college or more education ($M=85.4$, $CI=84.1-86.7$) ($p < 0.05$). Men in the lowest education group (0–11 years) have standard deviation above mode ($SD(M+)$) of 8.5 ($CI=7.8-9.2$) that is statistically larger than that of men in the highest education group (13+ years) ($SD(M+)=6.5$, $CI=5.9-7.0$) ($p < 0.05$). A similar situation holds for women. The education differences between women with 0–11 years of education ($M=81.9$, $CI=80.5-83.4$; $SD(M+)=7.8$, $CI=7.1-8.4$), 12 years

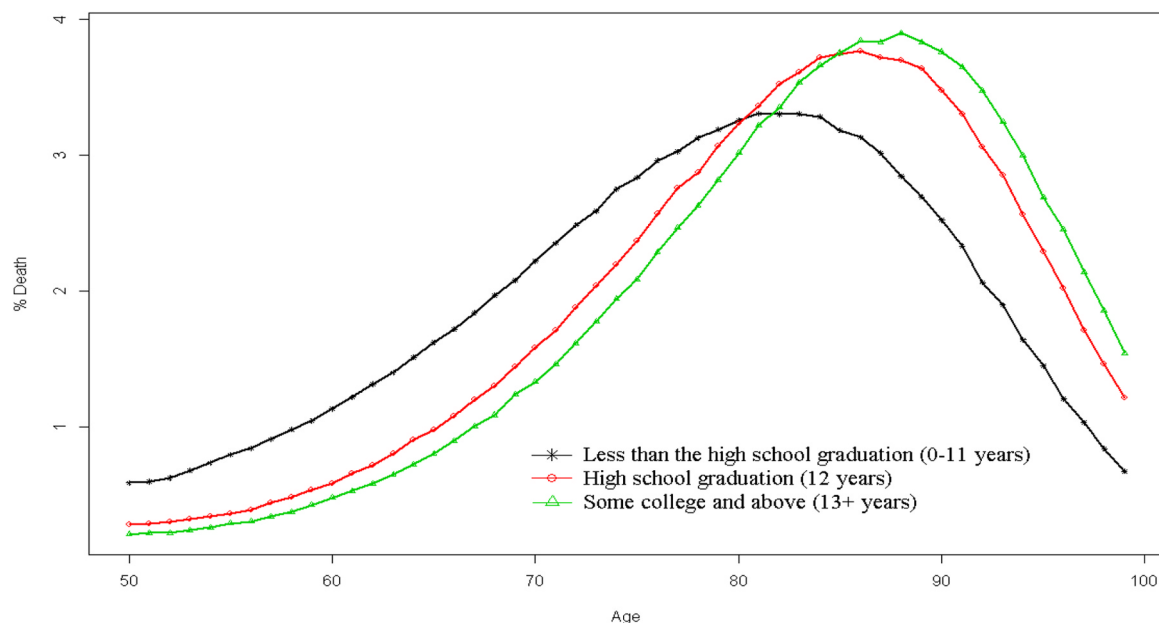


Fig. 4. Age-specific percentage of life table deaths from simulation models for older American women aged 50 and above by education.

