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The bidirectional relationship between sense of purpose in life and physical activity: a longitudinal study

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Abstract People with a greater sense of purpose in life may be more likely to engage in physical activity. At the same time, physical activity can contribute to a sense of purpose in life. The present research tests these hypotheses using a cross-lagged panel model in a nationally representative, longitudinal panel of American adults ($N = 14{,}159$, $M_{age} = 68$). An increase in sense of purpose in life was associated with higher physical activity four years later, above and beyond past activity levels. Physical activity was positively associated with future levels of sense of purpose in life, controlling for prior levels of purpose in life. Results held in a second national panel from the US with a nine-year follow-up ($N = 4{,}041$, $M_{age} = 56$). The findings demonstrate a bidirectional relationship between sense of purpose in life and physical activity in large samples of middle-aged and older adults tracked over time.

Introduction

Physical activity is associated with improved mental health (Schuch et al., 2018), decreased risk of diseases, and increased life expectancy (Lear et al., 2017). Yet, global statistics suggest that many people, especially older adults, do not engage in activity at sufficient levels (Sallis et al., 2016). Therefore, it is important to study determinants of physical activity and identify the factors that may affect activity behaviors in the long run as people age.

Researchers suggest that a critical health asset that can drive positive health outcomes (Kubzansky et al., 2018) and behaviors (Boehm et al., 2018) could be psychological well-being—a multi-faceted construct that involves positive feelings and thoughts necessary for psychological functioning. Motivated by this line of work, one of the aims of the current study is to investigate a specific component of psychological well-being, *sense of purpose in life*, as a potential longitudinal determinant of physical activity participation.

Sense of purpose in life arises from having goals and aims that give life direction and meaning (Ryff, 1989). Longitudinal studies have shown that middle-aged and older adults with a greater sense of purpose in life experience reduced risks of physical disease (e.g., Kim et al., 2013), better mental health outcomes (e.g., Windsor et al., 2015), and increased longevity (Hill & Turiano, 2014). These studies highlight the possibility that sense of purpose in life, among other beneficial influences, could also be linked to health behaviors, including physical activity.

Physical activity is a difficult behavior to initiate and maintain (Rhodes & Brujin, 2013). Theories (Ajzen, 1991; Fishbein & Ajzen, 2005) and empirical studies (Bauman et al., 2012; Rhodes et al., 2017) suggest that an important predictor of activity behaviors is intentions, the conscious decisions and motivations to enact a behavior. People with greater levels of sense of purpose in life may be more likely to have intentions to take care of their lives, which can include intentions to be physically active. Psychologists have long argued that having a sense of purpose manifests a willingness to live and a motivation to take actions that prolong life (Frankl, 1984). As Ryff and Singer state, "taking good

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care of oneself in terms of daily health practices presupposes a life that is worth taking care of" (1998, p. 22).

Sense of purpose in life may also influence activity behaviors by increasing people's efficiency and success in goal pursuit. A meta-analysis has shown that about 46% of those with intentions to exercise do not follow through with their intentions (Rhodes & Brujin, 2013); highlighting the role of other factors in activity participation. Recent studies found that post-motivational strategies (Sniehotta et al., 2005) such as *action planning* (i.e., making plans about when and where to exercise) and *coping planning* (e.g., making plans about overcoming barriers to goals) are effective in inducing behavior change in the context of physical activity (Robinson et al., 2019). People with a stronger sense of purpose in life may be more likely to plan where and how to exercise and make long-term commitments to be active (e.g., sign up for a gym). They may also be better prepared to tackle long-term barriers to activity goals such as age-related physical disabilities or reduced proximity to recreational facilities (Bauman et al., 2012).

