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Lives, Time and Place: A Life Course Perspective on Earlier-life Individual and Contextual Socioeconomic Conditions and Later-life Physical Activity

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RESEARCH PAPER

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Abstract

Purpose: Framed within the life course and ecological perspectives, this study investigated the association between earlier-life individual and contextual socioeconomic conditions and later-life physical activity. The mediating role of later-life characteristics was also examined.

Methods: Contemporary and historical Census data as well as three bi-annual waves of nationally representative panel data from the Understanding America Study (N=1,981) were used. Three types of physical activity were separately assessed: mild, moderate, and vigorous, to understand the effect of earlier-life circumstances on different types of physical activity over the life course. Multilevel growth curve models were used to address the research questions.

Results: A higher level of father's education in respondents' earlier life was associated with higher levels of mild (OR=1.13, $p<.05$) and moderate (OR=1.25, $p<.001$) physical activity in respondents' later life. Growing up in a higher-poverty area was associated with lower levels of moderate (OR=0.95, $p<.05$) and vigorous (OR=0.95, $p<.05$) physical activity in later life. Better health status before the age of 16 was associated with a slower decline (OR=1.05, $p<.05$) in moderate physical activity in later life. The associations between other earlier-life circumstances and later-life physical activity were largely mediated by later-life characteristics.

Discussion: Findings underscore the long-term ramifications of earlier-life circumstances for later-life physical activity, emphasizing that human development is shaped by a confluence of individual and contextual conditions throughout the life course. Study findings suggest that interventions to promote physical activity at older ages would benefit from a perspective that takes into account the individual and contextual circumstances over the life course.

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1. Introduction

The health benefits of physical activity in later life are well established (Taylor et al., 2004). Participation in physical activity contributes to cardiovascular, musculoskeletal, and psychosocial health (Callow et al., 2020; Soares-Miranda et al., 2016; Taylor et al., 2004), enhanced quality of life (Fisher & Li, 2004), and decreased risks for diabetes, hypertension, cancer, and mortality in older adults (DiPietro, 2001; Landi et al., 2008; Lim & Taylor, 2005). Despite the multitude of health benefits, more than half of adults aged 65 or older in the United States fail to meet the federal physical activity guidelines, with declining levels of physical activity among older cohorts (Centers for Disease Control and Prevention, 2018).

Prior research on the individual and contextual correlates of physical activity (Bauman et al., 2012; Mooney et al., 2017; Silveira et al., 2020) has identified micro- and macro-level attributes for evidence-based interventions to promote physical activity. However, existing research typically focused on the relationship between concurrent characteristics and physical activity within a specific stage of life, e.g. later-life characteristics and later-life physical activity (O’Donoghue et al., 2018), limiting our understanding of the accumulated effects of experiences across the life course on physical activity (Hirvensalo, & Lintunen, 2011). In particular, the potential long-term influences of earlier-life individual and contextual socioeconomic conditions on later-life physical activity remains understudied, hampering the development of interventions that take into account the experience and exposures over time. The present study addresses this gap in the literature by investigating the role of earlier-life individual as well as contextual socioeconomic conditions in shaping later-life physical activity from a life-course perspective, making connections between lives, time, and place.

1.1 Life Course and Physical Activity

The life course literature conceptualizes human development as a lifelong process, and suggests that a greater understanding of health and health behavior in later life requires a long-term perspective that recognizes the role of earlier-life circumstances (Elder et al., 2003; Kuh, 2007; Settersten, 2006). Indeed, the growing health literature from a life course perspective indicates that early-life circumstances impact health and health behaviors in mid- to late-adulthood, including individual experiences of material scarcity (Sommet & Spini, 2022), adverse events (Clark et al., 2010), and poor parenting (Umberson et al., 2010); as well as contextual exposures

to community deprivation (Hillsdon et al., 2008; Yang & South, 2020), poor social capital (Eriksson & Ng, 2015), and income inequality (Wen et al., 2003).

In the context of physical activity at older ages, research that adopts a life course perspective – particularly using a longitudinal study design – is scarce (Hirvensalo, & Lintunen, 2011; O’Donoghue et al., 2018). Most existing literature on physical activity has been framed within psychosocial theories to explain the motivations, beliefs, and attitudes relating to physical activity participation (Cotter & Lachman, 2010; King et al., 2002), and also increasingly framed within ecological theories to elucidate the environmental barriers and motivators of physical activity, including both the built and social environment (Barnett et al., 2017; Wen & Zhang, 2009). While a few studies on physical activity have drawn insights from the life course perspective (e.g. Pudrovskaja & Anishkin, 2013), this stream of research has largely focused on micro-level individual and family characteristics, neglecting the concurrent role of macro-level social spaces in shaping physical activity over the life course. As such, our understanding of later-life physical activity and its antecedents across time and place remains limited.