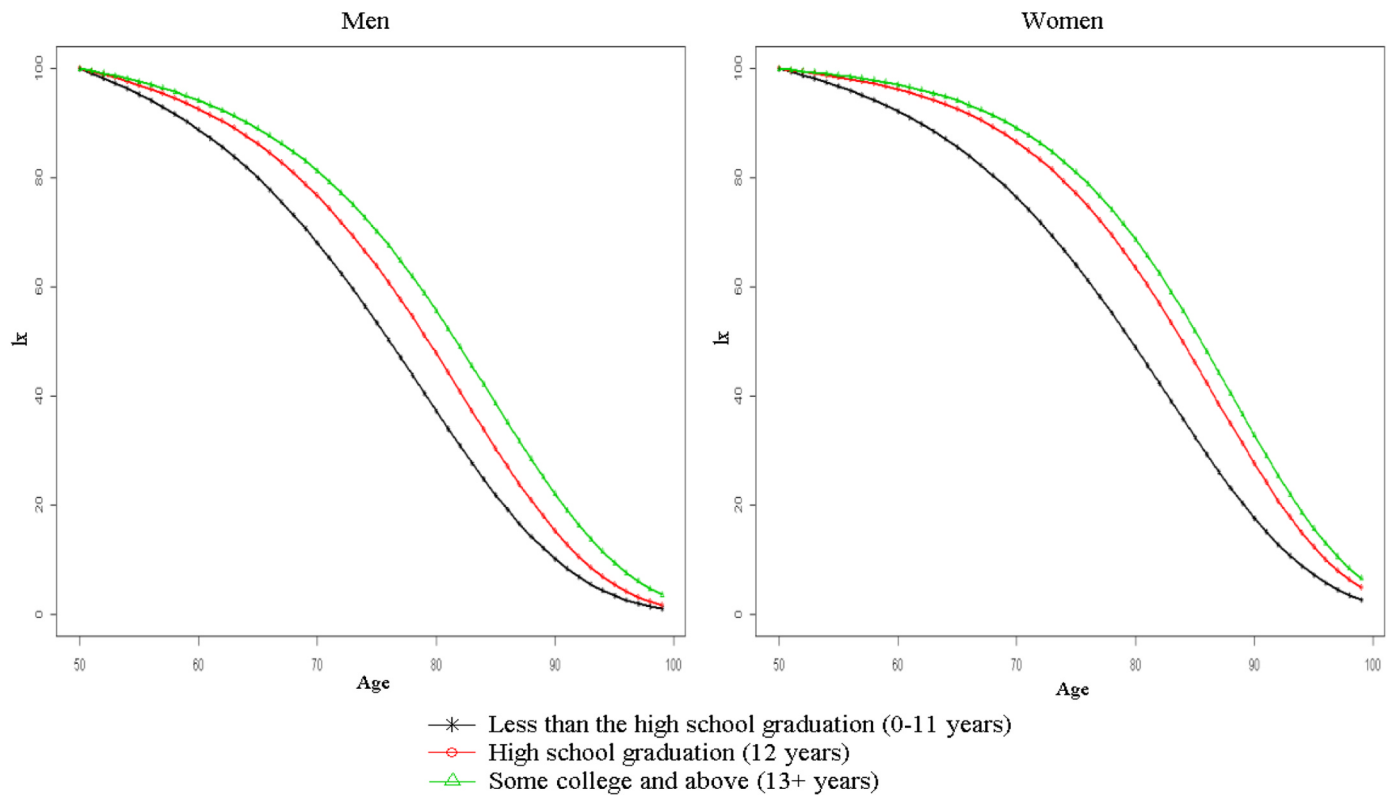


Fig. 5. Age-specific percentage of life table survivors from simulation models for older American men and women aged 50 and above by education.

of education ($M=86.3$, $CI=85.2-87.4$; $SD(M+)=6.2$, $CI=5.7-6.8$), and 13+ years of education ($M=88.5$, $CI=87.5-89.5$; $SD(M+)=5.2$, $CI=4.7-5.6$) are all statistically significant ($p < 0.05$) (Table 1).

The right side of Table 1 shows the results for disability incidence. Men with 0–11 years of education have a modal age at disability incidence at 62.1 ($CI=57.2-66.9$) that is 14 years earlier than men with 13+ years of education ($M=76.1$, $CI=73.8-78.4$) ($p < 0.05$), and statistically the former's variation above the mode ($SD(M+)=14$, $CI=12.1-15.9$) is also significantly larger than the latter ($SD(M+)=10$, $CI=9.0-11.0$) ($p < 0.05$). The same general patterns hold for women, but the educational gradients in

disability incidence and compression are shallower for men than women. Therefore, education not only shifted the whole distribution to the right but also alters the shape of disability incidence and compressed the distribution of disability incidence.

We also examined more refined education categories to better understand whether the results of 13+ years of education reflect the associations with advanced education. They do. However, because of sample size considerations, we chose to report the results for the three-category measure of education, which more clearly show the pattern and statistical differences.