It is also possible that while sense of purpose in life contributes to engagement in physical activity, at the same time, physical activity may foster a sense of purpose in life. *Social cognitive theory* suggests that behavioral engagement is driven by the perception that a specific behavior will lead to desired outcomes (Bandura, 1977). Consistent with this, qualitative studies indicate that one of the reasons why adults, especially older adults, engage in physical activity is to feel a sense of purpose in life (Morgan et al., 2019). Older adults report that being active leads to a sense of purpose in life by providing structure and goals to their daily lives (e.g., determining when and where to exercise) (Beck, Gillison, & Standage, 2010) and through a feeling that they do something worthwhile with their time, pursuing activities that align with the broader, meaningful goal of living a healthy and productive life (Kosteli, Williams, & Cumming, 2016). Motivated by this qualitative evidence, a second aim of the current study is to investigate whether physical activity may longitudinally predict sense of purpose in life.

Several cross-sectional studies have shown a positive association between sense of purpose in life and physical activity[1] (Hill et al., 2017; Holahan & Suzuki, 2006; Holahan et al., 2008, 2011; Hooker & Masters, 2016). However, longitudinal studies are needed to identify the direction of the relationship between sense of purpose in life and physical activity. One longitudinal study has found a positive association between a composite index of psychological well-being (control, autonomy, self-realization, and pleasure) and physical activity over 11 years (Kim et al., 2017). However, sense of purpose in life is a conceptually distinct measure of psychological well-being (Ryff, 1989), which can have a unique relationship with physical activity. Recently, another longitudinal study has shown that physically active individuals who reported higher levels of sense of purpose in life were less likely to reduce their engagement in activity over four years (Kim et al., 2020).

Studies that examine the opposite pathway from physical activity to sense of purpose in life are limited. In one longitudinal study, researchers did not find evidence that physical activity was linked to future sense of purpose in life (Chen et al., 2020). However, in this study, activity was measured as a dichotomous variable (i.e., frequently active vs. not) and sense of purpose in life was measured with a single item (i.e., "I have a sense of direction and purpose in life"). Taken together, these studies highlight the need for further longitudinal studies with robust measures to investigate whether physical activity can contribute to sense of purpose in life and to simultaneously model the potentially bidirectional relationship between sense of purpose in life and physical activity.

In the present research, we hypothesized that i) individuals with greater levels of sense of purpose in life would experience more positive changes in activity levels over time, and ii) individuals with greater levels of activity engagement would experience more positive changes in sense of purpose in life over time. Using a cross-lagged panel model, we tested these hypotheses simultaneously while controlling for the lagged values of the dependent variables. This method improved the estimates by tackling potential sources of bias due to reverse causality (VanderWeele et al., 2016) and by addressing some of the unobserved historical factors that could have biased the estimates (e.g., stable components of personality and social environment) (Wooldridge, 2010). We used a large and representative longitudinal panel of older adults ($M_{age}=68$) surveyed at four-year intervals as part of the Health and Retirement Study. The robustness of the results was tested in an independent sample with a different age profile ($M_{age}=56$) and a follow-up period of nine years. Multi-item self-report measures of sense of purpose in life and physical activity were used in both surveys. Through the application of longitudinal methods, the current study tested the bidirectional relationship between physical activity and sense of purpose in life, two outcomes that are critical for middle-aged and older adults who tend to experience lower levels of activity engagement (Sallis et al., 2016) and sense of purpose in life (Springer, 2011).

[1] Only one study, in which older women with pain were over-sampled, did not find a significant correlation between purpose in life and physical activity (Salt et al., 2017).