1.2 Micro- and Macro- Socioeconomic Conditions

Incorporating elements from ecological theories (Bronfenbrenner, 1979), the life course perspective (Elder et al., 2003; Settersten, 2006) helps to explain the micro- and macro-processes of physical activity over the lifespan by emphasizing time and place; that is, the ways in which development over time is shaped by social contexts in which individuals are embedded. The micro-context refers to individuals and their immediate connections (e.g. parents), while macro-context refers to the broader social and economic environment (e.g. states) (Bronfenbrenner, 1979). Seen from a life course perspective (Spini et al., 2017), therefore, both micro- and macro-level socioeconomic conditions may exert influences on an individual’s health behavior over time (**Figure 1**), including physical activity. Research from a life course perspective that integrates the micro- and macro-contexts would thus advance the literature by connecting lives, time, and place, and provide evidence for targeted interventions to promote physical activity by taking into account the interrelationship between the individual and his social spaces across the continuum of life.

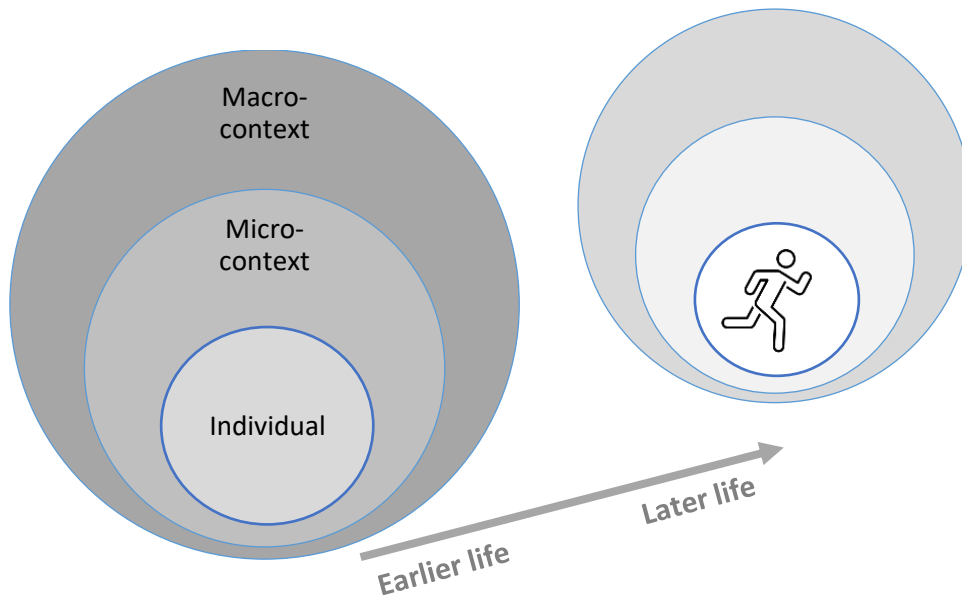


Figure 1: Micro- and macro-contexts of physical activity over the life course

At the micro-level, research indicates the influence of earlier-life socioeconomic conditions on later-life health and health behavior, encompassing such factors as individual and family financial conditions, urban/rural status, and parental educational attainment (Cohen et al., 2010; Moody-Ayers et al., 2007). Both material and psychosocial mechanisms underlie the links between earlier-life socioeconomic conditions and adulthood health behavior, including access to material resources, family socialization and support, and healthy behavioral norms (Pampel et al., 2010; Umberson et al., 2010). For physical activity, research shows that parental socioeconomic status and familial support in earlier life play an important role in shaping sports and activity participation (Mutz & Albrecht, 2017; Pudrovska & Anishkin, 2013).

At the macro-level, research shows that contextual socioeconomic conditions such as income inequality and community economic deprivation influence health and health behaviors, independent of the micro-level effects of individual and household socioeconomic status (Lang et al., 2008; Wen et al., 2003; Yang & South, 2020; Yao & Robert, 2008). The mechanisms that underpin these contextual effects include social capital (e.g. neighborly trust) (Kawachi & Berkman, 2003) as well as access to physical activity resources (Estabrooks et al., 2003). In the context of physical activity, research elucidates the socioeconomic gradient of environmental

motivators and barriers for physical activity, including both the built and social environment (Estabrooks et al., 2003; Hillsdon et al., 2008; Wen & Zhang, 2009; Wen et al., 2007).

1.3 The present study

In sum, extant research highlights the need for a life course approach to physical activity that simultaneously considers the micro- and macro-level socioeconomic conditions over the continuum of life. The present study undertakes this effort by conceptualizing physical activity from a life course perspective and situating it within the micro-context (i.e. individual and family) and the macro-context (i.e. broader society). It builds upon the growing body of literature on health behavior from a life course perspective by looking at the extent to which *both* individual and contextual factors in earlier life shape physical activity in later life, with emphasis on socioeconomic conditions. In particular, the present study addresses three focal questions: 1) To what extent are earlier-life individual socioeconomic conditions associated with later-life physical activity? 2) To what extent are earlier-life individual and contextual socioeconomic conditions jointly associated with later-life physical activity? 3) To what extent are earlier-life socioeconomic conditions (individual and contextual) associated with the rate of change in later-life physical activity?

Additionally, research suggests that the effect of earlier-life socioeconomic conditions on health over the life course may be explained by adulthood characteristics (Hayward & Gorman, 2004; Marmot et al., 2001). Yet, it remains unclear whether and to what extent adulthood characteristics – both individual and contextual – mediate the effect of earlier-life socioeconomic conditions on later-life physical activity. The present study will explore the potential mediating role of adulthood conditions.

