Creation and Validation of a Polysocial Score for Mortality among Community-Dwelling Older Adults in the US: The Health and Retirement Study

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A thesis submitted in partial
fulfillment of the requirements for the degree of
Master of Science in the Graduate Program
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ABSTRACT

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Abstract

Background: The interrelatedness between social determinants of health impedes researchers to identify important social factors for health. Older populations have highly diverse social backgrounds, and a new approach is needed to quantify the aggregate effect of social factors and develop person-centered social interventions. We aim to create a polysocial score index to comprehensively assess the social and physical environments as well as their combined effect on health among older adults.

Methods: We included a total of 7,383 adults, consisted of 3,651 participants in 2006 and 3,732 participants in 2008, who were at least 65 years and completed an additional psychosocial questionnaire in the Health and Retirement Study (HRS), a longitudinal study of a nationally representative sample of non-institutionalized residents in the United States. We searched the entire HRS data set and selected 24 social determinants of health encompassing five social domains: (1) economic stability, (2) neighborhood and physical environment, (3) education, (4) community and social context, and (5) health care system. The outcome was five-year mortality. We used a forward stepwise logistic regression model with a threshold of P-value equal to 0.1 to screen for important social factors; those having a 2-sided P value < 0.1 were retained in the final model. We assigned the polysocial score to each participant by summing the score for each social variable based on the raw coefficients of the regression model. The

score of each variable was calculated as the absolute value of the raw coefficient times 10. Both continuous and categorical polysocial scores (low: 0-29, intermediate: 30-39, and high: 40+) were constructed. Participants with higher scores had a better social environment. Logistic regressions were used to assess the unadjusted and adjusted associations between polysocial score and five-year mortality. Demographic (age, gender, and race/ethnicity), lifestyles (body mass index, smoking status, and alcohol use), and health conditions (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health) were included in the adjusted models. Interaction analyses were conducted in additive scales and multiplicative scales to evaluate whether the association between polysocial score and death was different by sex and race/ethnicity.

Results: Polysocial score was created using 15 social determinants of health selected from 24 social determinants of health: total household income, total wealth, out-of-pocket medical expenditure, education level, employment status, marital status, type of house, regions of residence, used language, long-term care insurance coverage, life insurance coverage, social engagement, discrimination, stress level, and neighborhood social cohesion. The total score ranged from 7 to 59; the mean (SD) was 35.5 (7.5). Of the 7,383 participants, 491 (30.8%), 599 (17.2%), and 166 (7.8%) deaths occurred over five years among participants with a low (0-29), intermediate (30-39), and high (40+) polysocial score, respectively. In the fully adjusted logistic regression model in which

polysocial score was modeled as a continuous variable, a one-point higher polysocial score was associated with 3% (Odds Ratio [OR]= 0.97; 95% CI, 0.96-0.98) lower odds of death over five years. In the fully adjusted model where polysocial score was modeled as a three-level categorical variable, the odds of death were 24% (Odds Ratio [OR]=0.76; 95% CI, 0.65-0.89) and 54% (OR=0.46; 95% CI, 0.36-0.59) lower among participants with an intermediate or high polysocial score, respectively, than those in the low category. Females had lower odds of mortality than males in the unadjusted logistic regression model. Results of racial/ethnic interaction analyses showed that Hispanic/Latino participants had lower five-year mortality (low: 17.2%; intermediate: 11.9%; high: 6.0%) than non-Hispanic white (low: 34.9%; intermediate: 17.9%; high: 7.3%) and other (low: 25.8%; intermediate: 14.3%; high: 6.3%) racial/ethnic subgroup in the additive scale, while we did not find a significant interaction between polysocial score and race/ethnicity in the multiplicative scale.

Conclusions: We created a novel polysocial score including 15 social determinants of health encompassing multiple dimensions: economic stability, physical and neighborhood environment, education, community and social context, and the healthcare system. Higher polysocial score was significantly associated with lower five-year mortality among older adults in the US after adjusting for socio-demographic, lifestyles, and health conditions. The polysocial approach may offer possible solutions to

monitor social environments and provide evidence-based suggestions for older adults to improve their social status for specific health outcomes.

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1. Introduction

Social determinants of health encompass social and physical features of an environment and lived experiences that shape health. [1] In 2008, The World Health Organization (WHO) emphasized the mission of improving the social and physical environment to promote well-being. Additionally, the Office of Disease Prevention and Health Promotion in the US and other nonprofit organizations shared the emphasis from WHO and further classified numerous social determinants of health into six social domains: economic stability, neighborhood and physical environment, education, food, community and social context, and health care system. [2,3] Each of these six social domains has been documented to be associated with multiple health outcomes, such as mortality, morbidity, life expectancy, healthcare expenditures, health status, and functional limitation.[3]

The social determinant of health started to gain attention since researchers realized that medical care alone is not able to improve health outcomes. [4,5] Previous research showed that the contribution of clinical care to health outcomes was only 16% and around 50% of the contribution to health was from social determinants including socioeconomic factors and physical environment. [6] Despite that social determinants of health are able to shape health directly, social determinants can also influence health outcomes through impacting other social determinants of health. Previous research

provided a simplified conceptual framework of social determinants of health that classified social determinants into upstream social determinants (economic and social opportunities and resources) and downstream social determinants (living and working conditions). [5] The upstream social determinants such as economic status can influence health directly since the associations between financial background and health were well-documented in previous investigations in various settings. [7–9] Additionally, the upstream social determinants are able to influence living and working conditions to indirectly affect individual health behaviors and medical care choices and cause adverse health outcomes. For example, people with low socioeconomic status were more likely to live in a low-quality neighborhood containing a higher level of individual smoking, which was well-investigated as a risk factor of respiratory diseases and lung cancers. [10] Moreover, older adults living in a poor neighborhood environment were more likely to have a lower level of physical activity compared to younger adults. [11]

1.1 Economic Stability and Health

Economic stability represents individuals' resilience toward daily or catastrophic expenditure including individual and household wealth, income, and employment status. Economic status was well-documented to be associated with mortality as well as other adverse outcomes in developing and developed regions. A prospective cohort

study of more than ten thousand community-dwelling adults aged over 50 years in England assessed the associations between total wealth and mortality. Results showed that individuals with disadvantaged financial backgrounds had a higher risk of cardiovascular and cancer mortality than those with high total wealth among participants aged 50 years or above. [12] A cross-national study using the World Health Survey found that low wealth level was associated with high rates of disability among middle-aged participants in low- and middle-income countries. [13] Additionally, economic stability is considered as a fundamental risk factor for adverse health outcomes because financial status was associated with other social factors such as the neighborhood environment, the access to healthcare services, and educational attainment. [5,14] People with low wealth and household income were more likely to have low education and high crime rates in neighborhoods, which would lead to an increased risk of mortality and morbidity. [15,16]

1.2 Physical Environment and Health

The physical environment is defined as the objectives and contexts where individuals stay, such as a house, neighborhood quality, community safety, and regions of residence. The physical environment shapes individual health by influencing people's opportunities to access high-quality neighborhood services such as schools, hospitals,

and employment resources. [17] While the physical environment is often considered as separated from the social environment, we consider it as an important part of the social environment because older adults are less likely to travel frequently and more likely to interact with the environment nearby their residence. [18] Previous research has demonstrated that poor quality of physical environmental characteristics such as air quality, water sanitation, crime rate, schools, and transportation was associated with physical limitation and low quality of life among older adults. [5] A cross-sectional study including multiple surveys assessed the socioeconomic status, convenience shore concentration, and smoking status among eighty-two neighborhoods in the US. Results showed that socially disadvantaged neighborhoods were associated with a high rate of convenience store concentration and a higher level of individual smoking rate compared to those neighborhoods with better socioeconomic status. [10] Another cross-sectional study showed that neighborhood contexts including nearby parks, physical facilities, and community safety were associated with a higher level of physical activity. [19] Findings from a meta-analysis suggested that poor neighborhood context was associated with a high risk of mobility impairment among community-dwelling older adults. [20]

1.3 Education and Health

Education, similar to economic status, was well-documented as an important social determinant of health that can influence health because education is able to improve people's health knowledge including balanced diet choices, regular exercises, and arrangement of healthcare insurances. People with a low level of health knowledge are more likely to engage in risk behaviors such as smoking and excessive alcohol use, and bad management of healthcare resources such as medical care for themselves and their family members. [21] A cross-sectional study assessed the association between health literacy, defined as the ability to read, understand, and respond to written medical prescriptions or instructions on medicine boxes, and health-promoting behaviors among older adults. The results revealed the association between a shorter duration of schooling and a low level of health literacy, insufficient consumption of healthy food, and low frequency of physical activity. [22] Additionally, education is able to influence individuals' employment status, which is able to link to economic status as well as social networks, to shape their health behaviors and health. Well-educated persons are more likely to have a low unemployment rate, healthy working environment, and high income than those with a low education level. [23–25] Higher educational level is also associated with better social support from relatives and friends. A cross-sectional study including data from seven European countries showed that elders aged over 60 years

with higher education were more likely to have better-living conditions such as large household, receive supports from spouse/partners or other persons. [7]