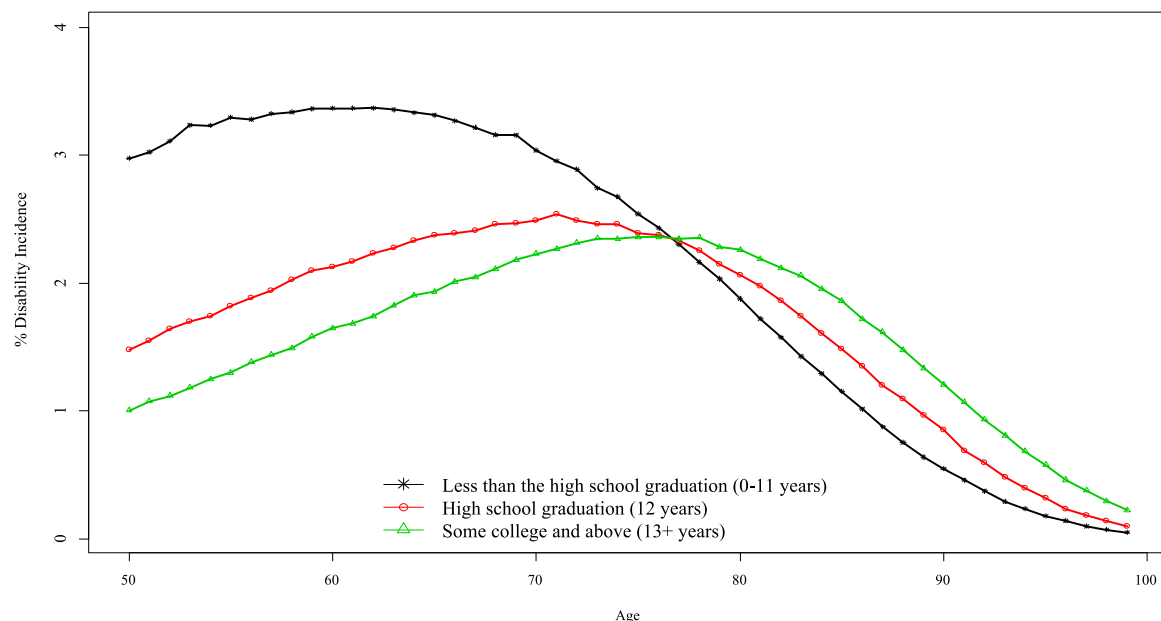


Fig. 6. Age-specific percentage of disability incidence from simulation models for older American men aged 50 and above by education.

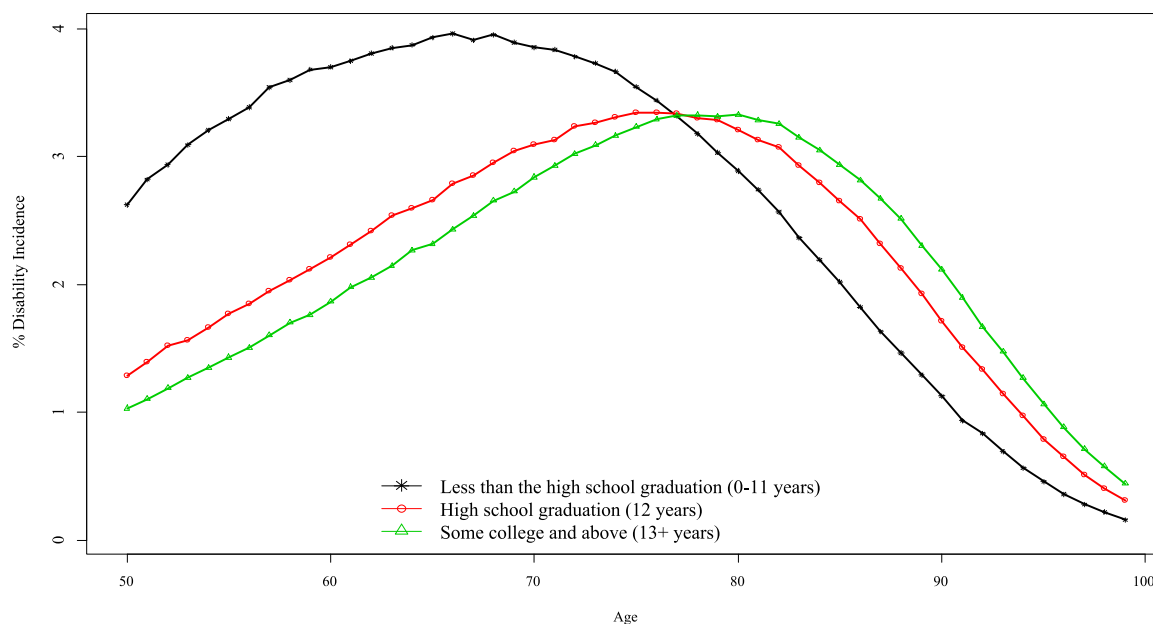


Fig. 7. Age-specific percentage of disability incidence from simulation models for older American women aged 50 and above by education.