Table 1 Descriptive statistics and zero-order correlations in Health and Retirement Study

Variables	1	2	3	4	5	6	7	8	9	10	11
(1) Activity-T1	1										
(2) Activity-T2	0.427*	1									
(3) Activity-T3	0.366*	0.473*	1								
(4) Purpose in Life-T1	0.226*	0.193*	0.175*	1							
(5) Purpose in Life-T2	0.190*	0.235*	0.210*	0.599*	1						
(6) Purpose in Life-T3	0.178*	0.212*	0.254*	0.571*	0.626*	1					
(7) Age	−0.141*	−0.147*	−0.151*	−0.137*	−0.142*	−0.148*	1				
(8) Gender	−0.092*	−0.088*	−0.079*	−0.001	−0.01	0.006	−0.038*	1			
(9) Education	0.177*	0.180*	0.177*	0.199*	0.204*	0.232*	-0.143*	−0.044*	1		
(10) Chronic Disease	−0.121*	−0.120*	−0.126*	−0.094*	−0.099*	−0.108*	0.269*	0.018	−0.091*	1	
(11) BMI	−0.135*	−0.151*	−0.145*	−0.048*	−0.053*	−0.079*	−0.165*	−0.145*	−0.036*	0.106*	1
Mean	3.23	3.05	3.02	4.59	4.59	4.54	68.30	0.59	12.63	0.86	33.42
SD	1.33	1.34	1.35	0.93	0.94	0.94	10.46	0.49	3.07	0.35	7.78
Range	1–5	1–5	1–5	1–6	1–6	1–6	25–104	0 or 1	0–17	0 or 1	11–84
Skewness	−0.63	−0.43	−0.38	−0.37	−0.39	−0.36	0.07	−0.38	−0.96	−2.09	0.99
Kurtosis	2.07	1.79	1.73	2.59	2.59	2.62	2.69	1.15	4.95	5.36	5.07

*$p < .001$. Age, BMI and chronic disease were measured at Time 1. Three-wave data was from the two cohorts in Health and Retirement Study (Cohort 1: 2006–2010-2014 and Cohort 2: 2008–2012-2016)

Method

Study population

HRS. The primary sample was drawn from the Health and Retirement Study (HRS), a panel study that investigates the physical and economic well-being of aging American adults (Health & Retirement Study, 2006–2016). HRS was first fielded in 1992 and every two years since then. The initial sample consisted of people between ages 51 and 61 and their spouses. Over time, new cohorts were added to make the sample more representative of the US population (Sonnega et al., 2014; also see http://hrsonline.isr.umich.edu).

In 2006, 50% of the HRS panel was randomly chosen for an interview and responded to a lifestyle questionnaire at the end of the interview. This module included questions on sense of purpose in life and had a longitudinal follow-up in 2010 and 2014. The remaining 50% of the sample participated in the questionnaire in 2008, with follow-ups in 2012 and 2016 (Sonnega et al., 2014). 14,159 individuals who completed and returned the lifestyle questionnaire at the initial waves were used as the analytic sample in this study. The sample was 59% female, 84% White, 12% Black, and 4% Other Race. The average age at the baseline was 68 [$SD = 11$, Range = 25–104]. Table 1 presents sample characteristics and summary statistics for HRS data.

MIDUS. For replication analysis, the sample was drawn from the National Survey of Midlife Development in the US (MIDUS), a panel study that investigates physical and psychological functioning in the US (Radler, 2014). The primary sample was recruited via random digit dialing and expanded with the siblings of the main sample, a national sample of twins, and oversamples from metropolitan areas in the US to increase representation. A follow-up was completed in 2004 (75% retention), and a second follow-up was completed in 2013 (83% retention) (Radler & Ryff, 2010; also see http://www.icpsr.umich.edu/icpsrweb/NACDA).

Participants of MIDUS II (2004) and III (2013) were used for the current study as these waves included a psychometrically sound measure of sense of purpose in life. The analytic sample included people who completed the self-administered mail questionnaire where questions about sense of purpose in life existed (81% of the sample in MIDUS II and 83% in MIDUS III) ($N = 4041$). The sample was 55% female, 92% White, 4% Black, 4% Other Race. The average age at the baseline was 56 [$SD = 12$, Range = 30–84]. Summary statistics for this sample are provided in the Supplementary Material (Table S4).