1.4 Community and Social Context and Health

Community and social context encompass a variety of social determinants of health that evaluate the quality of individuals' social relationships within the household and community such as social isolation, social support, social engagement, and social cohesion. Previous research demonstrated that community and social context were each significantly associated with older adults' physical and cognitive health. [26] A population-based study assessed the association between social isolation, defined as a small social network, fewer social participation in activities, and loneliness and physical and mental health among older adults. Their results demonstrated that socially isolated participants were more likely to have low levels of self-rated physical health. [27] A longitudinal study evaluated the effect of the social network, social engagement with friends, children, and other relatives on cognitive function among community-dwelling adults aged over 65. The results showed that elders with poor social connections such as no membership in a community, no attendance to a social activity in a community center, and poor social engagement with family members and friends were more likely to be demented after four years. [26]

1.5 Healthcare System and Health

The Healthcare system covered a wide range of healthcare services and complex medical, financial, and human resources mobilization such as healthcare insurance coverage, the diversity of service providers, and healthcare satisfaction. The majority of research mainly covered one or two aspects of the healthcare system and assess its association with adverse health outcomes since it is difficult to evaluate the protective effect of the healthcare system on individuals' health. For example, numerous investigations have evaluated varied types of insurance and their effect on mortality risk among older adults in different settings. Their results showed that private insurance such as long-term care insurance or life insurance or government insurance such as Medicare/Medicaid in the US was associated with lower mortality risk among older adults. Uninsured individuals were more likely to have approximately 20% to 25% higher risk of mortality than those with health insurance. [28–30] The care satisfaction was mainly evaluated among individuals who have received medical care from healthcare centers. A retrospective study using clinical data on patients with severe myocardial infarction from 2001 to 2006 evaluated the associations between patients' satisfaction with health care and inpatient mortality. The results showed that higher care satisfaction

among patients is associated with better response to medical guidance from physicians or nurses and a lower inpatients mortality rate. [31]

1.6 Research Gap

The majority of previous studies attempting to identify important social determinants of health have examined these variables independently and have not adequately accounted for the fact that social factors are often interrelated. For example, an eight-year follow-up study using survey data from 1982 to 1990 showed that neighborhood crime rate was associated with increased risk of incident physical disability among community-dwelling elders aged 65 years and over whose income level was below the poverty line. [32] Two other studies using a more recent national representative sample in the US from 2008 to 2010 revealed similar results, showing that poor neighborhood environment and social relationship with relatives and friends were associated with a higher risk of mobility limitation and loneliness among community-dwelling older adults aged over 50 years. [33,34] These aforementioned results indicated that the elders' physical and mental health were associated with multiple social and physical factors simultaneously. However, the social disparity in the aging population, which persisted for a long period, indicated that researchers or other key stakeholders may not be able to identify the key social determinants of health and improve the

quality of the social and physical environment by assessing the cumulative effect of multiple social and physical factors on health. This suggests a particular need to adopt a new method to quantify the aggregate effect of a variety of social factors, identify high-risk individuals, and develop person-centered social interventions.

Older adults represent a highly heterogeneous group with different social backgrounds, the polysocial score approach was recently proposed to calculate the overall effect of a variety of social factors on health. [35] Creating a polysocial score to predict a particular health outcome represents an aggregation of social risk that includes a wide range of social factors associated with that outcome. Researchers and other stakeholders can identify which social determinants of health are associated with a specific health outcome and excluded social factors that are not able to impact that outcome when assessing the effect of a variety of social determinants of health together in the same model. Additionally, compared with previous research assessing the effect of multiple lifestyle factors on health, the polysocial score approach can add weight to each social determinant of health and quantify their differential effect on health among older adults. [36] This approach was echoed by the approach of constructing polygenic risk score to the aggregation of genic risk that encompasses all known and relative genetic factors for a specific disease. [37] Similar to genetic factors, social determinants of health may not be able to cause adverse health outcomes independently. Therefore, by

combining the method of polygenic risk score, researchers are able to accurately and comprehensively select relevant social determinants of health and assess their combined contribution of health risk among older adults.

1.7 Research Aim

The present study aims to provide a novel score-based approach to create a polysocial score to assess the aggregated effect of multiple social determinants of health encompassing five domains to create the polysocial score: (1) economic stability, (2) neighborhood and physical environment, (3) education, (4) community and social context, and (5) health care system on five-year mortality among older adults aged over 65 and over. In addition, we also examined whether there were sex and racial/ethnic differences in the association between polysocial score and death. We hypothesized that a higher overall polysocial score was associated with a lower risk of five-year mortality among older adults aged 65 and over.

2. Methods

2.1 Setting and Participants

The Health and Retirement Study (HRS) is an ongoing longitudinal study of a nationally representative sample of non-institutionalized residents in the United States aiming to describe changes in health and financial status through the retirement transition among middle-aged and older adults. [38] The baseline survey was conducted in 1992 with biennial follow-ups. Adults aged 51 to 61 years were enrolled at baseline and additional cohorts were added. Written informed consent was collected from all HRS participants. Further details about the recruitment strategies, study design, and data collection of the HRS have been documented elsewhere. [39]

In 2006 and forward, approximately half of the participants were randomly selected to complete an additional psychosocial questionnaire – a leave-behind questionnaire that participants returned by mail and collected information regarding subjective well-being, lifestyle and experience of stress, quality of social ties, personality traits, work-related beliefs, and self-related beliefs. [40] The other half of the HRS participants were asked to complete the same questionnaire in the next interview wave in 2008.

2.2 Inclusion criteria

In the present study, we included a total of 14,311 participants consisting of 6,819 participants in 2006 and 7,492 participants in 2008, who completed the additional questionnaire. We further excluded 4,845 participants who were under 65 years of age, 1,280 participants with incomplete data on social engagement, discrimination, stress events, neighborhood social cohesion, or social support, 14 participants without data on death date, 631 participants with missing data on employment status, type of house, insurance coverage, or care satisfaction, 141 participants who were unemployed or disabled, and 17 participants who lived in a nursing home or senior retirement community. The final analytical sample included 7,383 participants (**Figure 1**).

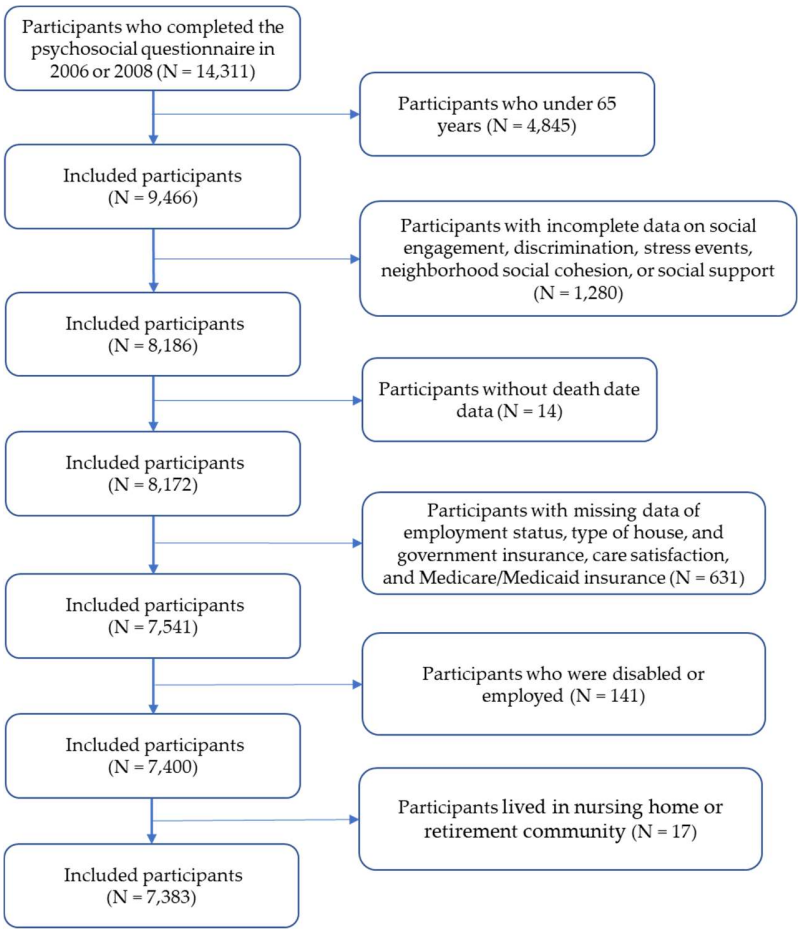

Figure 1: Flow chart of inclusion criteria

2.3 Outcome

The outcome was five-year mortality. The death date (month and year) of participants was recorded in the HRS tracker files summing death information for all participants from the exit interviews in every wave of the HRS. The interview date (month and year) of participants at baseline year when participants completed the

psychosocial questionnaire in the face-to-face interview. Participants who finished the additional psychosocial questionnaires in the face-to-face interview in 2006 were followed until 2011 and participants who completed the additional psychosocial questionnaires in face-to-face interviews in 2008 were followed until 2013. The survival time of each participant was calculated as the number of years from the interview date to the death date. We focused on mortality over five years instead of the entire study period because participants' social factors might have changed over the entire study period.

