Maturitas 134 (2020) 21–28

Contents lists available at ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

Educational differences in trajectories and determinants of healthy ageing in midlife and older Americans

Sara J. McLaughlin[a,*], Seonjin Kim[b], Lydia W. Li[c], Jiaan Zhang[d]

[a] Department of Sociology and Gerontology, Miami University, 375 Upham Hall, Oxford, OH 45056, USA
[b] Department of Statistics, Miami University, 311 Upham Hall, Oxford, OH 45056, USA
[c] School of Social Work, University of Michigan, 1080 S. University, Ann Arbor, MI 48109, USA
[d] Department of Social Work, Fudan University, 220 Handan Rd, Shanghai, 200433, China

ARTICLE INFO

Keywords:
Longitudinal
Socioeconomic status
Successful ageing

ABSTRACT

Objectives: To advance knowledge of the influence of educational level on trajectories and determinants of healthy ageing in midlife and older Americans.
Study design: Data are from the Health and Retirement Study, a nationally representative, longitudinal survey of Americans age 51 and over. We used generalized estimating equations to examine trajectories and determinants of healthy ageing by level of education among 17,591 adults followed over a 14-year period. Educational level was categorized as less than a high school diploma, high school diploma, some college education, and a college or higher degree. Potential determinants included demographic factors, early-life characteristics (childhood health and childhood poverty), health-related factors (health behaviours, physical and mental health conditions), and psychosocial characteristics (perceived neighbourhood safety, volunteerism, and work status).
Main outcome measures: Informed by earlier work, we defined healthy ageing as freedom from cognitive impairment, freedom from disability, and high physical functioning.
Results: The log odds of healthy ageing declined over time in all educational groups. Importantly, the decline was smaller in adults with a college or higher degree than in those without a high school diploma. Age, gender, wealth, health behaviours, productive engagement, depressive symptoms, and the presence of chronic conditions predicted healthy ageing across the educational spectrum; however, the impact of several factors (age, gender, race/ethnicity, childhood poverty, and volunteerism) varied by educational level.
Conclusions: Education shapes trajectories of healthy ageing in the United States. Similarities and differences in determinants of healthy ageing are evident across levels of education. Findings highlight broad-based and education-specific targets for intervention.

1. Introduction

Although there is no universally accepted definition of healthy ageing, it is typically conceptualized as the maintenance of robust health across multiple domains (e.g., [1]). Longitudinal studies of healthy ageing in North America [2–4] and Europe [5–7] generally suggest that adults with higher education are more likely to experience healthy ageing than their less educated counterparts. Not surprisingly, however, the association is attenuated or nullified in analyses that control for factors that presumably fall on the causal pathway between education and healthy ageing (e.g. [2,8]).

Education is believed to promote health via multiple means. In addition to better positioning one for occupations that allow for engagement in creative activities [9,10], the knowledge, cognitive skills, and psychological resources that education fosters are thought to facilitate healthier lifestyles and more effective coping in the face of challenges [10–12]. Higher educated individuals also tend to have greater work-related earnings [13], affording them access to health-protective resources and living environments [11].

While investigations comparing healthy ageing *between* educational groups are essential for monitoring educational inequalities in late-life health, it is also important to examine factors associated with healthy ageing *within* educational groups. In particular, failure to investigate the occurrence of healthy ageing in educationally-disadvantaged circumstances is a missed opportunity to identify pathways by which to promote healthy ageing in those at greatest risk of poor health [14].

In keeping with this line of thought, McLaughlin [15] used cross-sectional data from the US Health and Retirement Study (HRS) to

* Corresponding author.
E-mail addresses: mclaugsj@miamioh.edu (S.J. McLaughlin), kims20@miamioh.edu (S. Kim), lydiali@umich.edu (L.W. Li), jazhang@fudan.edu.cn (J. Zhang).

https://doi.org/10.1016/j.maturitas.2020.01.002
Received 16 April 2019; Received in revised form 28 November 2019; Accepted 7 January 2020

investigate factors associated with healthy ageing in Americans who did not complete high school and whether identified correlates were similar to those observed in more educated Americans. Early-life disadvantage, black race, less household wealth, obesity, chronic conditions, and depressive symptoms reduced the odds of healthy ageing across educational groups; alcohol use and physical activity increased the odds. While not formally tested, there was some evidence that the effect of age, gender, and Hispanic ethnicity varied by education.

Because education shapes access to other resources [11,16], those growing older in the context of educational disadvantage do so in a more "constrained" context [17]. As a result, the impact of risk and protective factors may vary by education. In their theory of resource substitution, Mirowsky and Ross [18] argue that "the effect of having a specific resource is greater for those who have fewer alternative resources." This suggests that beneficial resources may exert a larger effect in those with less education. Likewise, the impact of risk factors may be "amplified" in the context of low education [16]. Mirowsky and Ross [16] found, for instance, that low income exerted a greater negative effect on health in those without a high school degree than their more educationally-advantaged counterparts. They speculated that education enables individuals to more effectively manage the challenges associated with low income.

Building on existing work, we examine healthy ageing and its determinants within and between educational groups in a national sample of midlife and older Americans using a range of educational categories and data gathered over a 14-year period. A more nuanced understanding of how education shapes healthy ageing will aid in the identification of broad-based and education-specific targets for intervention.

2. Methods

2.1. Sample

The HRS is a national study of US adults over age 50; multi-stage area probability sampling was used to select participants [19]. Although the HRS began in 1992, it was restructured in 1998. Thus, 1998 served as our baseline year. HRS data are collected biennially, with eight "core interviews" occurring between 1998 and 2012. In 1998, the response rate for the HRS was 83.8 % [20].[1]

In 1998, 21,384 individuals were interviewed. Of those, 1334 had sampling weights of zero (i.e., interviewed, but ineligible), 1693 were proxies, and 766 had missing data, producing an analytic sample of 17,591 individuals with 97,020 observations over the 14-year period.

2.2. Measures

2.2.1. Education

Education was classified as less than a high school (HS) diploma (referent), HS diploma (hereafter, HS graduates), some college, and a college or higher degree (hereafter, college graduates). Some college includes individuals with education beyond high school that did not result in a bachelor's degree (e.g., vocational training, associate's degree). Evidence suggests that Americans with some college education fare better in the labour market than their less educated peers [13,16].