Unlike most existing research that looks at a specific level of activity intensity, this study takes a holistic view of physical activity by investigating a range of intensity levels: mild, moderate, vigorous, given research suggesting that different intensity levels may require distinct interventions (Rhodes & De Bruijn, 2010), as lower-intensity physical activities (e.g. walking) tend to be more habitual whereas higher-intensity activities (e.g. swimming, tennis, aerobics) depend on greater motivation.

2. Methods

2.1 Data

The main data source is the Understanding America Study (UAS), a nationally representative panel supported by the U.S. Social Security Administration and the National Institute on Aging (Alattar, Messel, & Rogofsky, 2018). The UAS provides more than 300 modules covering such topics as physical health, disability, income, and retirement (Alattar et al., 2018). In particular, the UAS Health and Retirement panel is uniquely suited to this study for three reasons. First, it contains geographic information (state level) relating to the macro-environment in which respondents lived. Second, the information on state of residence is available for respondents' earlier life as well as later life, facilitating an investigation into the contextual socioeconomic conditions over the life course. This is important because a sizable share of the sample lived in a different state in later life relative to where they grew up in earlier life. Third, this panel allows merging with other UAS modules for richer information about the respondents, their family, and their locations of residence.

The first wave of the UAS Health and Retirement panel began in 2014, with follow-up surveys conducted every two years, including information on physical activity in each wave. A survey section on life history was conducted in 2014 (baseline) for all respondents. A total of 7773, 4637, and 8829 respondents aged 18 and older participated in the 2014, 2016, 2018 surveys, respectively (the 2020 wave was not finalized at the time of this writing). Given the study's focal research question on the association between earlier-life individual and contextual socioeconomic conditions and later-life physical activity, respondents were excluded if they 1) were below age 50 in the baseline; and 2) grew up in a foreign country before age 16 (<2%), which made it difficult to meaningfully compare the conditions of their earlier-life environment to that of a state in the US at concurrent times. Less than 3% of the cases were dropped due to missing information on key variables of interest, based on preliminary analysis indicating comparable results using imputed data (Allison, 2002). The analytic sample included 1,981 respondents, or 5,943 person-wave observations.

Current and historical public data were employed to assess contextual characteristics at the state level during respondents' early life and later life. All contextual information for later life was assessed in 2014, consistent with the UAS baseline wave, using data from the 2014 American Community Survey (ACS) 5-year estimates by the United States Census, given research showing that these estimates provided greater statistical reliability for population groups and geographic areas, relative to the 1-year estimates (US Census, 2017). Contextual information for earlier life

was assessed using data on general social and economic characteristics from the 1970 Census for two reasons. First, a respondent representing the sample’s median age (60 in 2014) reached age 16 in 1970, consistent with the age for which other earlier-life conditions were assessed in the UAS data. Second, historical data were accessible for all measures of state-level socioeconomic conditions in 1970 (US Census, 1972).

2.2 Measures

Physical activity. Three waves of physical activity were assessed using questions on the type and frequency of physical activity involved in daily life. Comparable with previously validated instruments (Centers for Disease Control and Prevention, 2021; Folsom et al., 1985), mild activities included “vacuuming, laundry, home repairs”; moderate activities included “gardening, cleaning the car, walking at a moderate pace, floor or stretching exercises”; and vigorous activities included “running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel”. Response options were categorical: 1=more than once a week, 2=once a week, 3=one to three times a month, 4=hardly ever or never. All responses were reverse coded so that higher numbers indicated greater frequency.

Earlier-life individual and family characteristics. Respondents were asked the following questions focusing on the period before age 16: 1) *Whether grew up in rural area*: “were you living in a rural area most of the time?” (1=yes, 0=no); 2) *Family economic condition*: “would you say your family during that time was pretty well off financially, about average, or poor?” (1=poor, 2=average, 3=well off); 3) *Father’s (and mother’s) educational attainment*: “what is the highest grade of school your father [and separately for mother] completed?” (1=college or above, 0=less than college); and 4) *Childhood health status* (1=poor to 5=excellent). These characteristics were chosen based on prior literature suggesting their associations with physical activity in later life (Bauman et al., 2012; Haley & Andel, 2010; Hirvensalo & Lintunen, 2011; Lim & Taylor, 2005; O’Donoghue et al., 2018).

Later-life individual characteristics. Time-varying variables assessed at each wave included current health status (1=poor to 5=excellent), retirement status (1=yes, 0=no), disability status (1=yes, 0=no), and household income (only categories available: from < \$29,999 to >= \$75,000). Time-invariant characteristics assessed at baseline (2014) included age (range 50-98), gender (1=female, 0=male), marital status (1=married or partnered, 0=otherwise), education (1=college

or above, 0=less than college), and race/ethnicity (1=yes and 0=no for non-Hispanic white, non-Hispanic black, non-Hispanic Asian, non-Hispanic other, and Hispanic).