In order to evaluate the reliability of polysocial score that did not vary in different follow-up periods, we conducted sensitivity analyses by using the same statistical method as the main analysis to assess the association between the polysocial score (categorical and continuous) and mortality in different follow-up periods (four-year mortality and six-year mortality), respectively.

2.4 Social Determinants of Health

Guided by previous literature,[3] we searched the entire HRS data set and selected 24 factors from five categories: economic stability, neighborhood and physical environment, education, community, and social context, and health care system to capture the overall individual-level social risk (**Figure 2**). The detailed information of all selected social determinants of health was listed in **Appendix A**. We excluded the food domain because data on food environments were not available in the HRS.

Economic Stability	Neighborhood and Physical Environment	Education	Community and Social Context	Health Care System
Annual individual income	Type of house	Education level	Marital Status	Healthcare insurance coverage
Total household income	Type of residence	Language	Neighborhood social cohesion	Long-term care insurance coverage
Total wealth	Region of residence		Social support	Life insurance coverage
Total non-housing wealth	Neighborhood safety rate		Discrimination	Care satisfaction
Total debts			Stress	
Out-of-pocket medical expenditure			Social engagement	
Total housing values				
Employment status				

Figure 2: Classification of social factors

2.4.1 Economic stability

The economic stability contained eight social determinants of health including annual individual income, total household income, total wealth, total non-housing wealth, total debts, out-of-pocket medical expenditure, total housing values, and employment status.

Annual individual income was a sum of participants' earnings, income from SDI and SSI, unemployment compensations, and other government transfers. Total household income was a sum of participants' and their spouses' earnings, pensions and annuities, Supplemental Security Income (SSI), Social Security Disability Income (SDI), Social Security retirement income, unemployment and workers' compensation, other government transfers, household capital income, and other income. Total wealth was a sum of all wealth components less debt including net value of the first and second residence, the net value of the real estate, the net value of vehicles, the net value of businesses, the net value of individual retirement arrangement (IRA), the net value of stocks and other investments, the net value of bonds, and the net value of all other savings. Total non-housing wealth was a sum of the net value of the real estate, the net value of vehicles, net value of businesses, net value of IRA, the net value of stocks and other investments, the net value of bonds, and the net value of all other savings. Total debt was a sum of the first and second house mortgages, home equity line of credit

balances, home equity loans, credit card balances, medical debts, life insurance policy loans, and loans from relatives. Out-of-pocket medical expenditure was a sum of total out-of-pocket medical expenditure from participants and spouses or partners. Total housing value was a sum of the net value of the primary residence and the net value of the secondary residence. Annual individual income, total household income, total wealth, total non-housing wealth, out-of-pocket medical expenditure, total housing values were classified into regular quartiles. Total debts were classified categorically into no debts and having debts because over half of the participants did not have debts. Employment status was categorized into retired (retired or partly retired) or working (full-time or part-time).

2.4.2 Neighborhood and physical environment

The neighborhood and physical environment domain contained three social factors including housing types, residence types, and neighborhood safety.

Housing types indicated the type of house that the participants mainly living in and were categorized as the mobile house, one-family house, two-family house/duplex, or three-four family house. Participants living in apartment or condominiums were merged with a three-four family house category. Residence types were classified as rural or urban areas. Regions of residence were categorized as South, Northeast, Midwest, or

West. Neighborhood safety was self-reported by participants and was classified as poor/fair, good, very good, or excellent. The categories of poor and fair neighborhood safety were merged due to the limited sample size of the category of poor neighborhood safety.

2.4.3 Education

The education domain contained two variables including education level and primary language.

Education level was recorded as the duration of receiving education and was categorized as less than high school, high school graduate, or postsecondary. The primary language was recorded as the spoken language during the interview in the HRS and was classified into English or Spanish.

2.4.4 Community and social context

The community and social context domain contained six social determinants of health including marital status, neighborhood social cohesion, social support, social engagement, discrimination, and stress.

Marital status was classified as widowed, married/partnered, or separated/divorced. Neighborhood social cohesion [34] was assessed by rating seven

conditions of the neighborhood areas within a 20-minute walk or a mile: (i) feel part of this area; (ii) no vandalism and graffiti; (iii) people can be trusted; (iv) people are afraid of walking alone in the dark; (v) most people are friendly; (vi) this area is kept very clean; (vii) people help you if in trouble; (viii) no vacant or deserted houses. Participants rated each condition with a score ranging from 1 (worst) to 7 (best) and were averaged to measure overall neighborhood social cohesion. Social support [33] was assessed by five questions measuring participants' need for psychological assistance from their children, other family members, and friend: (i) "How much do they really understand the way you feel about things?"; (ii) "How often do they make too many demands on you?"; (iii) "How much do they criticize you?"; (iv) "How much do they let you down when you counting on them?"; and (v) "How much do they get on your nerves?". Participants answered each question with "A lot", "Some", "A little", or "Not at all". These responses were coded as "A lot" (3) "Some" (2), "A little" (1), and "Not at all" (0) for the first question and were reverse coded for the other four questions. We used the average score to measure the overall level of social support with a higher score indicating more social support. The methods for assessing social engagement, [41] discrimination (rudeness, unequal services, social isolation, harassment), [42] and stress (life-threatening illness, natural disasters, relatives' death, addiction, unemployment, crime) [43] were presented in previous research.

2.4.5 Health care system

Healthcare insurance coverage was classified into uninsured, governmental insured only, and government and private insurance insured. Long-term care insurance included nursing home care and in-home care, and life insurance contained both whole life insurance policies and term life insurance policies. [44] Care satisfaction was measured as the quality, costs, and convenience of health care services and was classified as not satisfied or satisfied (very satisfied or somehow satisfied).

2.5 Covariates

Demographic: age (years), sex (male and female), and race/ethnicity were categorized as non-Hispanic white, Hispanic/Latino, and others. Participants who were non-Hispanic black or Asian were merged in the other category due to the limited observations.

Lifestyle characteristics: smoking status was categorized as never, former, and current. Alcohol use was classified by the frequency of alcohol use per week (0 drinks per week, 1-2 drinks per week, 3-4 drinks per week, and 5+ drinks per week). Body mass index (BMI) was calculated as body weight (kg) divided by standing height (m) squared

and classified into underweight or normal (BMI ≤24.9 kg/m^2), overweight (BMI: 25.0-30.0 kg/m^2), and obese (BMI ≥30.0 kg/m^2).

Health condition: disability in activities of daily living (ADLs) was assessed using five ADLs (bathing, dressing, eating, getting in and out of bed, and using the toilet). Participants were asked, "Because of a health or memory problem do you have any difficulty with …". Those who answered "Yes" to one or more ADLs questions were classified as ADLs disabled. Chronic diseases including hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, and arthritis were self-reported. Self-reported health was classified into three categories (excellent/very good, good, and fair/poor).

2.6 Statistical Analysis

To construct the polysocial score, we used forward stepwise logistic regression to screen for the social factors important for five-year mortality. We used a threshold of P-value equal to 0.1; variables having a 2-sided P value < 0.1 were retained in the final forward stepwise model. We assigned the polysocial score to each participant by summing the score for each social variable based on the raw coefficients of the final stepwise logistic regression model. The score of each variable was calculated as the absolute value of the raw coefficient times 10. The score of each social factor was

summed to build the polysocial score of each participant. We modeled the polysocial score both continuously and categorically (low: 0-29, intermediate: 30-39, and high: 40+) with higher scores indicating a better social environment. Cut points for classifying the categorical polysocial score were based on the sample distribution and quartiles of the overall score (**Figure 3**).

We described the demographic, lifestyle, and health characteristics of the study participants by categories of the polysocial score (0-29, 30-39, and 40+) and tested differences between score categories using the analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical variables. We calculated the number and proportion of deaths for each polysocial score category and used logistic regression to examine the association between polysocial score and five-year mortality. We fit three models: Model 1 adjusted for demographics; lifestyle characteristics were additionally included in Model 2; health conditions were further added in Model 3. Additionally, we conducted a sensitivity analysis by repeating these three multivariate logistic regression models to assess the association between the polysocial score (categorical and continuous) and four-year mortality as well as six-year mortality, respectively. We repeated the logistic regression analyses for each sex subgroup and racial/ethnic subgroup (Non-Hispanic white, Hispanic/Latino, and others). We further used the interaction approach in the logistic regression model to examine whether the

association between polysocial score and five-year mortality differed by sex and race/ethnicity in additive and multiplicative scales.

All tests were two-sided with a significance level of 0.05. All statistical analyses were conducted in Stata/SE 15.0.