2.2.2. Healthy ageing

Healthy ageing encompasses freedom from cognitive impairment, freedom from disability, and high physical functioning [21]. *Freedom from cognitive impairment* was defined as a score ≥ 12 (out of 27) on a measure involving immediate and delayed word recall, serial subtraction, and backwards counting [22]. *Freedom from disability* was defined as the ability to perform six activities of daily living (e.g., dressing) and five instrumental activities of daily living (e.g., managing money) without difficulty. *High physical functioning* was defined as ≤ 1 difficulty performing 11 tasks (e.g., climbing stairs). Details on the validity and components of our measure of healthy ageing are available elsewhere [15,21].

2.2.3. Determinants of healthy ageing

Potential determinants included demographic (age category, gender, marital status, race/ethnicity, household wealth), early-life (childhood health, childhood poverty), health-related (alcohol use, body mass index, physical activity, smoking history, chronic conditions, depressive symptoms), and psychosocial (perceived neighbourhood safety, volunteerism, work status) factors. Details on the measurement of each determinant are included in Table 1. Unless otherwise indicated, determinants were time-varying.

2.3. Statistical analysis

We first calculated descriptive statistics for the sample at baseline by education. We then used generalized estimating equations (GEE) to assess how education shapes trajectories of healthy ageing. Specifically, in a single GEE model, we regressed healthy ageing on time, education, time*education interaction terms, and demographic covariates. Next, we examined the impact of demographic, early-life, health-related, and psychosocial characteristics on healthy ageing. To allow the effect of determinants to vary by education, we used education-specific models. In these models, beta estimates capture the effect of each determinant on the log odds of healthy ageing averaged across time. Observed educational differences in effects were subsequently tested in a GEE model containing education by determinant interaction terms and all covariates.

All analyses account for features of the HRS sampling design (i.e., oversampling, stratification, clustering). Descriptive statistics were weighted using respondent-level weights provided by HRS; corresponding standard errors were adjusted for stratification and clustering. In all GEE models, we incorporated respondent-level sampling weights adjusted for attrition and a variable capturing sampling stratum and primary sampling unit. We considered an association statistically significant when $p < .01$. SAS version 9.4 was used for the analysis.

3. Results

3.1. Sample characteristics

Table 2 contains baseline sample characteristics by educational level. While household wealth and the percentage of married adults were higher in those with more education, the percentage of females and old-old adults was lower. With increasing educational level, a generally smaller percentage reported childhood poverty and poor/fair childhood health. Alcohol use and physical activity were more common in those with more education, whereas obesity, depressive symptoms and chronic conditions were less so. Educational differences in psychosocial characteristics were also evident. With increasing educational level, a higher percentage of adults reported working and volunteering; a lower percentage perceived their neighborhood unsafe. Healthy ageing was more prevalent in those with more education, ranging from 22.9 % in those without a HS diploma to 62.6 % in college graduates.

3.2. Population trajectories of healthy ageing

Controlling for demographic covariates, the baseline odds of healthy ageing were 80 % higher for HS graduates ($\beta = 0.588$; $p < .001$), 118 % higher for those with some college ($\beta = 0.781$; $p < .001$), and 209%

[1] The response rate is a function of continued participation among existing panel members and the initial response rate for individuals newly sampled when the study was reconfigured in 1998. Initial response rates were higher for existing panel members when recruited in the early 1990's (approximately 80%) than for individuals newly recruited in 1998 (approximately 70%).

Table 1
Potential determinants of healthy ageing and their operationalization.

Determinants	Operationalization	Time-Varying
Demographic		
Age category at baseline	Middle-age (50–64 years; referent), Young-old (65–74 years), Old-old (75 years and over)	No
Gender	Female, Male (referent)	No
Household wealth percentile	Ranges from 1 to 100; Captures assets minus debt (see [41] for details)	Yes
Marital status	Married, Not Married (referent)	Yes
Race/ethnicity	Hispanic, Non-Hispanic Black (Black), Non-Hispanic Other (Other), Non-Hispanic White (White; referent)	No
Early-life		
Childhood health	"Consider your health while you were growing up, before you were 16 years old. Would you say that your health during that time was excellent, very good, good, fair, or poor?" Responses were categorized as fair/poor vs. good/very good/excellent (referent).	No
Childhood poverty	"Now think about your family when you were growing up, from birth to age 16. Would you say your family during that time was pretty well off financially, about average, or poor?" Responses were categorized as poor or not poor (pretty well off financially/about average; referent).	No
Health-related		
Alcohol use	"Do you ever drink any alcoholic beverages such as beer, wine, or liquor?" Yes vs. no (referent)	Yes
Body mass index	Using self-reported height and weight, body mass index was categorized as: normal/underweight (< 25; referent), overweight (≥ 25, < 30), or obese (≥ 30)	Yes
Physical activity at baseline	Because measurement of physical activity changed over the study period, only baseline physical activity was considered: "On average over the last 12 months have you participated in vigorous physical activity or exercise three times a week or more? By vigorous physical activity, we mean things like sports, heavy housework, or a job that involves physical labor." Yes vs. no (referent)	No
Smoking history at baseline	Respondents were categorized as never smokers vs. ever (current/former) smokers (referent). Note that baseline values were used because values were virtually unchanged across time.	No
Number of chronic conditions	The sum of seven self-reported conditions: arthritis, cancer, chronic lung disease, diabetes, heart disease, hypertension, and stroke; higher scores indicate more conditions	Yes
Number of depressive symptoms[a]	8-item CES-D scale; Scores range from 0 to 8, with higher scores indicating more symptoms.	Yes
Psychosocial		
Neighbourhood safety	"Would you say the safety of [your] neighborhood is excellent, very good, good, fair or poor?" Responses were categorized as good/very good/excellent vs. fair/poor (referent)	Yes
Volunteerism	"Have you spent any time in the past 12 months doing volunteer work for religious, educational, health-related or other charitable organizations?" Yes vs. no (referent)	Yes
Working status	"Are you doing any work for pay at the present time?" Yes vs. no (referent)	Yes

[a] Early work [42] on the 8-item CES-D demonstrated reasonable internal reliability (Cronbach's alpha = .78).

higher for college graduates (β = 1.127; p < .001) relative to those without a HS diploma (Table 3).[2] The log odds of healthy ageing declined over time in all educational groups; however, compared to those without a HS diploma, the slope of decline was less steep for college graduates (β = 0.022; p = .002; Table 3). Fig. 1 illustrates trajectories of healthy ageing by education.