Contextual conditions. Earlier- and later-life contextual conditions were assessed using indicators of the respondents' state of residence during the respective period: state-level poverty rate (%), college-level educational attainment (%), and income inequality (Gini coefficient) (0 to 1). To capture the potential influences of the built and social environment on physical activity, a set of indicators pertaining to the neighborhood of residence in later life was included (all coded 1=yes, 0=no): trust in neighbors, neighbors offer help, and being close to open space, bodies of water, grocery stores, and restaurants. These characteristics were selected based on prior research indicating their influence on physical activity participation (Barnett et al., 2017; Bauman et al., 2012; Haley & Andel, 2010; Mooney et al., 2017).

2.3 Analytic strategy

Descriptive analyses were first conducted to characterize physical activity at each wave and the study sample at baseline. Multilevel mixed-effects ordered logistic regression models were used to address the research questions (Singer & Willett, 2003). Specifically, controlling for baseline demographic characteristics, I first estimated the association between earlier-life individual characteristics and physical activity, along with the effects of time trend (Model 1), and the effect of earlier-life contextual conditions (Model 2), followed by adding: later-life individual conditions (Model 3), and later-life contextual conditions (Model 4), to test whether later-life conditions mediated the association between earlier-life characteristics and physical activity (Zhang et al., 2009). I then used interaction terms between earlier-life characteristics and time to examine whether earlier-life conditions were associated with the *rate of change* in later-life physical activity. Time-varying variables were decomposed into within-person (level 1; calculated as deviations from the person-mean at each wave) and between-person (level 2; defined by the person-mean for each time-varying variable) components to reduce potential bias related to stable person-level characteristics (Hoffman & Stawski, 2009). Time-invariant variables were centered at sample mean (Hox, 2002). No evidence of multicollinearity was found (all VIF<2) (Stevens, 2012).

3. Results

Descriptive characteristics of the study sample are given in **Table 1**. The mean levels of physical activity in each of the three waves (2014, 2016, 2018) were: 3.46, 3.44, and 3.32 (mild), 3.08,

3.05, and 2.96 (moderate), 2.30, 2.28, and 2.18 (vigorous), respectively (range for each type of physical activity: 1-4). In terms of demographic characteristics at baseline, mean age was 61.5, about 53% were female, 35% attained college education or above, 62% were married, 36% retired, and 13% disabled. For earlier-life socioeconomic conditions, 46% of respondents grew up in a rural area, 17% reported that their father had a college education or higher (13% for mother), the mean state-level poverty rate was 14%, mean state-level college education attainment was 10%, and the mean Gini coefficient was 0.45 (range 0.42-0.55). For later-life socioeconomic conditions, 25% had a household income < \$29,999, 21% had \$30,000 - \$49,999, 21% had \$50,000 - \$74,999, and 33% had household income > \$75,000, the mean state-level poverty rate was 16%, mean state-level college education attainment was 28%, and the mean Gini coefficient was 0.47 (range 0.41-0.53).

Tables 2, 3, and 4 show results from multilevel mixed-effects regression models for mild, moderate, and vigorous physical activity. Notably, father's educational attainment was consistently associated with higher odds of engaging in mild ($OR=1.13, p<.05$; Table 2, Model 4) and moderate ($OR=1.25, p<.001$; Table 3, Model 4) physical activity later in life, while earlier-life state-level poverty rate was associated with lower odds of engaging in moderate ($OR=.95, p<.05$; Table 3, Model 4) and vigorous ($OR=.95, p<.05$; Table 4, Model 4) physical activity at older ages, controlling for all other individual and contextual conditions over the life course. Better childhood health was associated with decreasing odds of engaging in vigorous physical activity later in life ($OR=.82, p<.05$; Table 4, Model 4). The associations between other earlier-life characteristics and later-life physical activity were mediated by later-life conditions.

Table 5 provides results from multilevel mixed-effects regression models for the rate of change in physical activity (PA). On average, respondents reported substantial decline in the odds of engaging in all types of PA during the observation period: mild PA ($OR=.89, p<.001$), moderate PA ($OR=.93, p<.001$), and vigorous PA ($OR=.91, p<.001$). No significant effect was found between earlier-life socioeconomic conditions and the rate of decline in PA, after controlling for all other individual and contextual characteristics over the life course. However, respondents who reported better childhood health showed slower decline in moderate PA ($OR=1.05, p<.01$) relative to respondents who reported worse childhood health.

4. Discussion

The present study, framed within the life course and ecological perspectives, investigated the association between earlier-life individual and contextual socioeconomic conditions and later-life physical activity (frequency of participation as well as rate of change), along with the mediating role of later-life characteristics, utilizing current and historical Census data. While a few studies on physical activity have previously adopted a life course perspective, existing research typically focused on the micro-level characteristics over time, neglecting the concurrent role of macro-level socioeconomic conditions in shaping physical activity. Although a substantial literature framed within the ecological theories has examined the macro-environmental mechanisms relating to physical activity, this research often separately focused on early or late adulthood, and is limited in that environmental motivators and barriers may exert influence throughout the life course, rather than merely at a specific stage of life. Making connections between lives, time, and place, the present study advances the literature by considering both the micro- and macro-levels of socioeconomic conditions in both earlier- and later-life and their associations with physical activity among respondents in the same sample.