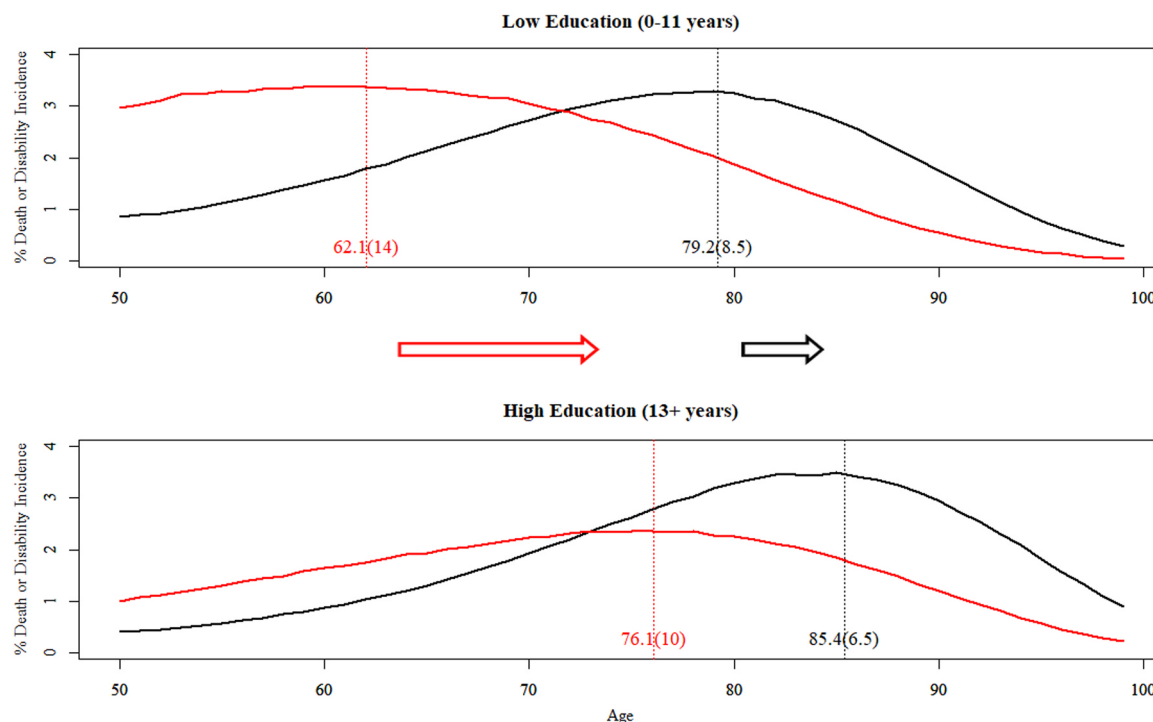


Fig. 8. Compression of disability incidence for older American men aged 50 and above, by high and low education groups.

Discussion

The study shows the existence of educational differences in compression of disability incidence. As education increases, within a population the variation in ages of disability incidence above the mode becomes smaller. Fundamental cause theory (Link & Phelan, 1995; Phelan & Link, 2005) explains persisting associations between education and health and mortality in terms of personal resources, such as “knowledge, money, power, prestige, and social connections.” The associations between education and health and mortality might change over time but would endure because the resources are transportable. In other words, the central principle of the theory is the staying power of education (Masters, Hummer, & Powers, 2012; Masters, Link, & Phelan, 2015).

The mechanisms responsible for the staying power of education on health and mortality can be discussed from four perspectives (Hayward et al., 2015; Hummer & Hernandez, 2013). People with higher levels of education are more likely to access better, subjectively rewarding jobs and earn higher incomes, have access to health insurance, and endure less economic hardship, all of which positively influence health and mortality (Lynch, 2003; Ross & Wu, 1995). The better educated are more likely to lead health lifestyles, refrain from smoking, drink moderately, and be more physically active (Cutler & Lleras-Muney, 2006, 2010b; Ross & Wu, 1995). Compared to the poorly educated, the well-educated enjoy higher levels of social support, better social relationships, and more valuable networks (Hout, 2012; Lin, 1999; Ross & Mirowsky, 1989), all of which benefit health (House, Landis, & Umberson, 1988). A recent study by Baker and colleagues