3.3. Determinants of healthy ageing

3.3.1. Demographic characteristics

Relative to middle-aged adults, the odds of healthy ageing were 31.2 % to 56.7 % lower for the young-old (β= -0.374 to -0.838) and 62.0 % to 79.1 % lower for the old-old (β= -0.967 to -1.567), depending on educational level (Table 4). The negative effects of older age tended to increase with rising education, with formal testing for educational variation in the impact of older age revealing that the effects of being young-old and old-old were significantly more negative in college graduates than in those without a HS diploma ($\beta_{young\text{-}old*COLL}$= -0.284, p = .006; $\beta_{old\text{-}old*COLL}$= -0.355, p = .008; Fig. 2A; Supplemental Table 1). No other interactions were significant.

Across educational groups, the odds of healthy ageing were 20.3 % to 52.5 % (β= -0.227 to -0.745) lower for females than males (Table 4). While the negative effect of female gender generally increased with rising education, formal interaction testing revealed that the effect of female gender was significantly more negative only in college graduates when compared to the effect observed in those without a HS diploma ($\beta_{female*COLL}$= -0.449, p < .001; Fig. 2B; Supplemental Table 1).

[2] Odds are derived from exponentiation of beta coefficients. For example, exponentiation of the beta for HS graduates (β = 0.588) produces an odds ratio of 1.80, meaning that the odds of HS graduates experiencing healthy ageing are 80% higher than for those without a HS diploma.

The odds of healthy ageing increased with increasing wealth in all educational categories. Specifically, for each percentile increase in wealth, the odds of healthy ageing increased by .5% to .9% (β = .005 to .009), depending on educational level (Table 4). No significant educational variation in the effect of wealth was evident.

In adults without a HS diploma, the odds of healthy ageing were 28.0 % lower for black adults relative to their white counterparts (β= -0.329, p = .002; Table 4). Effects were smaller and failed to reach statistical significance in those with higher education. Formal testing for educational variability in the effect of black race confirmed that the effect was significantly less negative in those with some college ($\beta_{black*SC}$ =0 .446, p = .002) and college graduates ($\beta_{black*COLL}$ = 0.441, p = .005) relative to adults without a HS diploma (Fig. 2C; Supplemental Table 1).

The pattern for Hispanic ethnicity was different, with a significant negative effect observed only in college graduates (β= -0.537; p = .003). Specifically, in college graduates, the odds of healthy ageing were 41.6 % lower for Hispanic adults relative to white adults. With those without a HS diploma serving as the referent group, formal testing for educational variability in effects revealed that Hispanic ethnicity exerted a less favourable effect in college graduates ($\beta_{Hispanic*COLL}$= -0.508; Fig. 2C; Supplemental Table 1); however, the difference attained only borderline statistical significance (p = .011). Given the small number of Hispanic college graduates (n = 71), the latter may reflect limited statistical power.

3.3.2. Early-life characteristics

Having a poor childhood family reduced the odds of healthy ageing by 17.9 % in those without a HS diploma (β= -0.197; p = .005), with no significant effects in those with more education (Table 4). Formal testing for a poverty*education interaction confirmed that the effect of childhood poverty was significantly weaker in those with some college ($\beta_{Childhood\ poverty*SC}$ = 0.266; p = .008; Fig. 2D; Supplemental Table 2) and college graduates ($\beta_{Childhood\ poverty*COLL}$ = 0.323; p = .002)

Table 2
Sample characteristics by level of education.

Characteristics	Less than HS diploma, n = 4672	HS graduate, n = 6340	Some college, n = 3475	College graduate, n = 3104
Demographic				
Age category, % (95 % CI)				
Middle-age (50–64)	38.5 (35.6–41.3)	53.5 (51.5–55.5)	59.1 (56.3–62.0)	61.5 (59.0–64.1)
Young-old (65–74)	31.6 (29.4–33.8)	27.0 (25.1–29.0)	23.5 (21.5–25.5)	24.6 (22.8–26.5)
Old-old (75 +)	29.9 (27.9–32.0)	19.4 (18.3–20.6)	17.4 (15.5–19.2)	13.8 (12.2–15.4)
Female, % (95 % CI)	60.0 (58.5–61.6)	60.7 (59.4–61.9)	58.1 (56.2–60.0)	43.8 (42.5–45.2)
Household wealth in USD, mean (95 % CI)	129,340 (115,604-143,076)	274,527 (244,997-304,058)	398,823 (315,604-482,042)	624,537 (558,743-690,331)
Married, % (95 % CI)	53.3 (50.8–55.8)	65.1 (63.5–66.8)	66.7 (64.6–68.7)	74.1 (72.1–76.2)
Race/ethnicity, % (95 % CI)				
Hispanic	14.3 (9.3–19.4)	3.4 (2.4–4.3)	3.7 (2.6–4.9)	2.2 (1.6–2.8)
Non-Hispanic black	16.2 (13.5–19.0)	7.2 (6.3–8.1)	6.9 (5.8–8.1)	4.6 (3.5–5.6)
Non-Hispanic other	2.3 (0.7–3.8)	1.3 (0.8–1.8)	1.8 (1.3–2.4)	2.9 (2.2–3.6)
Non-Hispanic white	67.2 (62.0–72.3)	88.1 (86.6–89.6)	87.5 (85.8–89.2)	90.3 (88.9–91.7)
Early-life, % (95 % CI)				
Fair/poor childhood health	9.9 (8.8–11.0)	5.1 (4.4–5.8)	5.4 (4.5–6.4)	4.3 (3.5–5.2)
Poor childhood family	45.4 (43.4–47.3)	30.0 (28.8–31.3)	24.9 (23.4–26.5)	19.9 (18.0–21.9)
Health-related				
Alcohol use, % (95 % CI)	32.6 (30.3–34.9)	50.2 (48.5–52.0)	61.2 (58.6–63.8)	69.6 (67.3–71.8)
Body mass index, % (95 % CI)				
Normal/underweight	34.9 (33.0–36.7)	35.9 (34.3–37.4)	37.7 (36.1–39.4)	42.6 (40.3–45.0)
Overweight	39.4 (37.9–40.9)	39.6 (38.0–41.2)	38.6 (36.7–40.5)	38.7 (36.4–41.0)
Obese	25.8 (23.8–27.8)	24.5 (23.4–25.6)	23.7 (21.8–25.6)	18.7 (16.9–20.5)
Never smoker, % (95 % CI)	38.5 (36.7–40.3)	40.7 (39.2–42.2)	37.5 (35.6–39.4)	44.4 (42.2–46.6)
Vigorous physical activity ≥ 3 times/week, % (95 % CI)	35.8 (34.1–37.6)	46.1 (44.1–48.1)	49.0 (47.0–51.0)	50.7 (48.4–53.0)
Chronic health conditions, mean (95 % CI)	1.9 (1.9–2.0)[a]	1.5 (1.5–1.6)[a]	1.4 (1.4–1.5)[a]	1.2 (1.1–1.3)
Depressive symptoms, mean (95 % CI)	2.3 (2.1–2.4)	1.5 (1.4–1.6)	1.3 (1.2–1.4)	1.0 (0.9–1.0)[a]
Psychosocial, % (95% CI)				
Neighbourhood perceived to be unsafe	15.8 (14.3–17.3)	7.5 (6.5–8.5)	5.9 (5.1–6.8)	4.1 (2.9–5.2)
Volunteered in past 12 months	17.6 (16.2–19.0)	29.3 (27.3–31.2)	38.8 (36.7–41.0)	51.4 (49.3–53.5)
Working for pay	25.5 (23.7–27.2)	42.4 (40.9–43.9)	50.7 (48.6–52.9)	60.2 (57.8–62.6)
Healthy ageing, % (95% CI)	22.9 (21.3–24.4)	41.9 (40.2–43.5)	49.5 (47.6–51.4)	62.6 (60.3–64.8)