Findings from this study complement and extend existing literature. The study found that father's education in respondents' earlier life was positively associated with participation in mild and moderate physical activity in respondents' later life. Although research accounting for the longitudinal influence of parental education on older adults' physical activity is sparse, this finding concurs with research showing the considerable positive influence of paternal education on health (Cohen et al., 2010; Moody-Ayers et al., 2007) and physical activity in earlier life (Gracia-Marco et al., 2010; La Torre et al., 2006). Potential underlying mechanisms include greater paternal involvement in offspring's sports and activities (La Torre et al., 2006), likely cultivating a more active lifestyle behavioral norm, as well as greater familial socioeconomic conditions among respondents whose father had a higher educational attainment (Gracia-Marco et al., 2010), both of which might have their activity-enhancing benefits carried over into later life. The fact that the positive influence of paternal education was only found for mild and moderate physical activity, but not for vigorous physical activity might suggest that the former was more habit-based than the latter (Rhodes & De Bruijn, 2010), but further research is needed to confirm the underlying causal links.

The study also found that earlier-life state-level poverty rate, objectively measured using historical Census data, was negatively associated with participation in moderate and vigorous

physical activity in later life, over and above the effect of individual socioeconomic conditions. This confirms research evidence from other domains of health and health behavior on the role of contextual socioeconomic conditions over the life course (Wen & Gu, 2011; Yang & South, 2020; Yao & Robert, 2008), and a recent study on life course area-level deprivation on physical activity in British women (Hillsdon et al., 2008). This finding offers a more holistic picture for both men and women regarding their childhood contextual economic circumstance and later-life physical activity. Potential mechanisms underpinning the present finding include better access to activity resources, healthier behavioral norms and greater social capital, which are shown to motivate physical activity (Estabrooks et al., 2003; Wen et al., 2007, 2009).

Furthermore, although neither individual nor contextual socioeconomic conditions in earlier life were associated with the rate of change in later-life physical activity, the study found that better childhood health was associated with a slower decline in moderate physical activity in later life. This finding concurs with existing literature on the “long arm” of childhood health which continues to shape functional health at older ages (Haas, 2008), and shows that the “long arm” of childhood health does extend to physical activity participation in later life. It is unclear why this link was only significant for moderate physical activity. Future research is needed to elucidate the mechanisms underlying later-life declines in physical activity by intensity level.

Limitations. No statements of causality should be made given the limitations associated with observational data, despite the temporal order of events seen in this study. Although earlier-life state-level conditions were objectively measured, respondents’ retrospective reports of earlier-life individual and family characteristics are subject to recall bias. While this study has extended the literature by concurrently examining aspects of individual and contextual socioeconomic conditions relating to physical activity, other relevant contextual factors were not included due to data limitations. Given data limitations, income was measured categorically. While it might be possible for father’s education to capture elements of adulthood income and education, the present paper emphasized the potential early-life behavioral and economic advantages relating to father’s education. Still, due to data limitations, the frequency of physical activity participation is self-reported and may not objectively reflect respondents’ actual participation. Future research should use objectively measured physical activity to investigate its antecedents across time and place.

Despite these limitations, the present study, framed within the life course and ecological perspectives, made several contributions to the scientific literature regarding the association

between socioeconomic conditions and later-life physical activity. Relying on contemporary and historical public data, this study extended the literature on physical activity in later life beyond the examination of concurrent socioeconomic characteristics by embracing a life course perspective and focusing on the role of earlier-life circumstances in shaping later-life sports and activity participation. The study also extended the literature on the environmental correlates of later-life physical activity by looking at the role of earlier-life socioeconomic environment in later-life activity. In combination, the study jointly considered both micro- and macro- socioeconomic conditions in both earlier- and later-life within the same sample, for a holistic portrayal of physical activity across social environments and over the continuum of life, thereby making connections between lives, time, and place.

The study has implications for policy and practice. Understanding the role of earlier-life circumstances in shaping later-life sports and physical activity participation helps to develop synergistic and targeted interventions to promote physical activity in older populations. The effort to reduce inequities in access to resources and services may have a greater impact on physical activity and health promotion by adopting a life course perspective and intervene at various stages of life. Efforts to promote physical activity and an active lifestyle at older ages would benefit from longitudinally designed programs that take into account earlier-life circumstances of the individual and his family, in particular, parental socioeconomic statuses, and also with attention to the place of residence over the life course, given the ways in which contextual conditions shape physical activity above and beyond individual characteristics.