3. Results

3.1 Creation of Polysocial Score

In the stepwise logistic regression screening all 24 social factors, 15 factors were significantly associated with five-year mortality and were retained in the final model: total household income, total wealth, out-of-pocket medical expenditure, education level, employment status, marital status, type of house, regions of residence, used language, long-term care insurance coverage, life insurance coverage, social engagement, discrimination, stress level, and neighborhood social cohesion (**Table 1**). The polysocial score ranges from 7 to 59, and the mean (SD) of the polysocial score was 35.5 (7.5). The distribution of polysocial score was nearly normal (**Figure 3**). The lower, middle, and upper quartile of the score was 30, 36, and 41, respectively.

Table 1: Stepwise regression for selecting social variables for constructing the polysocial score

Social factors	Stepwise analysis [a]		P-value	Scores
	Coefficient	OR (95%CI)		
Total household income [b]				
0 – 20000	Ref.	Ref.		0
20000 – 35160	-0.12	0.89 (0.75 - 1.07)	0.216	1
35160 – 62780	-0.39	0.68 (0.55 - 0.85)	<0.001	4
62780 – 352919	-0.45	0.64 (0.50 - 0.82)	<0.001	5
Total wealth [c]				
-769100 – 80500	Ref.	Ref.		0
80500 – 258000	-0.09	0.91 (0.76 - 1.09)	0.309	1
258000 – 605300	-0.30	0.74 (0.61 - 0.91)	0.004	3
605300 – 4960000	-0.26	0.77 (0.61 - 0.98)	0.030	3
Out-of-pocket medical expenditure [d]				
3400 – 23150	Ref.	Ref.		0
1520 – 3400	-0.27	0.76 (0.64 - 0.91)	<0.001	3
576 – 1520	-0.47	0.63 (0.52 - 0.75)	<0.001	5
0 – 576	-0.43	0.65 (0.54 - 0.78)	0.001	4
Education level (N, %)				
Less than high school	Ref.	Ref.		0
High school graduate	-0.23	0.79 (0.67 - 0.93)	0.005	2
Postsecondary	-0.21	0.81 (0.68 - 0.96)	0.014	2
Employment status (N, %)				
Retired	Ref.	Ref.		0
Working	-0.76	0.47 (0.34 - 0.65)	<0.001	8
Marital status (N, %)				
Widowed	Ref.	Ref.		0
Separated/Divorced	-0.57	0.57 (0.47 - 0.72)	<0.001	6
Married/Partnered	-0.21	0.81 (0.69 - 0.95)	0.009	2
Type of house (N, %)				
Two family house/duplex	Ref.	Ref.		0
Mobile house	-0.31	0.74 (0.55 – 0.99)	0.042	3
Three-four family house	-0.54	0.79 (0.46 – 0.73)	<0.001	5
One family house	-0.83	0.44 (0.36 - 0.53)	<0.001	8
Region of residence (N, %)				
South	Ref.	Ref.		0
Northeast	-0.12	0.88 (0.73 - 1.07)	0.211	1
Midwest	-0.20	0.82 (0.69 - 0.97)	0.014	2
West	-0.24	0.79 (0.65 - 0.95)	0.012	2
Used language (N, %)				
English	Ref.	Ref.		0
Spanish	-0.87	0.42 (0.27 - 0.67)	<0.001	9
Long-term care insurance coverage (N, %)				
No	Ref.	Ref.		0
Yes	-0.20	0.82 (0.67 - 1.00)	0.050	2
Life insurance coverage (N, %)				
No	Ref.	Ref.		0
Yes	-0.12	0.89 (0.77 - 1.01)	0.074	1
Social engagement (N, %)				
Low	Ref.	Ref.		0

Moderate	-0.47	0.63 (0.55 - 0.72)	<0.001	5
High	-0.69	0.50 (0.40 - 0.64)	<0.001	7
Discrimination [e] (N, %)				
0.00 - 4.20	Ref.	Ref.		0
4.20 - 4.60	-0.13	0.88 (0.73 - 1.06)	0.185	1
4.60 - 5.00	0.07	1.08 (0.93 - 1.24)	0.331	-1
Stress level (N, %)				
3 and more events	Ref.	Ref.		0
2 events	-0.09	0.92 (0.77 - 1.09)	0.319	1
1 event	-0.30	0.74 (0.62 - 0.88)	0.001	3
0 event	-0.35	0.71 (0.59 - 0.85)	<0.001	5
Neighborhood social cohesion (N, %)				
1.00 - 4.38	Ref.	Ref.		0
4.38 - 4.75	-0.10	0.90 (0.73 - 1.12)	0.335	1
4.75 - 5.75	-0.01	0.99 (0.84 - 1.16)	0.844	0
5.75 - 7.00	-0.25	0.78 (0.65 - 0.93)	0.005	3

[a] Stepwise analysis was adjusted for other social factors including total household income, total wealth, out-of-pocket medical expenditure, education level, employment status, marital status, type of house, type of residence, region of residence, neighborhood safety rate, used language, healthcare insurance coverage, long-term care insurance coverage, life insurance coverage, care satisfaction, social engagement, discrimination, stress level, and neighborhood social cohesion.

[b] Total household income was a sum of participants' and their spouses' earnings, pensions and annuities, Supplemental Security Income (SSI), Social Security Disability Income (SDI), Social Security retirement income, unemployment and workers' compensation, other government transfers, household capital income, and other income. [44]

[c] Total wealth was a sum of the all wealth components less debt including net value of the first and second residence, the net value of the real estate, the net value of vehicles, net value of businesses, net value of individual retirement arrangement (IRA), the net value of stocks and other investments, net value of bonds, and the net value of all other savings. [44]

[d] Out-of-pocket medical expenditure was a sum of total out-of-pocket medical expenditure from participants and spouses or partners. [44]

[e] Discrimination was reversed coded and a higher discrimination score representing less discrimination.

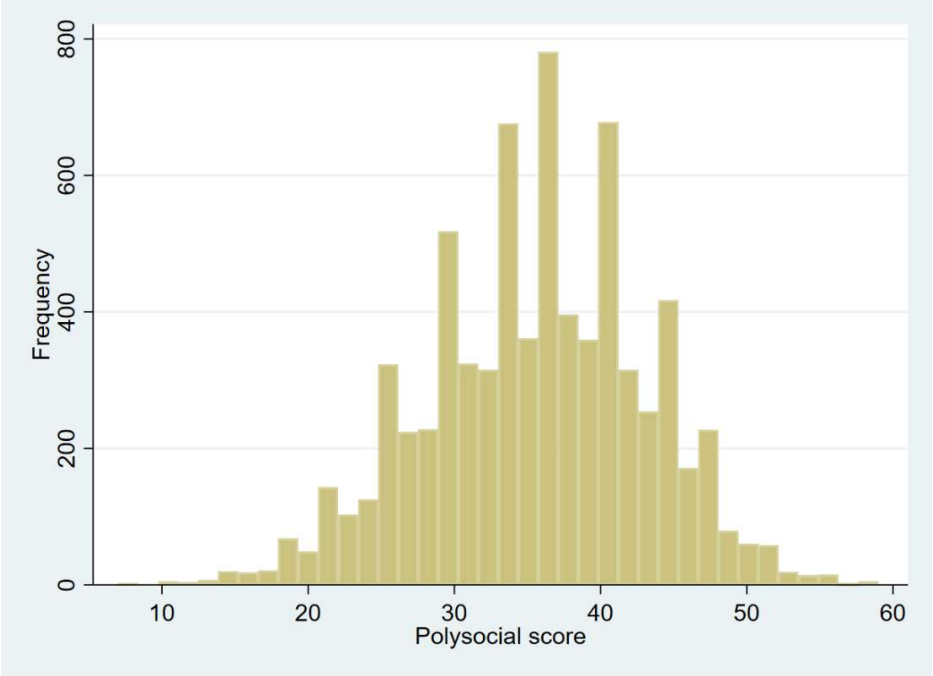

Figure 3: Distribution of polysocial score

3.2 Sample Characteristics

A total of 7,383 participants were included. The mean (SD) age of the entire cohort was 74.4 (6.9) years; 3,357 (45.5%) were males; 6,054 (82.0%) were non-Hispanic white and 406 (5.5%) were Hispanic or Latino (**Table 2**). A total of 1,589 (21.5%), 3,481 (47.2%), and 2,313 (31.3%) participants had a low (0-29), intermediate (30-39), and high (40+) polysocial score, respectively. Participants with better polysocial score were younger, more likely to be male and white, and less likely to smoke. The mean (SD) age was 77.3 (8.1), 74.6 (6.7), and 72.0 (5.4) years among participants with a low, intermediate, and high polysocial score, respectively. We found a steep gradient in the prevalence of ADL disability and chronic conditions from low to high polysocial score. For example, among participants with a high polysocial score (40+), 4.6% were disabled in ADL, 14.3% had diabetes, 20.3% had heart disease, and 3.0% had a stroke, while 69.4% of those with a low polysocial score (0-29) had ADL disability, 28.7% had diabetes, 39.3% had heart diseases, and 12.7% had a stroke.