[a] Confidence limit includes point estimate due to rounding. CI = confidence interval; HS = high school; Means and percentages are weighted; Sample numbers are not weighted; Percentages may not sum to 100 due to rounding.

Table 3
Adjusted effects of education on the log odds of healthy ageing over time: Results of GEE analysis.

	β	SE	P
Intercept	−0.229	0.090	0.011
Education (Ref = Less than HS diploma)			
HS graduate (HSGrad)	0.588	0.051	<.001
Some college (SC)	0.781	0.057	<.001
College graduate (COLL)	1.127	0.060	<.001
Time, years	−0.082	0.006	<.001
Time*HSGrad	0.017	0.007	0.012
Time*SC	0.011	0.007	0.110
Time*COLL	0.022	0.007	0.002

β = parameter estimate; SE = standard error; HS = High School; Adjusted for age category, gender, marital status, household wealth percentile (centered), and race/ethnicity; n = 17,591.

compared to the effect in those without a HS diploma.

While poor/fair childhood health reduced the log odds of healthy ageing in all educational categories, the effect was statistically significant only in HS graduates (β = -0.317; p = .005; Table 4). When formally tested, no significant educational variation in the effect of childhood health was evident.

3.3.3. Health-related characteristics

The log odds of healthy ageing were significantly higher in those reporting alcohol use (β = 0.158 to 0.329) and engagement in vigorous physical activity (β = 0.419 to 0.598) in all educational groups (Table 4). In contrast, obesity (β = -0.612 to -0.434), increasing chronic conditions (β = -0.477 to -0.443), and increasing depressive symptoms (β = -0.227 to -0.197) significantly reduced the log odds of healthy ageing. Never smoking exerted a significant positive effect in HS graduates (β = 0.161, p = .002). No significant educational variation in the effects of health-related characteristics were observed in formal testing.

3.3.4. Psychosocial characteristics

Perceived neighbourhood safety significantly increased the log odds of healthy ageing in the lowest educational categories (< HS: β = 0.234, p = .004; HS graduates: β = 0.292; p = <.001). Although the effect of neighborhood safety appears smaller in those with some college and college graduates (Table 4), educational differences were not statistically significant when formally tested.

With one exception—volunteering in college graduates—productive engagement in the form of volunteering (β = 0.121 to 0.354) and working (β = 0.277 to 0.488) significantly increased the log odds of healthy ageing in all educational groups. Consistent with the pattern in Table 4, formal testing for a volunteer*education interaction indicated that the effect of volunteering was smaller in HS graduates ($\beta_{Volunteer*HS}$ = -0.145, p = .052), those with some college ($\beta_{Volunteer*SC}$ = -0.208, p = .009), and college graduates ($\beta_{Volunteer*COLL}$ = -0.272, p = .001) than in those without a HS diploma (Fig. 2E; Supplemental Table 2). No significant educational variation in the effect of working was evident.

4. Discussion

We examined educational differences in healthy ageing and its determinants over a 14-year period in midlife and older Americans. Across time, the log odds of healthy ageing were lowest in those with the least education and greatest in those with the most. In all educational categories, the log odds of healthy ageing declined over time; however, the

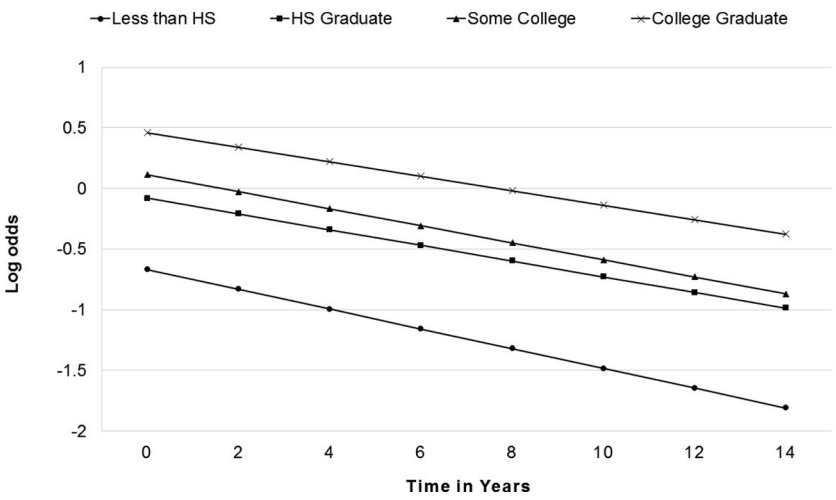

Fig. 1. Logs odds of healthy ageing by education between 1998 and 2012.
Less than a high school (HS) diploma: n = 4672; HS graduate: n = 6340; Some college: n = 3475; College graduate: n = 3104; Depicted trajectories are for a middle-aged (age referent), unmarried (marital referent), white (race referent) woman of average wealth.