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Table 1: Descriptive characteristics of the study sample

Variable	M	SD	%
<i>Frequency of physical activity in later life, 2014 to 2018</i>			
Mild physical activity (range 1-4)			
2014	3.46	0.87	
2016	3.44	0.89	
2018	3.32	0.98	
Moderate physical activity (range 1-4)			
2014	3.08	1.15	
2016	3.05	1.18	
2018	2.96	1.23	
Vigorous physical activity (range 1-4)			
2014	2.30	1.31	
2016	2.28	1.31	
2018	2.18	1.30	
<i>Earlier-life individual characteristics</i>			
Born in the U.S.			94.8
Grew up in a rural area			45.5
Childhood health (range 1-5)	4.37	0.85	
<i>Earlier-life family characteristics</i>			
Family economic condition (range 1-3)	1.82	0.55	
Father had college education or above			16.9
Mother had college education or above			12.5
<i>Earlier-life state characteristics</i>			
% below poverty (mean)			13.7
% attained college education (mean)			10.3
Gini coefficient	0.45	0.02	
<i>Later-life individual characteristics (baseline)</i>			
Age (range 50-98)	61.47	8.11	
Female			52.9
Race/ethnicity			
Non-Hispanic white			85.2
Non-Hispanic black			8.1
Non-Hispanic Asian			1.9
Non-Hispanic other			1.6
Hispanic			4.1
College education or above			34.9
Self-rated health (range 1-5)	3.35	1.01	
Married or partnered			61.6
Retired			35.9
Disabled			12.7
Household income			
Less than \$29,999			25.4
\$30,000 to \$49,999			20.5
\$50,000 to \$74,999			20.9
\$75,000 or more			33.2
<i>Later-life neighborhood characteristics</i>			
People in neighborhood can be trusted			87.7
Neighbors are willing to offer help			91.5
Open space within a half block (e.g. park)			70.7
Bodies of water within a half block (e.g. lake or pond)			34.1
Grocery stores within walking distance			88.6
Restaurants or businesses within a half block			24.3
<i>Later-life state characteristics</i>			
% below poverty (mean)			15.6
% attained college education (mean)			28.4
Income inequality (Gini coefficient)	0.47	0.02	

N=1,981. All measures assessed at baseline unless otherwise noted.

Physical activity: 1 (hardly ever/never) to 4 (more than once a week).

Self-rated health: 1 (poor) to 5 (excellent).

Family economic condition: 1 (poor) to 3 (well-off).

Table 2: Results from multilevel mixed-effects ordered logistic regression models for mild physical activity in later life, 2014 to 2018

Variable	Model 1			Model 2			Model 3			Model 4		
	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
Time	0.90	0.02	***	0.90	0.02	***	0.89	0.02	***	0.89	0.02	***
<i>Earlier-life individual characteristics</i>												
Born in the U.S.	0.75	0.22		0.86	0.37		0.90	0.36		0.80	0.32	
Grew up in a rural area	0.75	0.09	*	0.87	0.11		0.95	0.11		0.92	0.11	
Childhood health	1.54	0.10	***	1.45	0.10	***	1.06	0.07		1.06	0.07	
<i>Earlier-life family characteristics</i>												
Family economic condition				1.08	0.13		1.02	0.11		1.00	0.11	
Father's educational attainment				1.21	0.07	**	1.12	0.06	*	1.13	0.06	*
Mother's educational attainment				1.03	0.07		0.97	0.06		0.97	0.06	
<i>Earlier-life state characteristics</i>												
Poverty rate				0.96	0.02	**	0.97	0.02	*	0.97	0.02	
College education rate				0.98	0.05		0.98	0.04		1.01	0.05	
Income inequality (Gini coefficient)				1.05	0.05		1.03	0.05		1.02	0.05	
<i>Later-life individual characteristics</i>												
Age	0.96	0.01	***	0.97	0.01	***	0.95	0.01	***	0.95	0.01	***
Female	1.36	0.16	**	1.37	0.17	**	1.64	0.20	***	1.63	0.19	***
<i>Race/ethnicity</i>												
Non-Hispanic white (ref.)												
Non-Hispanic black	0.23	0.05	***	0.33	0.08	***	0.39	0.09	***	0.42	0.09	***
Non-Hispanic Asian	0.34	0.15	*	0.35	0.20		0.33	0.17	*	0.36	0.19	
Non-Hispanic other	0.48	0.22		0.51	0.24		0.76	0.34		0.80	0.36	
Hispanic	0.54	0.16	*	0.53	0.18		0.55	0.17		0.60	0.19	
College education or above							1.16	0.16		1.14	0.16	
Married or partnered							1.44	0.19	**	1.39	0.18	*
<i>Within-person effects</i>												
Self-rated health							1.34	0.11	***	1.33	0.11	***
Retired							1.60	0.35	*	1.59	0.35	*
Disabled							1.72	0.66		1.73	0.66	
Household income							0.91	0.08		0.91	0.08	
<i>Between-person effects</i>												
Self-rated health							2.32	0.18	***	2.32	0.18	***
Retired							1.43	0.24	*	1.41	0.24	*
Disabled							0.78	0.15		0.78	0.15	
Household income							1.13	0.07		1.12	0.07	
<i>Later-life neighborhood characteristics</i>												
People in neighborhood can be trusted										1.09	0.21	
Neighbors are willing to offer help										1.20	0.27	
Open space within a half block (e.g. park)										1.43	0.19	**
Bodies of water within a half block (e.g. lake or pond)										1.04	0.13	
Grocery stores within walking distance										1.13	0.21	
Restaurants or businesses within a half block										0.94	0.13	
<i>Later-life state characteristics</i>												
Poverty rate										0.95	0.05	
College education rate										0.97	0.03	
Income inequality (Gini coefficient)										1.03	0.06	
Random intercept variance		4.3			4.2			3.4			3.3	
Akaike information criterion		10888.4			9844.9			9578.2			9527.9	