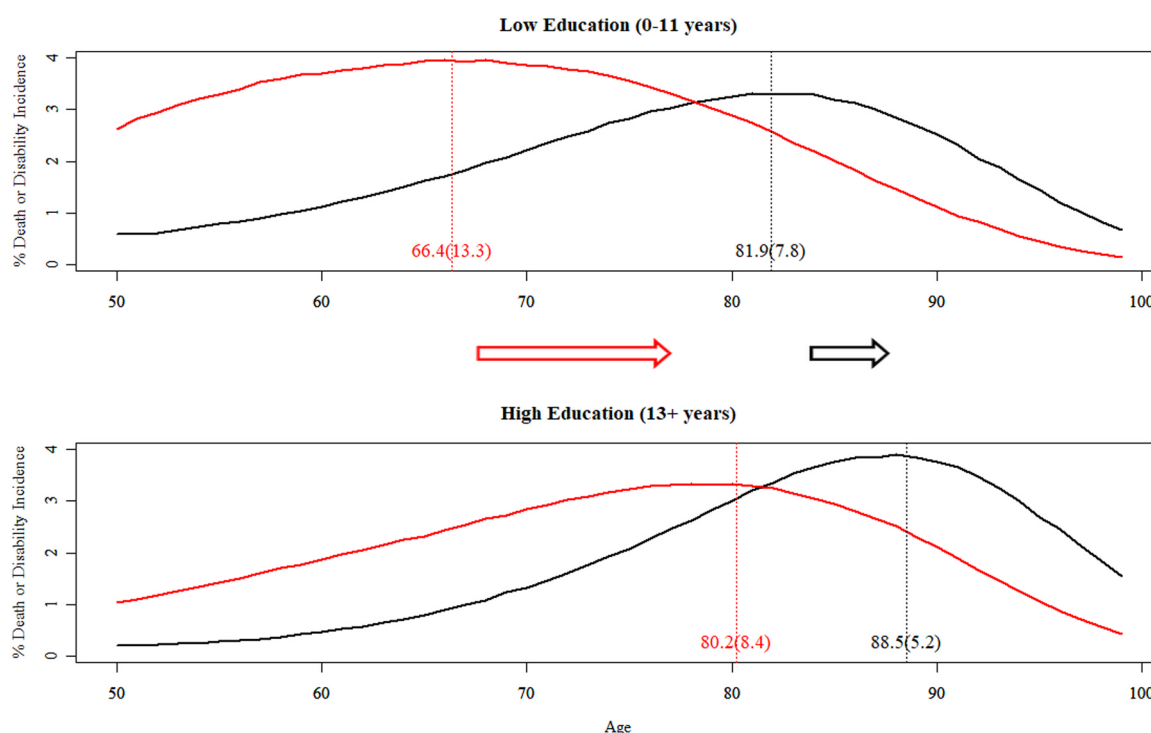


Fig. 9. Compression of disability incidence for older American women aged 50 and above, by high and low education groups.

Table 1

Education and gender differences in the modal age (M) and the standard deviation above the modal age (SD(M+)) for life table death and disability incidence.

Education	Life table deaths			Disability incidence		
	0–11 Years	12 Years	13+ Years	0–11 Years	12 Years	13+ Years
Women						
Modal Age	81.9 (80.5 ,83.4)	86.3 (85.2 ,87.4)	88.5 (87.5 ,89.5)	66.4 (63.4 ,69.3)	76.3 (74.3 ,78.3)	80.2 (78.6 ,81.8)
SD(M+)	7.8 (7.1 ,8.4)	6.2 (5.7 ,6.8)	5.2 (4.7 ,5.6)	13.3 (12.0 ,14.5)	9.8 (8.9 ,10.7)	8.4 (7.7 ,9.2)
Men						
Modal Age	79.2 (77.6 ,80.8)	82.3 (80.9 ,83.8)	85.4 (84.1 ,86.7)	62.1 (57.2 ,66.9)	71.5 (67.9 ,75.1)	76.1 (73.8 ,78.4)
SD(M+)	8.5 (7.8 ,9.2)	7.4 (6.8 ,8.1)	6.5 (5.9 ,7.0)	14.0 (12.1 ,15.9)	11.0 (9.5 ,12.4)	10.0 (9.0 ,11.0)

suggested that schooling-enhanced cognitive skills are the reasons why educational attainment has become so crucial to adult mortality and health (Baker, Leon, Smith Greenaway, Collins & Movit, 2011). Therefore, the better educated were more likely to have better access to new knowledge, practices, and life-saving technologies to reduce mortality risk (Chang & Lauderdale, 2009; Link & Phelan, 1995; Phelan, Link, Diez-Roux, Kawachi & Levin, 2004), and enjoy longer life (Braveman et al., 2010; Crimmins & Saito, 2001; Manton et al., 1997) compared to their less-educated counterparts. These educational differences in longevity within a population are also accompanied by mortality compression at more advanced ages (Brown et al., 2012).