Table 4
The effect of demographic, early-life, health-related, and psychosocial factors on the log odds of healthy ageing by education: Results of GEE analysis.

	Less than HS diploma, n = 4672 β (SE)	HS graduate, n = 6340 β (SE)	Some college, n = 3475 β (SE)	College graduate, n = 3104 β (SE)
Intercept	0.001 (0.216)	0.647 (0.154)***	0.646 (0.203)**	1.413 (0.230)***
Time in years	−0.050 (0.006)***	−0.035 (0.004)***	−0.037 (0.005)***	−0.032 (0.005)***
Demographic characteristics				
Age category (Ref = Middle-age)				
Young-old	−0.374 (0.080)***	−0.512 (0.054)***	−0.603 (0.072)***	−0.838 (0.074)***
Old-old	−0.967 (0.101)***	−1.283 (0.076)***	−1.339 (0.100)***	−1.567 (0.106)***
Female (Ref = Male)	−0.227 (0.079)**	−0.396 (0.053)***	−0.399 (0.070)***	−0.745 (0.069)***
Married (Ref = No)	0.102 (0.075)	−0.119 (0.049)	0.020 (0.063)	−0.062 (0.070)
Race/ethnicity (Ref = Non-Hispanic white)				
Hispanic	0.179 (0.115)	−0.167 (0.140)	0.022 (0.154)	−0.537 (0.180)**
Non-Hispanic black	−0.329 (0.105)**	−0.174 (0.093)	−0.075 (0.113)	0.013 (0.135)
Non-Hispanic other	−0.644 (0.247)**	0.131 (0.212)	0.119 (0.172)	−0.149 (0.197)
Household wealth percentile (centered)	0.007 (0.001)***	0.009 (0.001)***	0.008 (0.001)***	0.005 (0.001)***
Early-life characteristics				
Poor childhood family (Ref = No)	−0.197 (0.071)**	−0.055 (0.052)	0.066 (0.070)	0.069 (0.078)
Poor/fair childhood health (Ref = Good or better)	−0.275 (0.129)	−0.317 (0.114)**	−0.270 (0.156)	−0.225 (0.146)
Health characteristics				
Alcohol use (Ref = No)	0.329 (0.059)***	0.158 (0.037)***	0.177 (0.053)***	0.217 (0.057)***
Body mass index (Ref = Underweight/normal)				
Overweight	−0.114 (0.065)	−0.125 (0.043)**	0.050 (0.057)	−0.058 (0.055)
Obesity	−0.434 (0.085)***	−0.565 (0.056)***	−0.518 (0.079)***	−0.612 (0.077)***
Chronic conditions, number	−0.477 (0.029)***	−0.449 (0.019)***	−0.443 (0.025)***	−0.456 (0.025)***
Depressive symptoms, number	−0.222 (0.016)***	−0.225 (0.012)***	−0.227 (0.015)***	−0.197 (0.015)***
Never smoker at baseline (Ref = No)	0.173 (0.076)	0.161 (0.051)**	0.060 (0.068)	0.080 (0.067)
Physically active at baseline (Ref = No)	0.577 (0.071)***	0.483 (0.049)***	0.419 (0.064)***	0.598 (0.065)***
Psychosocial characteristics				
Neighbourhood safety (Ref = Poor/fair)	0.234 (0.082)**	0.292 (0.069)***	0.110 (0.104)	0.054 (0.133)
Volunteer (Ref = No)	0.354 (0.066)***	0.176 (0.037)***	0.121 (0.047)**	0.063 (0.046)
Working for pay (Ref = No)	0.488 (0.065)***	0.387 (0.042)***	0.338 (0.053)***	0.277 (0.056)***

β = parameter estimate; SE = standard error; HS = high school; *** p < .001; **p < .01.

average decline was significantly smaller in those with the most education relative to those with the least.

Consistent with our prior cross-sectional work [15], we found that age, gender, household wealth, alcohol use, obesity, physical activity, depressive symptoms, and the presence of chronic health conditions predicted healthy ageing across the educational spectrum. Productive engagement, which we had not previously examined, also predicted healthy ageing. While most determinants of healthy ageing behaved similarly across educational groups, educational variation in the effects of some determinants was evident.

Age exerted a greater negative effect in college graduates than in those without a HS diploma, which appears to reflect qualitative differences in middle-age comparison groups. As evident in our findings (Fig. 2A), middle-aged Americans with a college or higher degree are markedly healthier than middle-aged adults without a HS diploma. This is consistent with work demonstrating earlier onset of health problems in low SES adults, with SES-related health differences especially pronounced in middle-age [23]. While some evidence suggests that SES differences in health continue unabated into older adulthood, other evidence suggests that differences become smaller in advanced old age [24]. Possible reasons include selective survival of healthier low SES adults and/or biological limits on the postponement of health problems in advantaged older adults [24]. Marked health advantages in middle-age followed by smaller health advantages in older adulthood likely explain the larger negative effect of age observed in college graduates.

Research exploring how education influences the relationship between gender and health presents a mixed picture [18,25]. We observed a larger negative effect of female gender in college graduates than in