Table 2: Descriptive characteristics of study participants

Characteristics	Polysocial score				P-value [a]
	0 - 29	30 - 39	40 +	Total	
	1589 (21.5%)	3481 (47.2%)	2313 (31.3%)	7383 (100.0%)	
Age (Mean, SD)	77.3 (8.1)	74.6 (6.7)	72.0 (5.4)	74.4 (6.9)	<0.001
Male, N, %	608 (38.3%)	1567 (45.0%)	1182 (51.1%)	3357 (45.5%)	<0.001
Race (N, %)					<0.001
Non-Hispanic White	1083 (68.2%)	2899 (83.3%)	2072 (89.6%)	6054 (82.0%)	
Hispanic/Latino	204 (12.8%)	135 (3.9%)	67 (2.9%)	406 (5.5%)	
Others	302 (19.0%)	447 (12.8%)	174 (7.5%)	923 (12.5%)	
Smoking status (N, %)					<0.001
Never	630 (40.0%)	1368 (39.7%)	1056 (46.0%)	3054 (41.7%)	
Former	746 (47.3%)	1721 (49.9%)	1075 (46.9%)	3542 (48.4%)	
Current	200 (12.7%)	360 (10.4%)	163 (7.1%)	723 (9.9%)	
BMI category [b] (N, %)					0.006
Underweight or normal	512 (32.6%)	1097 (31.8%)	729 (31.8%)	2338 (32.0%)	
Overweight	583 (37.1%)	1356 (39.3%)	971 (42.3%)	2910 (39.8%)	
Obese	477 (30.3%)	996 (28.9%)	594 (25.9%)	2067 (28.3%)	
Alcohol use (N, %)					<0.001
0 drinks per week	1261 (79.4%)	2302 (66.2%)	1268 (54.8%)	4831 (65.5%)	
1-2 drinks per week	180 (11.3%)	544 (15.6%)	479 (20.7%)	1203 (16.3%)	
3-4 drinks per week	60 (3.8%)	204 (5.9%)	195 (8.4%)	459 (6.2%)	
5+ drinks per week	88 (5.5%)	428 (12.3%)	370 (16.0%)	886 (12.0%)	
ADL disabled [c] (N, %)	621 (26.9%)	463 (11.8%)	53 (4.6%)	1137 (15.4%)	<0.001
Hypertension (N, %)	1601 (69.4%)	2510 (64.0%)	649 (56.6%)	4760 (64.5%)	<0.001
Diabetes (N, %)	663 (28.7%)	771 (19.6%)	164 (14.3%)	1598 (21.7%)	<0.001
Cancer (N, %)	296 (12.8%)	478 (12.2%)	112 (9.8%)	886 (12.0%)	0.031
Lung disease (N, %)	410 (17.8%)	408 (10.4%)	69 (6.0%)	887 (12.0%)	<0.001
Heart disease (N, %)	908 (39.3%)	1154 (29.4%)	233 (20.3%)	2295 (31.1%)	<0.001
Stroke (N, %)	294 (12.7%)	268 (6.8%)	34 (3.0%)	596 (8.1%)	<0.001
Psychiatric disease (N, %)	470 (20.4%)	445 (11.3%)	76 (6.6%)	991 (13.4%)	<0.001
Arthritis (N, %)	1706 (74.0%)	2654 (67.5%)	691 (60.3%)	5051 (68.4%)	<0.001
Self-reported Health (N, %)					<0.001
Excellent/Very good	529 (23.0%)	1681 (42.8%)	705 (61.6%)	2915 (39.5%)	
Good	720 (31.3%)	1396 (35.5%)	339 (29.6%)	2455 (33.3%)	
Fair/Poor	1055 (45.8%)	852 (21.7%)	100 (8.7%)	2007 (27.2%)	

Abbreviations: ADL, activities of daily living; BMI, body mass index.

[a] Obtained from the analysis of variance tests and chi-square tests.

[b] BMI was calculated as body weight (kg) divided by standing height (m) squared and classified into underweight or normal (BMI≤24.9 kg/m^2), overweight (BMI 25.0-30.0 kg/m^2), and obese (BMI≥30.0 kg/m^2).

[c] Participants who had difficulties in performing one of the five ADLs (bathing, dressing, eating, getting in and out of bed, and using the toilet) were considered ADL disabled.

3.3 Association between Polysocial Score and Mortality

We found 491 (30.8%), 599 (17.2%), and 166 (7.8%) deaths over five years among participants with a low (0-29), intermediate (30-39), and high (40+) polysocial score, respectively (**Table 3**). In the unadjusted model, the categorical polysocial score was significantly associated with five-year mortality. The odds of death were 53% and 83% lower among participants with an intermediate (30-39) or high (40+) polysocial score, respectively, than those in the low category (score: 0-29). The association attenuated but persisted after additionally adjusting for lifestyles and health conditions. In the fully adjusted model, participants with an intermediate (30-39) and high polysocial score (40+) had 34% and 54% lower odds of death than those with a score of 0-29, respectively. When modeled as a continuous variable, the polysocial score was significantly associated with five-year mortality in both unadjusted and adjusted models (**Table 4**). After adjusting for socio-demographics, lifestyle, and health characteristics, a one-point higher polysocial score was associated with a 3% lower odds of death over five years.

Table 3: Associations between polysocial score and five-year mortality

Polysocial score	Death (N, %)	Unadjusted	Model 1 [a]	Model 2 [b]	Model 3 [c]
		OR (95% CI)			
0 - 29	491 (30.9%)	Ref.	Ref.	Ref.	Ref.
30 - 39	599 (17.2%)	0.47 (0.40 - 0.53)	0.54 (0.47 - 0.62)	0.59 (0.50 - 0.69)	0.76 (0.65 - 0.89)
40 +	166 (7.8%)	0.17 (0.14 - 0.21)	0.24 (0.20 - 0.30)	0.28 (0.23 - 0.36)	0.46 (0.36 - 0.59)

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.

[a] Model 1 adjusted for age, sex, and race/ethnicity (non-Hispanic white, Hispanic/Latino, and others).

[b] Model 2 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), and lifestyles (body mass index, smoking status, and alcohol use).

[c] Model 3 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).

Table 4: Association between continuous polysocial score and five-year mortality

Polysocial score	Death (N, %)	Unadjusted	Model 1 [a]	Model 2 [b]	Model 3 [c]
		OR (95% CI)			
Continuous	1256 (17.0%)	0.92 (0.91 - 0.93)	0.94 (0.93 - 0.95)	0.94 (0.94 - 0.95)	0.97 (0.96 - 0.98)

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.

[a] Model 1 adjusted for age, sex, and race/ethnicity (non-Hispanic white, Hispanic/Latino, and others).

[b] Model 2 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), and lifestyles (body mass index, smoking status, and alcohol use).

[c] Model 3 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).

3.4 Sensitivity analysis

We found a significant association between polysocial score and four-year mortality and six-year mortality, respectively (**Table 5**). Additionally, the odds of death were similar among participants within the same polysocial score categories after four-, five-, and six-year follow-up. In the fully adjusted models, participants having a high polysocial score (40+) and intermediate score (30-39) had 51% and 27% lower odds of death compared to those with low polysocial score (0-29) after four years. Similarly, the odds of death were 52% and 25% lower among participants with an intermediate polysocial score (30-39) and high polysocial score (40+) than those with a low polysocial score (0-29). Modeling the polysocial score as a continuous index, the odds of death were 3% lower when one point of polysocial score increased after four, five, and six years (**Table 6**).

Table 5: The comparison of association between polysocial score (categorical) and four-, five-, and six-year mortality

	Polysocial score	Five-year mortality	Four-year mortality	Six-year mortality
		OR (95CI%)		
Unadjusted	0 - 29	Ref.	Ref.	Ref.
	30 - 39	0.47 (0.40 - 0.53)	0.44 (0.37 - 0.51)	0.46 (0.41 - 0.53)
	40 +	0.17 (0.14 - 0.21)	0.17 (0.14 - 0.21)	0.18 (0.15 - 0.21)
Model 1 [a]	0 - 29	Ref.	Ref.	Ref.
	30 - 39	0.54 (0.47 - 0.62)	0.50 (0.43 - 0.59)	0.53 (0.46 - 0.61)
	40 +	0.24 (0.20 - 0.30)	0.24 (0.19 - 0.30)	0.25 (0.21 - 0.30)
Model 2 [b]	0 - 29	Ref.	Ref.	Ref.
	30 - 39	0.59 (0.50 - 0.69)	0.55 (0.47 - 0.65)	0.58 (0.50 - 0.67)
	40 +	0.28 (0.23 - 0.36)	0.28 (0.22 - 0.35)	0.30 (0.25 - 0.36)
Model 3 [c]	0 - 29	Ref.	Ref.	Ref.
	30 - 39	0.76 (0.65 - 0.89)	0.73 (0.62 - 0.87)	0.75 (0.64 - 0.87)
	40 +	0.46 (0.36 - 0.59)	0.49 (0.38 - 0.63)	0.48 (0.39 - 0.59)

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.