Person N = 1,981. Person-wave observation N = 5,943. OR=odds ratio. SE=standard error. Significance: *p < 0.05 **p < 0.01 ***p < 0.001

Table 3: Results from multilevel mixed-effects ordered logistic regression models for moderate physical activity in later life, 2014 to 2018

Variable	Model 1			Model 2			Model 3			Model 4		
	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
Time	0.93	0.02	***	0.92	0.02	***	0.93	0.02	***	0.93	0.02	***
<i>Earlier-life individual characteristics</i>												
Born in the U.S.	0.69	0.21		1.12	0.49		1.07	0.43		1.04	0.42	
Grew up in a rural area	0.58	0.07	***	0.75	0.10	*	0.92	0.11		0.87	0.11	
Childhood health	1.46	0.10	***	1.36	0.10	***	0.89	0.06		0.89	0.06	
<i>Earlier-life family characteristics</i>												
Family economic condition				0.98	0.12		0.88	0.10		0.87	0.10	
Father's educational attainment				1.41	0.08	***	1.25	0.07	***	1.25	0.07	***
Mother's educational attainment				1.06	0.08		0.96	0.06		0.95	0.06	
<i>Earlier-life state characteristics</i>												
Poverty rate				0.94	0.02	**	0.95	0.02	**	0.95	0.02	*
College education rate				0.99	0.05		0.99	0.04		1.00	0.05	
Income inequality (Gini coefficient)				1.06	0.05		1.06	0.05		1.05	0.05	
<i>Later-life individual characteristics</i>												
Age	0.99	0.01		1.00	0.01		0.97	0.01	**	0.97	0.01	***
Female	0.61	0.08	***	0.65	0.08	**	0.77	0.09	*	0.78	0.09	*
<i>Race/ethnicity</i>												
Non-Hispanic white (ref.)												
Non-Hispanic black	0.42	0.09	***	0.72	0.18		0.81	0.18		0.89	0.20	
Non-Hispanic Asian	0.94	0.46		0.69	0.43		0.54	0.30		0.65	0.36	
Non-Hispanic other	0.56	0.28		0.62	0.31		0.95	0.43		0.93	0.43	
Hispanic	0.76	0.24		0.82	0.30		0.87	0.28		0.98	0.31	
College education or above							2.09	0.29	***	2.04	0.28	***
Married or partnered							1.31	0.17	*	1.26	0.16	
<i>Within-person effects</i>												
Self-rated health							1.54	0.12	***	1.53	0.12	***
Retired							1.44	0.30		1.38	0.29	
Disabled							1.47	0.55		1.47	0.55	
Household income							1.03	0.08		1.02	0.08	
<i>Between-person effects</i>												
Self-rated health							3.12	0.25	***	3.07	0.24	***
Retired							1.87	0.32	***	1.82	0.31	***
Disabled							0.78	0.15		0.79	0.16	
Household income							1.05	0.07		1.03	0.07	
<i>Later-life neighborhood characteristics</i>												
People in neighborhood can be trusted										1.24	0.24	
Neighbors are willing to offer help										1.38	0.30	
Open space within a half block (e.g. park)										1.28	0.17	
Bodies of water within a half block (e.g. lake or pond)										1.14	0.14	
Grocery stores within walking distance										1.16	0.21	
Restaurants or businesses within a half block										0.85	0.12	
<i>Later-life state characteristics</i>												
Poverty rate										1.04	0.05	
College education rate										1.02	0.03	
Income inequality (Gini coefficient)										0.87	0.05	**
Random intercept variance		5.2			5.0			3.6			3.6	
Akaike information criterion		12700.1			11486.9			11044.7			10971.2	

Person N = 1,981. Person-wave observation N = 5,943. OR=odds ratio. SE=standard error. Significance: *p < 0.05 **p < 0.01 ***p < 0.001

Table 4: Results from multilevel mixed-effects ordered logistic regression models for vigorous physical activity in later life, 2014 to 2018