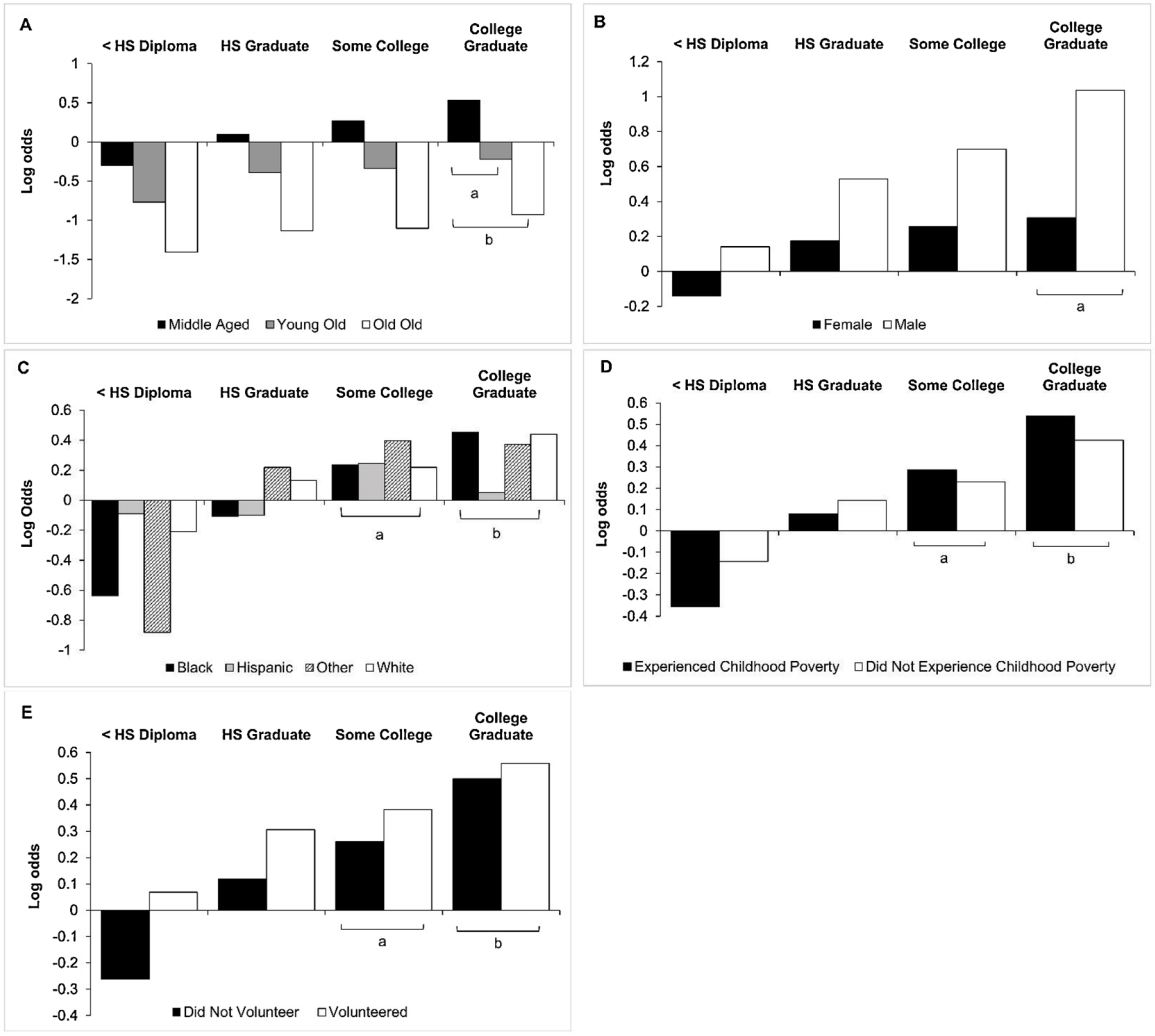

Fig. 2. Effect of select determinants on the log odds of healthy ageing by education.
(**A**) Log odds of healthy ageing by education and age category. Differences in the log odds of healthy ageing between young-old and middle-aged college graduates (a) and old-old and middle-aged college graduates (b) are significantly greater than the respective differences in those without a high school (HS) diploma (referent group).
(**B**) Log odds of healthy ageing by education and gender. The difference in the log odds of healthy ageing between female and male college graduates (a) is significantly greater than the difference observed between females and males without a HS diploma (referent group).
(**C**) Log odds of healthy ageing by education and race/ethnicity.
Differences in the log odds of healthy ageing between black and white adults with some college education (a) and black and white college graduates (b) are significantly smaller than the respective differences in those without a HS diploma (referent group).
(**D**) Log odds of healthy ageing by education and childhood poverty.
Differences in the log odds of healthy ageing between those who did and did not experience childhood poverty are significantly smaller for those with some college education (a) and college graduates (b) than for their respective counterparts without a HS diploma (referent group).
(**E**) Log odds of healthy ageing by education and volunteerism.
Differences in the log odds of healthy ageing between those who did and did not engage in volunteer activities are significantly smaller in those with some college education (a) and college graduates (b) than for their respective counterparts without a HS diploma (referent group).

those without a high school diploma, which appears to reflect an especially advantaged male comparison group (Fig. 2B). Mazzonna [26] found that higher education significantly reduced the likelihood of blue-collar work in older European men, enabling them to avoid occupational hazards. This was not true for women, which Mazzonna argued stems from gender differences in labour force participation in the examined cohorts. Given similar gender patterns in blue-collar work and labour force participation in the US [27], this may also be true for the cohort of adults examined herein. Another possibility is that the women examined in this study—all born in the late 1940's and earlier—did not reap the same absolute rewards from higher education as men owing to gender biases in the workplace [28] and gender norms surrounding domestic responsibilities [29,30].

Consistent with Barnes et al. [31], we found that higher education nearly eliminated the negative effect of black race. This suggests that initiatives enabling higher education among black youth would improve the health of future cohorts of older black adults. The opposite pattern was observed in those of Hispanic ethnicity, with a significant negative effect evident only in college graduates.

While consistent with earlier work [15], our finding regarding Hispanic ethnicity requires further investigation. The US Hispanic population is a diverse one, with a sizeable immigrant population [32] and health outcomes varying by place of birth [32,33]. Moreover, foreign-born Hispanic Americans are generally less likely to have a college degree than their native-born counterparts [34]. While more research is needed to fully understand this finding, our results suggest

that college graduates of Hispanic ethnicity face greater barriers to healthy ageing than their white counterparts.

Our finding that the effect of childhood poverty was lessened in those achieving at least some college education is consistent with research examining the impact of upward social mobility on health [35]. Importantly, it suggests that enabling higher education for those born into disadvantaged circumstances would improve population-level health.

While volunteerism generally promoted healthy ageing, its effect was pronounced in those without a HS diploma. Volunteering may create opportunities for participation in cognitively and socially-engaging activities [36] that are otherwise less available to those without a HS diploma. Notably, Proulx and colleagues [37] recently reported that the effect of volunteering on working memory and processing speed was especially favorable in older Americans with less education. Future research should more fully explore the precise reason for the differential effects of volunteering observed herein.