Measures

Sense of Purpose in life A seven-item scale of sense of purpose in life (Ryff & Keyes, 1995) was used in HRS and MIDUS. The questions ask about people's agreement with statements like i) "I have a sense of direction and purpose in life."; ii) "I don't have a good sense of what it is I'm trying to accomplish in life."; iii) "My daily activities often seem trivial and unimportant to me." Consistent with the original scale (Ryff & Keyes, 1995), respondents used a response scale of 1 (strongly disagree) to 7 (strongly agree) in MIDUS, but the scale was changed to 1 to 6 in the administration of HRS. Negatively worded items were reverse coded. We used an average of the seven items in HRS ($\alpha = 0.73$) and MIDUS ($\alpha = 0.70$). Scores for sense of purpose in life were moderately correlated across waves (see Table 1).

Physical activity A continuous measure of physical activity was constructed from questions on moderate and vigorous activity in both datasets. In HRS, the questions on moderate activity asked, "We would like to know the type and amount of physical activity involved in your daily life. How often do you take part in sports or activities that are moderately energetic such as, gardening, cleaning the car, walking at a moderate pace, dancing, floor or stretching exercises (more than once a week, once a week, one to three times a month, or hardly ever or never)?" Vigorous activity was assessed by the question, "How often do you take part in sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel: everyday, more than once a week, once a week, one to three times a month, or hardly ever or never?" Responses were reverse-coded so that higher scores indicate more frequent engagement in activity: 1 (hardly ever or never), 2 (one to three times a month), 3 (once a week), 4 (more than once a week), and 5 (every day).

Supporting the external validity of the physical activity measures in HRS, prior research has shown high concordance across activity measures from HRS and other large-scale national health surveys, including the National Health and Nutrition Examination Survey and the National Health Interview Survey (Jenkins, 2008). Following prior research (Cotter & Lachman, 2010; Rhodes et al., 2008), we used the highest score for either moderate or vigorous activity. This provides the best possible approximation to official US guidelines, which recommends adults complete either 150 min a week of moderate activity or 75 min a week of vigorous activity (US Department of Health & Human Services, 2018). 43% of the sample reported the same level of engagement in moderate and vigorous activities, while 51% had higher scores for moderate, and 6% had higher scores for vigorous activity. Moderate and vigorous activity measures were moderately correlated ($r = 0.40$, 95% CI = [0.394, 0.412]). The final activity measure was moderately correlated across waves (see Table 1).

In MIDUS, 12 questions asked about the frequency of engaging in moderate and vigorous physical activity in summer and winter, at home, at work, and during one's leisure time. Moderate activity was described as "Physical activity that is not physically exhausting, but it causes your heart rate to increase slightly, and you typically work up a sweat (e.g., leisurely sports like light tennis, slow or light swimming, etc.)." Vigorous activity was described as "Activity that causes your heart to beat so rapidly that you can feel it in your chest and you perform the activity long enough to work up a good sweat and are breathing heavily (e.g., competitive sports like running, vigorous swimming, etc.)." Responses were coded as 1 (never), 2 (less than once a month), 3 (once a month), 4 (several times a month), 5 (once a week), and 6 (several times a week). A detailed description of this measure is presented in the Supplementary Material.

To support the validity of these measures, researchers compared the prevalence of physical activity in the MIDUS sample to the prevalence rates reported by the Center for Disease Control and Prevention in the US (Cotter & Lachman, 2010). They find that activity rates were slightly lower in MIDUS, suggesting that the measures can be considered conservative. We followed prior research in constructing the final activity measures in MIDUS (Cotter & Lachman, 2010). For moderate activity, we first used the highest score among measures of activity at work, home, or leisure during summer and repeated this step for winter. This way, we could account for the possibility that the primary domain of activity may differ across people. The summer and winter scores were then averaged. The steps were repeated for vigorous activity, and the highest score for either moderate or vigorous activity was taken as the final measure. Moderate and vigorous activity measures were strongly correlated at the baseline ($r = 0.62$, 95% CI = [0.603, 0.642]).