[a] Model 1 adjusted for age, sex, and race/ethnicity (non-Hispanic white, Hispanic/Latino, and others).

[b] Model 2 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), and lifestyles (body mass index, smoking status, and alcohol use).

[c] Model 3 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).

Table 6: The comparison of association between polysocial score (continuous) and four-, five-, and six-year mortality

	Polysocial score	Five-year mortality	Four-year mortality	Six-year mortality
		OR (95CI%)		
Unadjusted	Continuous	0.92 (0.91 - 0.93)	0.92 (0.91 - 0.93)	0.92 (0.91 - 0.93)
Model 1 [a]		0.94 (0.93 - 0.95)	0.94 (0.93 - 0.95)	0.94 (0.93 - 0.94)
Model 2 [b]		0.94 (0.93 - 0.95)	0.94 (0.93 - 0.95)	0.94 (0.93 - 0.95)
Model 3 [c]		0.97 (0.96 - 0.98)	0.97 (0.96 - 0.98)	0.97 (0.96 - 0.98)

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.

[a] Model 1 adjusted for age, sex, and race/ethnicity (non-Hispanic white, Hispanic/Latino, and others).

[b] Model 2 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), and lifestyles (body mass index, smoking status, and alcohol use).

[c] Model 3 adjusted for age, sex, race/ethnicity (non-Hispanic white, Hispanic/Latino, and others), lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).

3.5 Subgroup Analysis

3.5.1 Sex-specific analysis

We found a significant multiplicative interaction between sex and categorical polysocial score in the unadjusted model. The association between polysocial score and five-year mortality was stronger among females than males (*P*-values for interactions in the unadjusted model= 0.02 and 0.02, **Figure 4**). The multiplicative interaction was attenuated and was no longer significant in fully adjusted models. On the additive scale, the difference in the association between polysocial score and five-year mortality was small between males and females (**Figure 5**). Mortality was 14.2% and 26.7% lower among males with an intermediate (30-39) and high polysocial score (40+) than those with a low score (0-29). For females, being in the intermediate and high polysocial score category was associated with 15.2% and 23.8% lower mortality.

3.5.2 Race-specific analysis

We found that the Hispanic or Latino participants had the lowest five-year mortality compared to either non-Hispanic whites or other racial/ethnic individuals in all the categories of polysocial score in the additive scale (**Figure 6**). The five-year mortality of Hispanic or Latino individuals were 17.7%, 6.1%, and 1.3% lower than that of non-Hispanic white in low (0-29), intermediate (30-39), and high (40+) polysocial score

categories, respectively. Similar results were revealed between Hispanic or Latino and other racial/ethnic subgroups, showing that the five-year mortality of Hispanic or Latino participants was 8.7%, 2.5%, and 0.4% lower than that of other racial/ethnic individuals in low, intermediate, and high level of polysocial score. We did not find that the association between polysocial score and mortality differed among non-Hispanic whites, Hispanic or Latino, and other racial/ethnic individuals on a multiplicative scale in unadjusted and adjusted models (Non-Hispanic whites/Hispanic or Latino: *P*= 0.16 and 0.18; non-Hispanic whites/others: *P*= 0.42 and 0.43, **Table 7**).

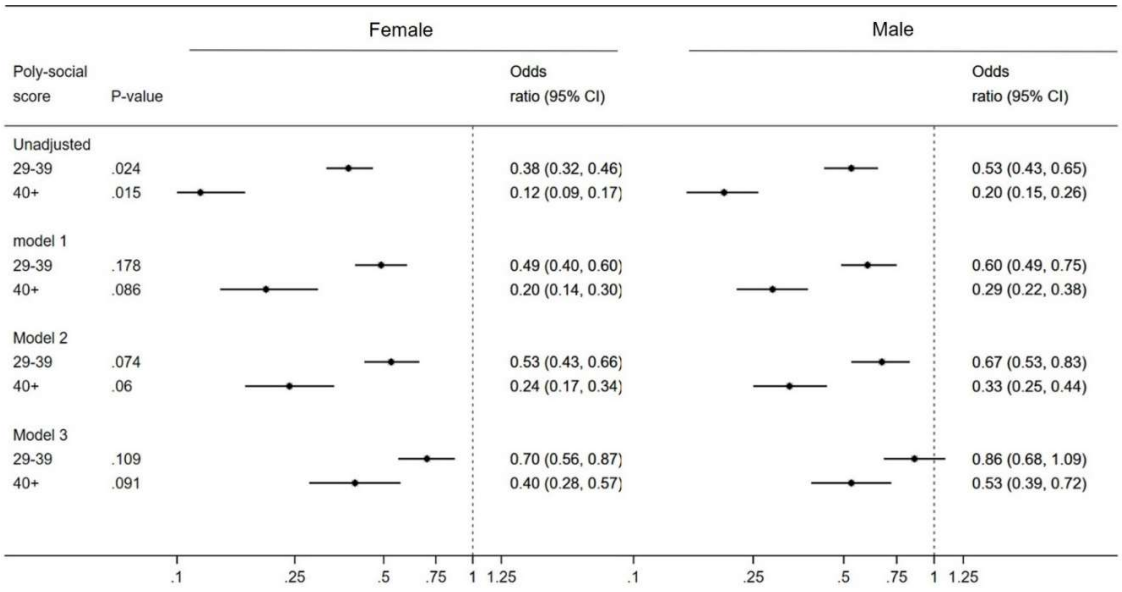

Figure 4: Sex-specific analysis between polysocial score and five-year mortality

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.
[a] Model 1 adjusted for age and race/ethnicity.
[b] Model 2 adjusted for age, race/ethnicity, and lifestyles (body mass index, smoking status, and alcohol use).
[c] Model 3 adjusted for age, race/ethnicity, lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).
[d] Obtained by the interaction between polysocial score and sex.

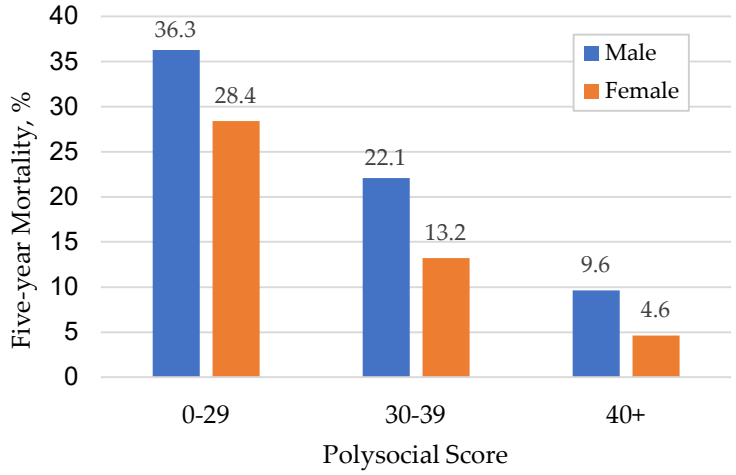

Figure 5: Sex-specific five-year probability of mortality by categories of polysocial score

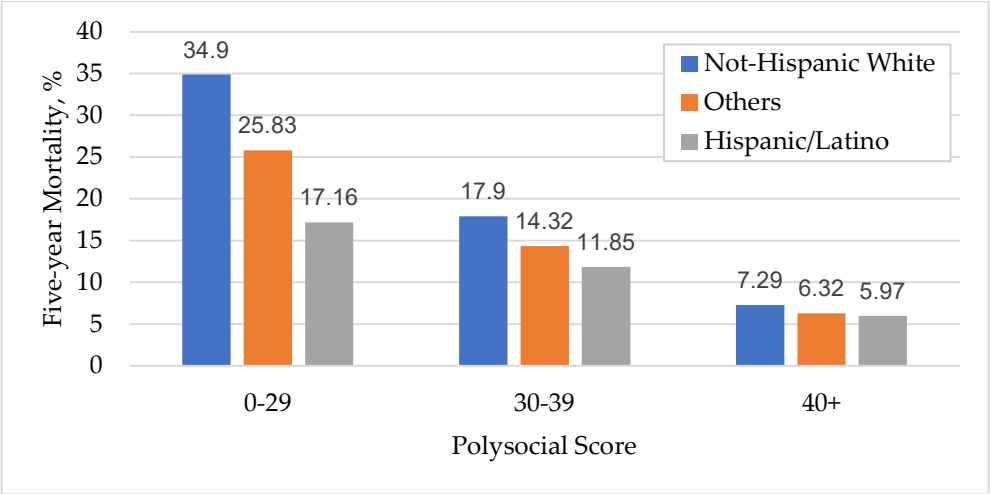

Figure 6: Race-specific five-year probability of mortality by categories of polysocial score