4.1. Limitations and strengths

Several limitations need noting. First, there is no scientific agreement on the definition of healthy ageing. We used a definition developed in prior research [21] that emphasizes functional health. It is likely, however, that the determinants of healthy ageing and observed effect sizes depend on the definition used. Second, we did not explore the degree to which trajectories and determinants of each component of healthy ageing vary by education. Although we observed an educational gradient for each component of our definition (Supplemental Table 3), education may have a larger effect over time on some components than others. Third, our set of determinants is not exhaustive and was influenced by the measures available in the HRS. Perceived stress, for instance, varies across the educational spectrum [38] and is thought to contribute to socioeconomic differences in health [11,39]. Because it was not meaningfully assessed in the HRS in 1998, we were unable to examine its impact on healthy ageing. Fourth, p-values were not corrected for multiple comparisons, which increases the likelihood of Type I errors. Fifth, we did not examine the extent to which the effects of determinants may vary over time and in combination with each other. Understanding of how education shapes healthy ageing would benefit from this type of analysis. Finally, owing to educational variation in race/ethnicity, early-life experiences, and perceived neighbourhood safety, it is difficult to test for educational differences in their effects. To better understand educational variation in the impact of these factors, over-sampling of small subgroups (e.g., Hispanic college graduates) is needed. Major strengths of this study include our use of a broad range of determinants, an educational continuum, a national sample of midlife and older adults, and longitudinal data.

4.2. Implications and conclusion

In this cohort of Americans, healthy ageing varied within and between educational levels. While higher education increased the likelihood of healthy ageing, the observed advantage was not shared equally; women and Hispanic adults who had graduated from college did not reap the same rewards as their respective counterparts. Likewise, the lack of a HS diploma did not exert a uniformly negative effect; women, black adults, and those with a history of childhood poverty were especially disadvantaged.

Americans of all educational levels would benefit from initiatives encouraging healthy body weight, physical activity, productive engagement, and the prevention/management of health conditions. Fostering volunteer opportunities may be especially effective in promoting healthy ageing in less educated Americans. All such efforts, however, must recognize that individuals are situated in a broader social context that shapes engagement in health-protective activities [40].

Contributors

Sara J. McLaughlin contributed to conceptualization, methodology, software, formal analysis, and writing of the original draft.

Seonjin Kim contributed to methodology, software, formal analysis, and review and editing of the paper.

Lydia W. Li contributed to methodology and review and editing of the paper.

Jiaan Zhang contributed to methodology and review and editing of the paper.

Conflict of interest

The authors declare that they have no conflict of interest.

Funding

The authors did not receive funding for this study.

Ethics

This investigation was approved by Research Ethics and Integrity at Miami University in Oxford, OH, USA.

Data sharing and collaboration

The data used in this analysis are publicly available at http://hrsonline.isr.umich.edu/.

Provenance and peer review

This article has undergone peer review.

CRediT authorship contribution statement

Sara J. McLaughlin: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Visualization. **Seonjin Kim:** Methodology, Software, Formal analysis, Writing - review & editing. **Lydia W. Li:** Methodology, Writing - review & editing. **Jiaan Zhang:** Methodology, Writing - review & editing.

Acknowledgements

The HRS is administered by the University of Michigan (Ann Arbor, MI, USA) with funding from the National Institute on Aging (NIA; Bethesda, MD, USA; grant number NIA U01AG009740). We used publically-available HRS data files prepared by the RAND Center for the Study of Aging (Santa Monica, CA, USA; RAND HRS Data, Version P; hd98f2c; h00f1c; h02f2c; h04f1a; h06f2b; h08f2a; hd10f5c; H12f1a), which is supported by the NIA and the United States Social Security Administration.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.maturitas.2020.01.002.

References

[1] J.W. Rowe, R.L. Kahn, Successful aging, Gerontologist 37 (4) (1997) 433–440.
[2] R.A. Pruchno, M. Wilson-Genderson, A longitudinal examination of the effects of early influences and midlife characteristics on successful aging, J. Gerontol. B Psychol. Sci. Soc. Sci. 70 (6) (2015) 850–859.
[3] M. Wilson-Genderson, R. Pruchno, A.R. Heid, Modeling successful aging over time in the context of a disaster, J. Gerontol. B Psychol. Sci. Soc. Sci. 72 (2) (2017) 328–339.
[4] T.M. Cooney, A.L. Curl, Transitioning from successful aging: a life course approach,