Main Covariates Following prior studies that reviewed the correlates and determinants of physical activity (Bauman et al., 2012; Sallis et al., 2016), we included the most consistent predictors of activity as covariates: age, gender (= 1 if female), education, baseline levels of activity, and health factors of BMI and chronic disease. Prior studies have linked these factors to sense of purpose in life, too (e.g., Kim et al., 2013; Ryff, 1989; Springer et al., 2011). Education was measured by years of education in HRS (0 to 17) and by the highest degree obtained in MIDUS (1 = no school or some grade school, 12 = JD, or another professional degree). BMI was constructed using self-reported height and weight in both datasets. Following prior research (Kim et al., 2017), chronic conditions were measured with a dummy variable that equaled one if people reported having at least one of the chronic conditions (i.e., diabetes, cancer, heart disease) in both datasets. We used baseline values of the time-varying covariates, age, BMI, and chronic disease and provided robustness checks with time-updated covariates (see Table S2).

Additional Demographic Covariates In robustness checks, we included other, less-consistent correlates of activity and sense of purpose in life (Bauman et al., 2012; Sallis et al., 2016): i) race (dummy-coded as White or not), ii) marital status (dummy-coded), iii) baseline values of household income (total wages and government transfers for all household members), and iv) baseline work

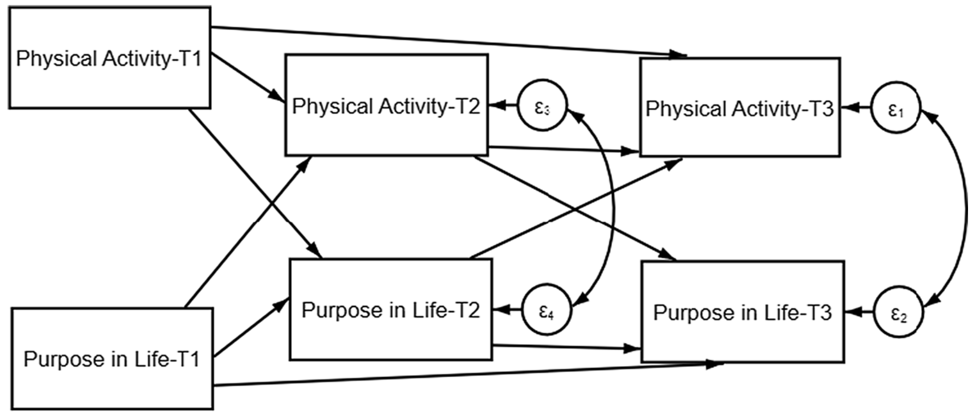

Fig. 1 Cross-lagged path models examining the relationship between sense of purpose in life and physical activity

status. Since retirement was found to be linked to both physical activity (Kämpfen & Maurer, 2016) and sense of purpose in life (Hill & Weston, 2017), we also controlled for being retired (vs. working) and being not in labor force (vs. working).

Additional Psycho-Social Covariates In robustness checks, we controlled for perceived health, which was rated on a scale of 1 (poor) to 5 (excellent). This single-item measure was related to objective physical health conditions (Pinquart, 2001) and the multi-item measurement of physical functioning (Mavaddat et al., 2011). Additionally, we controlled for i) positive and negative affect, which are widely accepted measures of psychological well-being (Kahneman, Diener, & Schwartz, 1999), and ii) depression and anxiety, two common indicators of mental distress (Wang, 2000). In including these covariates, our aim was to test whether sense of purpose in life could have a unique predictive relationship with physical activity above and beyond these related measures that have been shown to have a significant relationship with physical activity (McDowell et al., 2019; Schuch et al., 2018; Zhang & Chen, 2019).