Variable	Model 1			Model 2			Model 3			Model 4		
	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
Time	0.91	0.02	***	0.90	0.02	***	0.91	0.02	***	0.91	0.02	***
<i>Earlier-life individual characteristics</i>												
Born in the U.S.	0.41	0.14	*	0.69	0.35		0.57	0.25		0.57	0.26	
Grew up in a rural area	0.60	0.08	***	0.70	0.11	*	0.92	0.13		0.90	0.13	
Childhood health	1.44	0.12	***	1.37	0.12	***	0.82	0.07	*	0.82	0.07	*
<i>Earlier-life family characteristics</i>												
Family economic condition				1.04	0.15		0.90	0.12		0.90	0.12	
Father's educational attainment				1.27	0.09	***	1.11	0.07		1.10	0.07	
Mother's educational attainment				1.15	0.09		1.03	0.07		1.02	0.07	
<i>Earlier-life state characteristics</i>												
Poverty rate				0.95	0.02	*	0.96	0.02		0.95	0.02	*
College education rate				0.96	0.05		0.96	0.05		0.96	0.05	
Income inequality (Gini coefficient)				1.07	0.06		1.06	0.05		1.07	0.05	
<i>Later-life individual characteristics</i>												
Age	0.97	0.01	*	0.98	0.01		0.96	0.01	***	0.96	0.01	***
Female	0.36	0.05	***	0.37	0.06	***	0.44	0.06	***	0.44	0.06	***
<i>Race/ethnicity</i>												
Non-Hispanic white (ref.)												
Non-Hispanic black	0.76	0.20		1.16	0.33		1.51	0.39		1.65	0.44	
Non-Hispanic Asian	0.47	0.26		0.31	0.21		0.24	0.15	*	0.28	0.18	*
Non-Hispanic other	1.39	0.77		1.63	0.95		2.90	1.52	*	2.82	1.49	*
Hispanic	0.86	0.31		0.90	0.37		0.89	0.33		0.93	0.35	
College education or above							1.97	0.30	***	1.95	0.30	***
Married or partnered							1.19	0.18		1.14	0.17	
<i>Within-person effects</i>												
Self-rated health							1.78	0.14	***	1.77	0.14	***
Retired							1.50	0.32		1.45	0.31	
Disabled							2.15	1.07		2.14	1.06	
Household income							0.95	0.08		0.95	0.08	
<i>Between-person effects</i>												
Self-rated health							4.50	0.42	***	4.42	0.42	***
Retired							1.50	0.29	*	1.42	0.27	
Disabled							1.05	0.25		1.07	0.26	
Household income							1.18	0.09	*	1.17	0.09	*
<i>Later-life neighborhood characteristics</i>												
People in neighborhood can be trusted										1.34	0.31	
Neighbors are willing to offer help										1.10	0.29	
Open space within a half block (e.g. park)										1.15	0.18	
Bodies of water within a half block (e.g. lake or pond)										1.39	0.20	*
Grocery stores within walking distance										1.08	0.23	
Restaurants or businesses within a half block										0.85	0.14	
<i>Later-life state characteristics</i>												
Poverty rate										1.06	0.06	
College education rate										1.01	0.03	
Income inequality (Gini coefficient)										0.93	0.06	
Random intercept variance		7.3			7.1			5.2			5.1	
Akaike information criterion		12625.3			11544.0			11012.7			10946.6	

Person N = 1,981. Person-wave observation N = 5,943. OR=odds ratio. SE=standard error. Significance: *p < 0.05 **p < 0.01 ***p < 0.001

Table 5: Results from multilevel mixed-effects ordered logistic regression models for mild, moderate, and vigorous physical activity (PA) in later life, 2014 to 2018

Variable	Mild PA		Moderate PA		Vigorous PA	
	OR	Sig	OR	Sig	OR	Sig
Time	0.89	***	0.93	***	0.91	***
<i>Earlier-life characteristics</i>						
Childhood health	1.01		0.81	*	0.84	
Childhood health x Time	1.02		1.05	*	0.99	
Family economic condition	1.05		0.92		0.89	
Family economic condition x Time	0.98		0.97		1.00	
Father's education	1.12		1.23	**	1.19	*
Father's education x Time	1.00		1.01		0.96	
Mother's education	0.93		0.96		0.97	
Mother's education x Time	1.02		0.99		1.03	
State poverty rate	0.97		0.95	*	0.95	*
State poverty rate x Time	1.00		1.00		1.00	
State college education	0.99		0.98		0.99	
State college education x Time	1.01		1.01		0.99	
State income inequality	1.05		1.07		1.03	
State income inequality x Time	0.99		0.99		1.02	
Random intercept variance	3.3		3.6		5.1	
Akaike information criterion	9539.1		10980.4		10951.6	

Person N = 1,981. Person-wave observation N = 5,943. OR=odds ratio. Significance: *p < 0.05 **p < 0.01 ***p < 0.001

All models control for all other earlier- and later-life individual and contextual characteristics.

Appendix

Focal multilevel estimation equation:

$$PA_{ti} = b_{0i} + b_{1i}(Time_{ti}) + b_{2i}(TVC_{ti}) + e_{ti}$$

$$b_{0i} = \gamma_{00} + \gamma_{01}(ESEC_i) + \gamma_{02}(TIC_i) + \mu_{0i}$$

$$b_{1i} = \gamma_{10} + \gamma_{11}(ESEC_i) + \mu_{1i}$$

(Note: i =person i ; t =time t ; PA=physical activity; ESEC=earlier-life socioeconomic conditions; TVC=time-varying covariates; TIC=time-invariant covariates)

Association between Earlier-life Socioeconomic Conditions and Focal Later-life Characteristics (baseline)

Variable	Household income (category)		Self-rated health	
	OR	Sig	OR	Sig
<i>Earlier-life characteristics</i>				
Born in the U.S.	1.71		1.04	
Grew up in a rural area	0.28	***	0.70	*
Family economic condition	1.38		2.09	***
Father's educational attainment	1.88	***	1.38	***
Mother's educational attainment	2.33	***	1.19	

All models control for age, gender, and race/ethnicity at baseline. OR=odds ratio.

Significance: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$. Self-rated health: 1 (poor) to 5 (excellent).