J. Aging Health (2017) 898264317737892.
[5] A.A. Kok, M.J. Aartsen, D.J. Deeg, M. Huisman, Socioeconomic inequalities in a 16-year longitudinal measurement of successful ageing, J. Epidemiol. Community Health 70 (11) (2016) 1106–1113.
[6] T.D. Cosco, B.C.M. Stephan, C. Brayne, G. Muniz, M.R.C. CFAS, Education and successful aging trajectories: a longitudinal population-based latent variable modelling analysis, Can. J. Aging 36 (4) (2017) 427–434.
[7] G. Tampubolon, Trajectories of the healthy ageing phenotype among middle-aged and older Britons, 2004-2013, Maturitas 88 (2016) 9–15.
[8] M.S. Kaplan, N. Huguet, H. Orpana, D. Feeny, B.H. McFarland, N. Ross, Prevalence and factors associated with thriving in older adulthood: a 10-year population-based study, J. Gerontol. A Biol. Sci. Med. Sci. 63 (10) (2008) 1097–1104.
[9] J. Mirowsky, C.E. Ross, Creative work and health, J. Health Soc. Behav. 48 (4) (2007) 385–403.
[10] J. Mirowsky, C.E. Ross, Education, health, and the default American lifestyle, J. Health Soc. Behav. 56 (3) (2015) 297–306.
[11] P. Braveman, S. Egerter, D.R. Williams, The social determinants of health: coming of age, Annu. Rev. Public Health 32 (2011) 381–398.
[12] E.M. Lawrence, Why do college graduates behave more healthfully than those who are less educated? J. Health Soc. Behav. 58 (3) (2017) 291–306.
[13] M. Hout, Social and economic returns to college education in the United States, Annu. Rev. Sociol. 38 (2012) 379–400.
[14] National Research Council Committee on Future Directions for Behavioral and Social Sciences Research at the National Institutes of Health, Positive health: resilience, recovery, primary prevention, and health promotion, in: B.H. Singer, C.D. Ryff (Eds.), New Horizons in Health: An Integrative Approach, National Academy Press, Washington, DC, 2001, pp. 45–62.
[15] S.J. McLaughlin, Healthy aging in the context of educational disadvantage, J. Aging Health 29 (7) (2017) 1214–1234.
[16] J. Mirowsky, C.E. Ross, Education, Social Status, and Health, Aldine de Gruyter, Hawthorne, NY, 2003.
[17] P. Moen, Constrained choices: the shifting institutional contexts of aging and the life course, in: L.J. Waite, T.J. Plewes (Eds.), New Directions in the Sociology of Aging, National Academies Press, Washington, DC, 2013, pp. 175–216.
[18] C.E. Ross, J. Mirowsky, Gender and the health benefits of education, Sociol. Q. 51 (1) (2010) 1–19.
[19] A. Sonnega, J.D. Faul, M.B. Ofstedal, K.M. Langa, J.W. Phillips, D.R. Weir, Cohort profile: the Health and Retirement Study (HRS), Int. J. Epidemiol. 43 (2) (2014) 576–585.
[20] HRS, Sample Sizes and Response Rates, Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI, 2017.
[21] S.J. McLaughlin, A.M. Jette, C. M Connell, An examination of healthy aging across a conceptual continuum: prevalence estimates, demographic patterns, and validity, J. Gerontol. A Biol. Sci. Med. Sci. 67 (7) (2012) 783–789.
[22] E.M. Crimmins, J.K. Kim, K.M. Langa, D.R. Weir, Assessment of cognition using surveys and neuropsychological assessment: the Health and Retirement Study and the Aging, Demographics, and Memory Study, J. Gerontol. B Psychol. Sci. Soc. Sci. 66 (Suppl 1) (2011) i162–71.
[23] E.M. Crimmins, J.K. Kim, T.E. Seeman, Poverty and biological risk: the earlier "aging" of the poor, J. Gerontol. A Biol. Sci. Med. Sci. 64 (2) (2009) 286–292.
[24] A.M. O'Rand, S.M. Lynch, Socioeconomic status, health, and mortality in aging populations, in: M.D. Hayward, M.K. Majmundar (Eds.), Future Directions for the Demography of Aging: Proceedings of a Workshop, The National Academies Press, Washington, DC, 2018, pp. 67–96.
[25] C.E. Ross, R.K. Masters, R.A. Hummer, Education and the gender gaps in health and mortality, Demography 49 (4) (2012) 1157–1183.
[26] F. Mazzonna, The long lasting effects of education on old age health: evidence of gender differences, Soc. Sci. Med. 101 (2014) 129–138.
[27] U.S. Department of Commerce and Executive Office of the President, Women in America: Indicators of Social and Economic Well-Being, White House Council on Women and Girls, Washington, DC, 2011.
[28] M.E. Heilman, Description and prescription: how gender stereotypes prevent women's ascent up the organizational ladder, J. Soc. Issues 57 (4) (2001) 657–674.
[29] M. Blair-Loy, A. Hochschild, A.J. Pugh, J.C. Williams, H. Hartmann, Stability and transformation in gender, work, and family: insights from the second shift for the next quarter century, Community Work Fam. 18 (4) (2015) 435–454.
[30] A. Hochschild, The Second Shift: Working Parents and the Revolution at Home, Viking, New York, NY, 1989.
[31] L.L. Barnes, R.S. Wilson, L.E. Hebert, P.A. Scherr, D.A. Evans, C.F. Mendes de Leon, Racial differences in the association of education with physical and cognitive function in older blacks and whites, J. Gerontol. B Psychol. Sci. Soc. Sci. 66 (3) (2011) 354–363.
[32] R.D. Alarcón, A. Parekh, M.L. Wainberg, C.S. Duarte, R. Araya, M.A. Oquendo, Hispanic immigrants in the USA: social and mental health perspectives, Lancet Psychiatry 3 (9) (2016) 860–870.
[33] R.A. Hummer, I. Gutin, Racial/ethnic and nativity disparities in the health of older U.S. men and women, in: M.D. Hayward, M.K. Majmundar (Eds.), Future Directions for the Demography of Aging: Proceedings of a Workshop, The National Academies Press, Washington, DC, 2018, pp. 31–66.
[34] C.L. Ryan, K. Bauman, Educational Attainment in the United States: 2015, Current Population Reports, U.S. Census Bureau, Washington, DC, 2016.
[35] T.L. Gruenewald, A.S. Karlamangla, P. Hu, S. Stein-Merkin, C. Crandall, B. Koretz, T.E. Seeman, History of socioeconomic disadvantage and allostatic load in later life, Soc. Sci. Med. 74 (1) (2012) 75–83.
[36] N.D. Anderson, T. Damianakis, E. Kröger, L.M. Wagner, D.R. Dawson, M.A. Binns, S. Bernstein, E. Caspi, S.L. Cook, B.R.A.V.O. Team, The benefits associated with volunteering among seniors: a critical review and recommendations for future research, Psychol. Bull. 140 (6) (2014) 1505–1533.
[37] C.M. Proulx, A.L. Curl, A.E. Ermer, Longitudinal associations between formal volunteering and cognitive functioning, J. Gerontol. B Psychol. Sci. Soc. Sci. 73 (3) (2018) 522–531.
[38] S. Cohen, D. Janicki-Deverts, Who's stressed? Distributions of psychological stress in the United States in probability samples from 1983, 2006, and 2009, J. Appl. Soc. Psychol. 42 (6) (2012) 1320–1334.
[39] T. Seeman, E. Epel, T. Gruenewald, A. Karlamangla, B.S. McEwen, Socio-economic differentials in peripheral biology: cumulative allostatic load, Ann. N. Y. Acad. Sci. 1186 (2010) 223–239.
[40] D. Stokols, Establishing and maintaining healthy environments. Toward a social ecology of health promotion, Am. Psychol. 47 (1) (1992) 6–22.
[41] D. Bugliari, N. Campbell, C. Chan, O. Hayden, M. Hurd, R. Main, J. Mallett, C. McCullough, E. Meijer, M. Moldoff, P. Pantoja, S. Rohwedder, P. St. Clair, RAND HRS Data Documentation, Version P, RAND Center for the Study of Aging, Santa Monica, CA, 2016 August.
[42] C.L. Turvey, R.B. Wallace, R. Herzog, A revised CES-D measure of depressive symptoms and a DSM-based measure of major depressive episodes in the elderly, Int. Psychogeriatr. 11 (2) (1999) 139–148.