Positive affect was measured by frequency of feeling cheerful, in good spirits, etc., in past 30 days on a scale of 1 (none of the time) to 5 (all the time) (7-item in HRS: $\alpha = 0.91$, 11-item in MIDUS: $\alpha = 0.80$). Negative affect referred to feelings such as worthlessness, nervousness, etc. (7-item in HRS: $\alpha = 0.86$, 11-item in MIDUS: $\alpha = 0.86$) (Watson et al., 1988).

Depression questions in HRS overlapped significantly with negative affect items, hence, were not used ($r = 0.85$, 95% CI = [0.848, 0.860]). In MIDUS, depression was measured by the two-week presence of seven symptoms (e.g., loss of interest, feeling more tired than usual) during the past 12 months. In HRS, anxiety was assessed by five items from the Beck Anxiety Inventory, which distinguished anxiety from depression (Beck et al., 1988) ($\alpha = 0.80$). In MIDUS, a ten-item measure of anxiety was used (e.g., restlessness) (Wang et al., 2000). Correlations between these variables are shown in Tables S3 (HRS) and S7 (MIDUS) in the Supplementary Material. We used baseline values of these psycho-social covariates.

Statistical analyses

To study the reciprocal relationship between sense of purpose in life and physical activity in multi-wave data, we tested cross-lagged panel models (CLPM) using structural equation modeling (SEM). As seen in Fig. 1, we modeled sense of purpose in life and physical activity simultaneously and estimated the cross-lagged associations between them. One- and two-period lagged values of the dependent variables were included (see Fig. 1). Correlations between residual error terms of sense of purpose in life and physical activity were modelled to account for the contemporaneous associations between the constructs. Because of its three-wave data, we treated HRS as the primary data in the analyses.

When temporally preceding values of the dependent variable are available and integrated into the model, the potential biases from reverse causality can be partly addressed (VanderWeele et al., 2016). Similarly, such controls can also account for historical factors that predetermine the dependent variable and control the sources of unobserved heterogeneity that could bias the results through this channel. These factors include early life experiences, stable aspects of personality and genetics (Bauman et al., 2012), or physical and social environments (Sallis et al., 2016). Accounting for these effects is specifically important when studying physical activity behaviors since past activity engagement is the strongest predictor of future activity engagement (Bauman et al., 2012; Sallis et al., 2016).

Basic covariates were included in all models (age, gender, education, BMI, chronic disease). Extended covariates were included in robustness checks (ethnicity, marital status, work status, perceived health, positive affect, negative affect, anxiety, depression). We used baseline values of time-varying constructs. In robustness checks, we also used time-updated covariates such that when modeling Time-3 outcomes, we used Time-2 covariates, and when modeling Time-2 outcomes, we used Time-1 covariates (see Table S2).

We were primarily interested in i) the associations between Time-2 sense of purpose in life and Time-3 activity and ii) the associations between Time-2 activity and Time-3 sense of purpose in life. These associations can be considered the most reliable since we could include covariates that temporally precede (Time-1) the predictor. All variables were standardized ($M = 0$, $SD = 1$) in order to estimate standardized effect sizes. Robust standard errors were used in all analyses. The absolute values of skewness and kurtosis (see Table 1) were below the value of three and ten, respectively; thus, there were no significant threats to normality (Kline, 2011). All analyses were implemented in Stata software, version 15.1.

Missing Data. In HRS, 44% of the sample would have been lost if we applied complete-case analysis and excluded those who were not present at all waves. Additionally, 15% would have been lost due to item non-responses that were distributed across variables (10% can be attributed to the measurement of sense of purpose in life at Time 3). In MIDUS, 37% of the sample was lost to follow-up, and an additional 11% were missing due to item non-response. To tackle these sources of missing data, *full information maximum likelihood* was used in all models. This method is preferred for its ability to use all available data for each participant and was found to perform better than other imputation techniques or *complete-case analysis* when handling missing data, especially in longitudinal studies (Enders & Bandalos, 2001; Jelicić et al., 2009). To support the reliability of our methods, we conducted robustness checks using complete-case analysis where we excluded observations with missing data. Our main results remained consistent in this analysis (see Table S2).