Education has protective effects on health through its impacts on individuals' psychological and social processes (Herd, Goesling, & House, 2007). Hence, the delayed biological aging processes among the better-educated not only maximize life chances but also delay disablement processes through lower levels of age-specific biological risks and a later incidence of chronic disease (Crimmins, Kim, & Seeman, 2009), disability incidence (Jagger et al., 2007; Latham, 2012; Melzer et al., 2001). Therefore, the well-educated experience a compression of disability incidence compared to their less-educated counterparts. This

study reveals that education fundamentally affects not only the location, but also the shape of the dx curves for both men and women, which echoes the findings of Brown et al. (2012). Education has a fundamentally universal influence on age, disablement processes and compression of disability incidence for each gender.

Prior studies demonstrate the existence of profound educational differences in adult mortality and disability. This study shows that education is significantly associated with mortality compression and compression of disability incidence. In other words, with increased education, the modal age at death and disability incidence is higher, and mortality and disability incidence above the mode is more compressed. To our knowledge, no prior studies have examined educational difference in compression of disability incidence and conducted formal tests for statistical significance. Our study also points to gender differences in the association between education and compression of mortality and disability incidence. The distributions of ages of deaths and disability incidence are more compressed among women than men in the same education group. Therefore, education is important for people in terms of improvement of longevity, later incidence of disability, and compression of mortality and disability incidence. The future, of course, is uncertain in terms of life span variation in both mortality and disability

incidence for education groups in the United States. Sasson (2016) showed that while well-educated groups experienced both improved life expectancy and a compression in mortality, low education groups' declines in life expectancy were accompanied by an increase in life span variation in mortality. Whether the trend in mortality foreshadows a similar trend in disability incidence is unclear. However, current evidence is highly suggestive that there is growing inequality in life span variation in disability incidence – a key component of successful aging.

Funding

This research was supported by a research grant from the Ministry of Science and Technology (MOST 104-2410-H-001-93-). The funding source had no role in the design, methods, analysis and preparation of paper. This research was also supported by grant, P2CHD042849, Population Research Center, awarded to the Population Research Center at The University of Texas at Austin by the Eunice Kennedy Shriver National Institute of Child Health and Human Development. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

The authors have no financial or any other kind of personal conflicts with this paper.