Table 7: Race-specific analysis between polysocial score and five-year mortality

Polysocial score		OR (95CI%)		P Value [d]	OR (95%CI)	P Value [d]
		Non-Hispanic white	Hispanic/Latino		Others	
Unadjusted	0 - 29	Ref.	Ref.		Ref.	
	30 - 39	0.41 (0.35 - 0.48)	0.65 (0.34 - 1.23)	0.162	0.48 (0.33 - 0.69)	0.419
	40 +	0.15 (0.12 - 0.18)	0.31 (0.11 - 0.90)	0.186	0.19 (0.10 - 0.38)	0.431
Model 1 [a]	0 - 29	Ref.	Ref.		Ref.	
	30 - 39	0.49 (0.41 - 0.58)	0.57 (0.38 - 0.83)	0.162	0.57 (0.38 - 0.83)	0.360
	40 +	0.22 (0.17 - 0.27)	0.28 (0.14 - 0.55)	0.284	0.28 (0.14 - 0.55)	0.323
Model 2 [b]	0 - 29	Ref.	Ref.		Ref.	
	30 - 39	0.54 (0.46 - 0.65)	0.91 (0.45 - 1.83)	0.187	0.58 (0.39 - 0.86)	0.524
	40 +	0.26 (0.21 - 0.33)	0.45 (0.14 - 1.49)	0.374	0.30 (0.15 - 0.60)	0.374
Model 3 [c]	0 - 29	Ref.	Ref.		Ref.	
	30 - 39	0.70 (0.59 - 0.85)	1.11 (0.52 - 2.41)	0.121	0.66 (0.43 – 1.00)	0.544
	40 +	0.43 (0.34 - 0.55)	0.65 (0.18 - 2.39)	0.268	0.43 (0.21 - 0.88)	0.429

Abbreviations**:** OR, Odds Ratio; CI, Confidential Interval.

[a] Model 1 adjusted for age and sex.

[b] Model 2 adjusted for age, sex, and lifestyles (body mass index, smoking status, and alcohol use).

[c] Model 3 adjusted for age, sex, lifestyles (body mass index, smoking status, and alcohol use), and health measures (disability in activities of daily living, hypertension, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disease, arthritis, and self-reported health).

[d] Obtained by the interaction between polysocial score and race.

4. Discussion

4.1 Summary of Main Findings

Using data from a large cohort study, we created and validated a polysocial score for all-cause mortality among community-dwelling older adults in the US. The polysocial score included 15 social determinants of health encompassing five domains: economic stability, physical and neighborhood environment, education, community and social context, and the healthcare system. Participants with a higher polysocial score were younger, more likely to be males and white, and had better health conditions. Older adults with a higher polysocial score had a lower risk of five-year mortality.

4.2 Consistency with previous research

Our results were consistent with previous investigations examining the association of individual social factors with health among older adults. Several studies conducted in Europe showed that household income, total wealth, and employment status were associated with mortality in old age. [12,45,46] Older adults with long-term care insurance and life insurance had lower mortality than those without. [29] Studies conducted in the US found that older adults who were less educated, resided in the South, and lived in lower-priced housing had higher mortality. [8,47,48] Additionally, previous evidence suggested that older adults who have better marital quality, social

engagement from family members and friends, community cohesion, and fewer discriminatory and stressful events had a lower risk of death. [49–53]

Even though few studies are using the score-based approach to assess the effect of social factors on adverse health outcomes, our results were consistent with those who built a score index for a specific social determinant to evaluate its effect on health. For example, a prospective cohort study built a social engagement score to evaluate the frequency of connections between participants and their children, relatives, and friend and assess if a higher social engagement score was associated with better cognitive function after 4 years of follow-up among older adults. [26] The results showed that older adults with a higher social engagement score were more likely to better cognitive function. [26] Another study built a similar social engagement score by evaluating participants' marital status, weekly volunteering work for nonprofit organizations, and weekly contact with parents, offspring, and neighbors. [41] The results showed that older adults with a higher social engagement score had a better memory, mental status, and self-reported health. [41] A prospective study published last year built a cumulative score index of stressful life events and assessed if this cumulative score index is associated with Type 2 diabetes mellitus among middle-aged older adults. [43] The results showed that participants who encountered more stressful events had a higher adjusted risk of Type 2 diabetes mellitus compared to those participants with no stressful events after 8

years of follow-up. [43]

4.3 The association between primary language on mortality

We found that primary language is the strongest protective social factor for mortality among older adults in the US. Participants whose primary language is Spanish have lower odds of mortality than those speaking English as their primary language. Additionally, we found that Hispanic or Latino elders whose primary language was Spanish had lower mortality than those in other racial/ethnic groups. These results were consistent with previous research that documented lower mortality among Hispanic people than non-Hispanic whites among older adults in the US. [54,55] The Hispanic survival advantage may be explained by the salmon bias hypothesis, which states that that adverse health conditions could trigger migration and leave healthier individuals in the US. Therefore, Hispanic elders living in the US may have better health conditions than their non-Hispanic white counterparts because unhealthy Hispanics might have moved out of the states. Other potential explanations include the healthy migrant effect, suggesting that immigrants are in better health compared with their non-migrating peers; and differences in culture, such as lifestyle behaviors, and social networks. Previous research showed that Hispanic adults who were less acculturated are likely to maintain their origin diet patterns containing less amount of calories intake and low

level of saturated fat intake compared to Non-Hispanic Whites. [56,57] The prevalence of smoking and alcohol use was also lower among Hispanic individuals than that among Non-Hispanic Whites and these healthy lifestyle behaviors may be contributors to the mortality advantages among the Hispanic population. [57,58] Additionally, previous research demonstrated that Hispanic individuals may have strong social ties and larger social networks, which may also contribute to the Hispanic mortality advantages. [56]

4.3 Implications for creating polysocial score

Polysocial score offers a validated metric to predict synergistic effects of social factors on specific health outcomes among older adults. The aforementioned studies showed that mortality was associated with numerous social determinants of health including socioeconomic status, neighborhood environment, and social supports among older adults. [8,47,50,51] For instance, a US cohort study found that indicators of lower socioeconomic status (lower levels of education, household income, and household wealth) were significantly associated with higher ten-year mortality among older adults. [9] A multinational study conducted in 11 European countries showed that a lower level of education was associated with a higher risk of mortality and the mortality risk increased with age among older adults. [8] The polysocial score I developed and validated may serve as an initial screening tool for individuals who may have disadvantaged social and

physical environments and prioritize health investments for patient-centered interventions.

The creation and validation of the polysocial score offer a possible solution to screen and identify social determinants that were concurrently associated with one health outcome among older adults. As social determinants of health are interlinked, assessing the individual effect of each social factor may fail to capture the myriad of ways that social conditions can create disadvantages. For example, several poorly controlled health outcomes such as cardiovascular diseases may be related to insufficient total wealth and household income [59], lack of social support from their friend or relatives [60–62], and high frequency of daily discrimination and stressful events. [63,64] This polysocial score can combine a variety of social determinants of health from different dimensions of social and physical factors and assess the effect of all selected social factors simultaneously. With more disease-specific polysocial score indexes were created, we may be able to build a structured surveillance system to monitor the social and physical environment of the aging population as well as other vulnerable subgroups in the US.

4.4 Strengths and Limitations

Our study has several strengths. First, we were among the first to combine 15 social determinants of health from five categories including economic stability, physical and neighborhood environment, education, community and social context, and the healthcare system, and measured their aggregated effects on mortality among older adults aged over 65 years. Second, the polysocial score was weighted by using the coefficients of different social determinants of health specifically on mortality. This weighted polysocial score could capture the unequal effects of each social determinant on the risk of mortality, providing a valid assessment of social contexts and an improvement guideline of social conditions for older adults.

This study was not without limitations. First, we only included the social context in the entry time and the social and physical environment may be changed in the follow-up years so that we only assessed the association between the polysocial score and mortality in a relatively short follow-up period to control the impact of changes in participants' social and physical context in follow-up years. Further research can use the longitudinal study design to capture the variations of social determinants of health in every follow-up year and evaluated if the association between polysocial score and mortality retain when the social and physical environment change. Second, we may not be able to capture the time-to-event information by using the logistic regression model.

Further research can include the time-to-event information by using cox proportional hazard regression model with a longer follow-up period. Third, the polysocial score may not be easily generalized to other health outcomes. The reason is that the polysocial score in our research was created by the weights calculated by the coefficients of each social determinant of health from the logistic regressions. Further research can focus on creating multiple polysocial score indexes for varied adverse health outcomes and compared the difference in number and types of social determinants of health among different polysocial score indexes. Finally, we were not able to construct the polysocial score for different subgroups such as females and Hispanic/Latino people in this study due to the limited sample size of each subgroup. Further research can also focus on the difference in the number and weights of polysocial score for multiple subgroups if the sample size is sufficient.

5. Conclusion

In conclusion, we present a novel weighted polysocial score including 15 social determinants of health categorized into economic stability, physical and neighborhood environment, education, community and social context, and the healthcare system. The association between polysocial score and mortality was consistent with previous research, reflecting the high reliability and predictive validity of the polysocial score in assessing the risk of five-year mortality among older adults in the US. With a more comprehensive assessment of social environments around the older population, scientists could monitor social environments of, and offered suggestions for elders to improve their social status specifically. Additional studies are needed to test the generalizability of polysocial score in other settings and other health outcomes among older adults.