Results

Changes over time in sense of purpose in life and physical activity

To better understand the dynamics of how sense of purpose in life and physical activity scores change over time, we first examined mean-level changes in these outcomes in our primary dataset, HRS. On average, sense of purpose in life decreased during the four years from the baseline wave to the first follow-up ($M_{diff} = -0.07$, $SD_{diff} = 0.01$, $t(10{,}280) = -8.96$, $p < 0.001$) and from the second to the third follow-up ($M_{diff} = -0.14$, $SD_{diff} = 0.01$, $t(6{,}991) = -14.64$, $p < 0.001$). Engagement in activity also decreased during the first four years ($M_{diff} = -0.31$, $SD_{diff} = 0.01$, $t(11{,}093) = -23.59$, $p < 0.001$) and the second four years ($M_{diff} = -0.16$, $SD_{diff} = 0.01$, $t(7{,}961) = -11.26$, $p < 0.001$). These decreases were aligned with previous findings that demonstrate a declining trajectory for sense of purpose in life (Springer et al., 2011) and physical activity (Sallis et al., 2016) in older ages.

Cross-lagged panel models of sense of purpose in life and activity in HRS

First, we evaluated the fit of the overall cross-lagged model using several goodness-of-fit indices:i) the Comparative Fit Index (CFI), (2) the Tucker Lewis Index (TLI), (3) the Root Mean Square Error of Approximation (RMSEA).[2] The model is accepted to indicate a good fit when the CFI and TLI values are above 0.95, and when RMSEA is below 0.06 (Hu & Bentler, 1999). For our cross-lagged model, the goodness-of-fit statistics were strongly supportive of model fit: the values were 0.99 for CFI, 0.99 for TLI, and 0.024 (95% CI = [0.011, 0.040]) for RMSEA. Note that excluding two-period lagged values of the dependent variables significantly deteriorated our model fit: CFI was 0.93, TLI was 0.37, and RMSEA was 0.179 (95% CI = [0.169, 0.189]. As a result, both one-period and two-period lagged associations were included in the models as shown in Fig. 1.

The main results are shown in Table 2, which reports the coefficients estimated with CPLM. Supporting our hypotheses, the association between Time-2 sense of purpose in life and Time-3 physical activity was statistically significant and positive ($\beta = 0.08$, 95% $CI = [0.059, 0.101]$, $p < 0.001$). A similar-sized association existed between Time-1 sense of purpose in life and Time-2 physical activity ($\beta = 0.09$, 95% $CI = [0.070, 0.107]$, $p < 0.001$). The size of the associations between Time-1 sense of purpose in life and Time-2 activity did not differ significantly from the associations between Time-2 sense of purpose in life and Time-3 activity ($\beta_{diff} = -0.01$, 95% $CI = [-0.036, 0.020]$, $p = 0.561$).

Looking at the reverse pathway, we found that Time-2 physical activity was also a statistically significant predictor of Time-3 sense of purpose in life ($\beta = 0.06$, 95% $CI = [0.040, 0.080]$, $p < 0.001$). The association between Time-1 physical activity and Time-2 sense of purpose in life was positive and statistically significant ($\beta = 0.06$, 95% $CI = [0.045, 0.081]$, $p < 0.001$). Again, the associations between Time-1 activity and Time-2 sense of purpose in life were not statistically different from the associations between from Time-2 activity and Time-3 sense of purpose in life ($\beta_{diff} = -0.00$, 95% $CI = [-0.030, 0.024]$, $p = 0.825$).

[2] We did not rely on traditional chi^2 statistics ($\chi 2$) since these are most often uninformative when the sample size is large as they easily lead to the rejection of the null hypothesis (Kelloway, 1995).