References

- Baker, D. P., Leon, J., Smith Greenaway, E. G., Collins, J., & Movit, M. (2011). The education effect on population health: A reassessment. *Population and Development Review*, 37(2), 307–332. <https://doi.org/10.1111/j.1728-4457.2011.00412.x>.
- Braveman, P. A., Cubbin, C., Egerter, S., Williams, D. R., & Pamuk, E. (2010). Socioeconomic disparities in health in the United States: What the patterns tell us. *American Journal of Public Health*, 100(S1), S186–S196. <https://doi.org/10.2105/ajph.2009.166082>.
- Brown, D., Hayward, M., Montez, J. K., Hummer, R., Chiu, C.-T., & Hidajat, M. (2012). The significance of education for mortality compression in the United States. *Demography*, 49(3), 819–840. <https://doi.org/10.1007/s13524-012-0104-1>.
- Cai, L., Hayward, M., Saito, Y., Lubitz, J., Hagedorn, A., & Crimmins, E. (2010). Estimation of multi-state life table functions and their variability from complex survey data using the SPACE Program. *Demographic Research*, 22(6), 129–158. <https://doi.org/10.4054/DemRes.2010.22.6>.
- Cai, L., & Lubitz, J. (2007). Was there compression of disability for older Americans from 1992 to 2003? *Demography*, 44(3), 479–495. <https://doi.org/10.1353/dem.2007.0022>.
- Cantu, P. A., Hayward, M. D., Hummer, R. A., & Chiu, C.-T. (2013). New estimates of racial/ethnic differences in life expectancy with chronic morbidity and functional loss: Evidence from the national health interview survey. *Journal of Cross-Cultural Gerontology*, 1–15.
- Chang, V. W., & Lauderdale, D. S. (2009). Fundamental cause theory, technological innovation, and health disparities: The case of cholesterol in the era of statins. *Journal of Health and Social Behavior*, 50(3), 245–260.
- Cheung, S. L. K., & Robine, J. M. (2007). Increase in common longevity and the compression of mortality: The case of Japan. *Population Studies*, 61(1), 85–97. <https://doi.org/10.1080/00324720601103833>.
- Cheung, S. L. K., Robine, J. M., & Caselli, G. (2008). The use of cohort and period data to explore changes in adult longevity in low mortality countries. *Genus*, 64(1–2), 101–129. <https://doi.org/10.2307/41430837>.
- Cheung, S. L. K., Robine, J. M., Tu, E. J.-C., & Caselli, G. (2005). Three dimensions of the survival curve: Horizontalization, verticalization, and longevity extension. *Demography*, 42(2), 243–258.
- Crimmins, E. M., Hayward, M. D., & Saito, Y. (1994). Changing mortality and morbidity rates and the health status and life expectancy of the older population. *Demography*, 31(1), 159–175.
- Crimmins, E. M., Kim, J. K., & Seeman, T. E. (2009). Poverty and biological risk: The earlier “aging” of the poor. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 64(2), 286–292.
- Crimmins, E. M., & Saito, Y. (2001). Trends in healthy life expectancy in the United States, 1970–1990: Gender, racial, and educational differences. *Social Science and Medicine*, 52(11), 1629–1641.
- Cutler, D. M., & Lleras-Muney, A. (2006). Education and Health: Evaluating Theories and Evidence. National Bureau of Economic Research Working Paper Series, No. 12352.
- Cutler, D. M., & Lleras-Muney, A. (2010a). *The education gradient in old age disability. Research findings in the economics of aging*. University of Chicago Press 101–120.
- Cutler, D. M., & Lleras-Muney, A. (2010b). Understanding differences in health behaviors by education. *Journal of Health Economics*, 29(1), 1–28. <https://doi.org/10.1016/j.jhealeco.2009.10.003>.
- Efron, B. (1987). Better bootstrap confidence intervals. *Journal of the American Statistical Association*, 82(397), 171–185. <https://doi.org/10.1080/01621459.1987.10478410>.
- Efron, B., & Tibshirani, R. (1986). Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Statistical Science*, 1(1), 54–75.
- Fries, J. F. (1980). Aging, natural death, and the compression of morbidity. *The New England Journal of Medicine*, 303(3), 130.
- Fries, J. F., Bruce, B., & Chakravarty, E. (2011). Compression of morbidity 1980–2011: A focused review of paradigms and progress. *Journal of Aging Research*, 2011.
- Hayward, M., & Heron, M. (1999). Racial inequality in active life among adult Americans. *Demography*, 36(1), 77–91. <https://doi.org/10.2307/2648135>.
- Hayward, M. D., Hummer, R. A., & Sasson, I. (2015). Trends and group differences in the association between educational attainment and U.S. adult mortality: Implications for understanding education's causal influence. *Social Science and Medicine*, 127, 8–18. <https://doi.org/10.1016/j.socscimed.2014.11.024>.
- Health and Retirement Study. (2016). Public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, 2016.
- Herd, P., Goesling, B., & House, J. S. (2007). Socioeconomic position and health: The differential effects of education versus income on the onset versus progression of health problems. *Journal of Health and Social Behavior*, 48(3), 223–238. <https://doi.org/10.1177/002214650704800302>.
- House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, 241(4865), 540–545. <https://doi.org/10.2307/1701736>.
- Hout, M. (2012). Social and economic returns to college education in the United States. *Annual Review of Sociology*, 38(1), 379–400. <https://doi.org/10.1146/annurev.soc.012809.102503>.