Appendix A

Table 1: Twenty-four social factors selected from the Health and retirement study

Social determinants of health	Observation (N, %)	Interpretation of social factors
Annual individual income [a]		
0 - 10152	1814 (24.6%)	Annual individual income: 0 - 10152 thousand dollars
10152 - 16416	1844 (25.0%)	Annual individual income: 10152 - 16416 thousand dollars
16416 - 27991	1867 (25.3%)	Annual individual income: 16416 - 27991 thousand dollars
27991 - 128600	1858 (25.2%)	Annual individual income: 27991 - 128600 thousand dollars
Total household income [b]		
0 - 20000	1802 (24.4%)	Total household income: 0 - 20000 thousand dollars
20000 - 35160	1854 (25.1%)	Total household income: 20000 - 35160 thousand dollars
35160 - 62780	1864 (25.2%)	Total household income: 35160 - 62780 thousand dollars
62780 - 352919	1863 (25.2%)	Total household income: 62780 - 352919 thousand dollars
Total wealth [c]		
-769100 - 80500	1788 (24.2%)	The net value of total wealth: -769100 - 80500 thousand dollars
80500 - 258000	1848 (25.0%)	The net value of total wealth: 80500 - 258000 thousand dollars
258000 - 605300	1877 (25.4%)	The net value of total wealth: 258000 - 605300 thousand dollars
605300 - 4960000	1870 (25.3%)	The net value of total wealth: 605300 - 4960000 thousand dollars
Total non-housing wealth [d]		
-196500 - 13300	1797 (24.3%)	The net value of non-housing wealth: -196500 - 13300 thousand dollars
13300 - 91000	1839 (24.9%)	The net value of non-housing wealth: 13300 - 91000 thousand dollars
91000 - 353500	1876 (25.4%)	The net value of non-housing wealth: 91000 - 353500 thousand dollars
353500 - 4116000	1871 (25.3%)	The net value of non-housing wealth: 353500 - 4116000 thousand dollars
Total debts [e]		
No debts	4219 (57.1%)	Respondents had no debts
Have debts	3164 (42.9%)	Respondents had debts: 0 - 307000 thousand dollars
Out-of-pocket medical expenditure [f]		
3400 - 23150	1844 (25.0%)	Annual out of pocket medical expenditure: 3400 - 23150 thousand dollars
1520 - 3400	1865 (25.3%)	Annual out of pocket medical expenditure: 1520 - 10152 thousand dollars
576 - 1520	1855 (25.1%)	Annual out of pocket medical expenditure: 576 - 1520 thousand dollars
0 - 576	1819 (24.6%)	Annual out of pocket medical expenditure: 0 - 576 thousand dollars
Total housing value [g]		
-795000 - 40000	1848 (25.0%)	The net value of total housing value: -795000 - 40000 thousand dollars
40000 - 125000	1808 (24.5%)	The net value of total housing value: 40000 - 125000 thousand dollars
125000 - 250000	1867 (25.3%)	The net value of total housing value: 125000 - 250000 thousand dollars
250000 - 1176000	1860 (25.2%)	The net value of total housing value: 250000 - 1176000 thousand dollars
Education level (N, %)		

Less than high school	1825 (24.7%)	Respondents completed 1-11 years' education
High school graduate	2497 (33.8%)	Respondents completed 12 years' education
Postsecondary	3061 (41.5%)	Respondents completed more than 12 years' education
Employment status (N, %)		
Retired	6806 (92.2%)	Labor status: partly retired or retired
Working	577 (7.8%)	Labor status: work full-time or part-time
Marital status (N, %)		
Widowed	1837 (24.9%)	Lost spouse
Separated/Divorced	781 (10.6%)	Spouse alive but separated with respondents
Married/Partnered	4765 (64.5%)	Spouse alive and lived with respondents
Type of house (N, %)		
Mobile house	386 (5.2%)	Respondents lived in a mobile house
Two family house/duplex	754 (10.2%)	Respondents lived in a two-family house
Three-four family house	1190 (16.1%)	Respondents lived in a three-four family house
One-family house	5053 (68.4%)	Respondents lived in a one-family house
Type of residence (N, %)		
Rural	2465 (33.4%)	Respondents lived in the rural area
Urban	4918 (66.6%)	Respondents lived in the urban area
Region of residence (N, %)		
South	2978 (40.3%)	Respondents lived in the south region of America
Northeast	1138 (15.4%)	Respondents lived in the northeast region of America
Midwest	1956 (26.5%)	Respondents lived in the Midwest region of America
West	1311 (17.8%)	Respondents lived in the west region of America
Neighborhood safety rate (N, %)		
Fair	601 (8.1%)	Self-reported neighborhood safety condition: poor or fair
Good	1497 (20.3%)	Self-reported neighborhood safety condition: good
Very good	2471 (33.5%)	Self-reported neighborhood safety condition: very good
Excellent	2814 (38.1%)	Self-reported neighborhood safety condition: excellent
Used language (N, %)		
English	7193 (97.4%)	The language chosen in the interview: English
Spanish	190 (2.6%)	The language chosen in the interview: Spanish
Healthcare insurance coverage (N, %)		
Uninsured	67 (0.9%)	Respondents were neither covered by government insurance nor by private insurance
Governmental insured only	3050 (41.3%)	Respondents were covered by government insurance only
Governmental and private insured	4266 (57.8%)	Respondents were covered both by government insurance and private insurance
Long-term care insurance coverage (N, %)		
No	6242 (84.5%)	Respondents were not covered by long-term care insurance
Yes	1141 (15.5%)	Respondents were covered by long-term care insurance
Life insurance coverage (N, %)		
No	2580 (34.9%)	Respondents were not covered by life insurance
Yes	4803 (65.1%)	Respondents were covered by life insurance
Care satisfaction (N, %)		
Not satisfied	2867 (38.8%)	Self-rated healthcare quality: no satisfied or somewhat satisfied
Satisfied	4516 (61.2%)	Self-rated healthcare quality: very satisfied
Social engagement (N, %)		

Low	2920 (39.6%)	social engagement score: 0 - 1
Moderate	3653 (49.5%)	social engagement score: 2 - 3
High	810 (11.0%)	social engagement score: 4 - 5
Discrimination (N, %)		
0.00 - 4.20	2328 (31.5%)	Daily discrimination: 0 - 4.2
4.20 - 4.60	1454 (19.7%)	Daily discrimination: 4.2 - 4.6
4.60 - 5.00	3601 (48.8%)	Daily discrimination: 4.6 - 5
Stress level (N, %)		
3 and more events	2120 (28.7%)	Stressful events happened 3 or more times previously
2 events	1664 (22.5%)	Stressful events happened 2 times previously
1 event	2034 (27.5%)	Stressful events happened 1 time previously
0 event	1565 (21.2%)	Stressful events never happened previously
Neighborhood social cohesion (N, %)		
1.00 - 4.38	2152 (29.1%)	Neighborhood social cohesion score: 1 - 4.375
4.38 - 4.75	876 (11.9%)	Neighborhood social cohesion score: 4.375 - 4.75
4.75 - 5.75	2349 (31.8%)	Neighborhood social cohesion score: 4.75 - 5.75
5.75 - 7.00	2006 (27.2%)	Neighborhood social cohesion score: 5.75 - 7
Social support (N, %)		
0.00 - 1.75	1998 (27.1%)	Social support score: 0 - 1.75
1.75 - 2.10	1936 (26.2%)	Social support score: 1.75 - 2.1
2.10 - 2.45	1569 (21.3%)	Social support score: 2.1 - 2.45
2.45 - 3.00	1880 (25.5%)	Social support score: 2.45 – 3

[a] Annual individual income was a sum of participants' earnings, income from SDI and SSI, unemployment compensations, and other government transfers. [44]

[b] Total household income was a sum of participants' and their spouses' earnings, pensions and annuities, Supplemental Security Income (SSI), Social Security Disability Income (SDI), Social Security retirement income, unemployment and workers' compensation, other government transfers, household capital income, and other income. [44]

[c] Total wealth was a sum of all wealth components less debt including net value of the first and second residence, the net value of the real estate, the net value of vehicles, the net value of businesses, the net value of individual retirement arrangement (IRA), the net value of stocks and other investments, the net value of bonds, and the net value of all other savings. [44]

[d] Total non-housing wealth was a sum of the net value of the real estate, the net value of vehicles, net value of businesses, net value of IRA, the net value of stocks and other investments, the net value of bonds, and the net value of all other savings. [44]

[e] Total debt was a sum of the first and second house mortgages, home equity line of credit balances, home equity loans, credit card balances, medical debts, life insurance policy loans, and loans from relatives. [44]

[f] Out-of-pocket medical expenditure was a sum of total out-of-pocket medical expenditure from participants and spouses or partners. [44]

[g] Total housing value was a sum of the net value of the primary residence and the net value of the secondary residence. [44]

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