- Hummer, R. A., & Hernandez, E. M. (2013). The effect of educational attainment on adult mortality in the United States. *Population Bulletin*, 68(1).
- Jagger, C., Matthews, R., Melzer, D., Matthews, F., & Brayne, C. (2007). Educational differences in the dynamics of disability incidence, recovery and mortality: Findings from the MRC Cognitive Function and Ageing Study (MRC CFAS). *International Journal of Epidemiology*, 36(2), 358–365. <https://doi.org/10.1093/ije/dyl307>.
- Kannisto, V. (2001). Mode and dispersion of the length of life. *Population: An English Selection*, 13(1), 159–171.
- Latham, K. (2012). Progressive and accelerated disability onset by race/ethnicity and education among late midlife and older adults. *Journal of Aging and Health*, 24(8), 1320–1345. <https://doi.org/10.1177/0898264312459345>.
- Lin, N. (1999). Social networks and status attainment. *Annual Review of Sociology*, 25(1), 467–487. <https://doi.org/10.1146/annurev.soc.25.1.467>.
- Link, B. G., & Phelan, J. C. (1995). Social conditions as fundamental causes of disease. *Journal of Health and Social Behavior*, 35, 80–94 (Extra Issue: Forty Years of Medical Sociology: The State of the Art and Directions for the Future (1995)).
- Lynch, S. M. (2003). Cohort and life-course patterns in the relationship between education and health: A hierarchical approach. *Demography*, 40(2), 309–331.
- Manton, K. G., Stallard, E., & Corder, L. (1997). Education-specific estimates of life expectancy and age-specific disability in the U.S. elderly population 1982 to 1991. *Journal of Aging and Health*, 9(4), 419–450. <https://doi.org/10.1177/08982643970900401>.
- Masters, R. K., Hummer, R. A., & Powers, D. A. (2012). Educational differences in U.S. adult mortality: A cohort perspective. *American Sociological Review*, 77(4), 548–572. <https://doi.org/10.1177/0003122412451019>.
- Masters, R. K., Link, B. G., & Phelan, J. C. (2015). Trends in education gradients of ‘preventable’ mortality: A test of fundamental cause theory. *Social Science and Medicine*, 127(0), 19–28. <https://doi.org/10.1016/j.socscimed.2014.10.023>.
- Melzer, D., Izmirlian, G., Leveille, S. G., & Guralnik, J. M. (2001). Educational differences in the prevalence of mobility disability in old age: The dynamics of incidence, mortality, and recovery. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences*, 56(5), S294–S301.
- Mirowsky, J., & Ross, C. E. (1989). *Social causes of psychological distress*. New York: de Gruyter.
- Montez, J. K., Hummer, R. A., & Hayward, M. D. (2012). Educational attainment and adult mortality in the United States: A systematic analysis of functional form. *Demography*, 49(1), 315–336. <https://doi.org/10.1007/s13524-011-0082-8>.
- Phelan, J. C., & Link, B. G. (2005). Controlling disease and creating disparities: A fundamental cause perspective. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 60(Special Issue 2), S27–S33. https://doi.org/10.1093/geronb/60.Special_Issue_2.S27.
- Phelan, J. C., Link, B. G., Diez-Roux, A., Kawachi, I., & Levin, B. (2004). “Fundamental causes” of social inequalities in mortality: A test of the theory. *Journal of Health and Social Behavior*, 45(3), 265–285. <https://doi.org/10.1177/00221465040500303>.
- Rand, H. (2016). Data, Version O. Produced by the RAND Center for the Study of Aging, with funding from the National Institute on Aging and the Social Security Administration. Santa Monica, CA (February 2016).
- Ross, C. E., & Mirowsky, J. (1989). Explaining the social patterns of depression: Control and problem solving - or support and talking? *Journal of Health and Social Behavior*, 30, 206–219.
- Ross, C. E., & Mirowsky, J. (1995). Does employment affect health? *Journal of Health and Social Behavior*, 36(3), 230–243.
- Ross, C. E., & Wu, C.-L. (1995). The links between education and health. *American Sociological Review*, 719–745.
- Saito, Y., Chan, A., Malhotra, R., & Matchar, D. (2012). Active Life Expectancy by Sex and SES in Singapore. Paper presented at In Proceedings of the 24th Annual REVES Meeting, Taichung, Taiwan.
- Sasson, I. (2016). Trends in life expectancy and lifespan variation by educational attainment: United States, 1990–2010. *Demography*, 53(2), 269–293.
- van Raalte, A. A., Kunst, A. E., Deboosere, P., Leinsalu, M., Lundberg, O., Martikainen, P., ... Mackenbach, J. P. (2011). More variation in lifespan in lower educated groups: Evidence from 10 European countries. *International Journal of Epidemiology*, 40(6), 1703–1714. <https://doi.org/10.1093/ije/dyr146>.
- Zajacova, A. (2012). Health in working-aged Americans: Adults with high school equivalency diploma are similar to dropouts, not high school graduates. *American Journal of Public Health*, 102(S2), S284–S290.
- Zajacova, A., & Everett, B. G. (2014). The nonequivalent health of high school equivalents. *Social Science Quarterly*, 95(1), 221–238.
- Zajacova, A., Hummer, R. A., & Rogers, R. G. (2012). Education and health among US working-age adults: A detailed portrait across the full educational attainment spectrum. *Biomedical Research and Social Biology*, 58(1), 40–61.