Table 2 Cross-lagged panel models of sense of purpose in life and physical activity

Purpose in life—> Physical activity			
DV = Physical activity-T3		*DV = Physical activity-T2*	
Purpose in life-T2	0.080***	Purpose in life-T1	0.089***
	[0.059,0.101]		[0.070,0.107]
Physical activity-T2	0.369***	–	–
	[0.344,0.394]	–	–
Physical activity-T1	0.197***	Physical activity-T1	0.384***
	[0.172,0.223]		[0.365,0.404]
Age	− 0.125***	Age	− 0.130***
	[− 0.149, − 0.101]		[-0.150,-0.110]
Gender	− 0.038***	Gender	− 0.064***
	[− 0.057, − 0.019]		[− 0.080, − 0.047]
Education	0.052***	Education	0.080***
	[0.030,0.074]		[0.061,0.098]
Chronic Disease	− 0.022*	Chronic disease	− 0.021**
	[− 0.039, − 0.005]		[− 0.036,-0.006]
BMI	− 0.056***	BMI	− 0.101***
	[− 0.076, − 0.035]		[− 0.119, − 0.083]
Physical activity—> Purpose in life			
DV = Purpose in Life-T3		*DV = Purpose in Life-T2*	
Physical activity-T2	0.060***	Physical activity-T1	0.063***
	[0.040,0.080]		[0.045,0.081]
Purpose in life-T2	0.435***	-	–
	[0.409,0.461]	-	–
Purpose in life-T1	0.296***	Purpose in life-T1	0.583***
	[0.270,0.322]		[0.565,0.600]
Age	− 0.106***	Age	− 0.098***
	[− 0.128, − 0.084]		[− 0.117, − 0.079]
Gender	0.011	Gender	0.00
	[− 0.007,0.029]		[− 0.015,0.016]
Education	0.085***	Education	0.082***
	[0.063,0.106]		[0.064,0.099]
Chronic Disease	− 0.006	Chronic disease	− 0.013
	[− 0.022,0.010]		[− 0.028,0.002]
BMI	− 0.009	BMI	− 0.002
	[− 0.029,0.010]		[− 0.019,0.015]

Structural equation modelling with robust standard errors and maximum likelihood estimation was used (N = 14, 159). Age, BMI, and chronic disease were measured at Time 1. *$p < .05$, **$p < .01$, ***$p < .001$

We next tested whether the cross-lagged effects differed from one another. Results showed that the association between Time-2 sense of purpose in life and Time-3 activity did not differ significantly from the association between Time-2 activity and Time-3 sense of purpose in life ($\beta_{\text{diff}} =$ 0.02, 95% $CI = [-0.009, 0.049]$, $p = 0.179$).

To aid the interpretation of this association, we recoded activity engagement to reflect days in a month. The response of "hardly ever or never" was coded as 0, "one to three times a month" as 2, "once a week" as 4, "more than once a week" as 10, and "every day" as 30. Based on this coding, each standard deviation unit of increase in sense of purpose in life corresponded to 0.60 days of higher activity in a month. In addition, we also used an *ordered logit model,* which treated the dependent variable (physical activity) as an ordinal variable and estimated the marginal probabilities of being in a higher response category for physical activity engagement (e.g., "Every day" vs. "More than once a week") for each unit of change in sense of purpose in life. The results revealed that for each standard deviation of change in sense purpose in life, the odds of increasing the activity engagement to a higher category was 1.21 greater.

The main estimates were largely similar when we adjusted the model to the extensive set of controls as part of the robustness checks (Table S1). The results were robust i) with survey weights that render the sample representative of the US population, ii) with complete-case analysis, and iii) time-updated covariates (Table S2).

The nine-year follow-up in MIDUS

In MIDUS, the results from the CLPM were largely similar (Table S5). Time-1 sense of purpose in life predicted Time-2 activity ($\beta = 0.10$, 95% CI = [0.058, 0.136], $p < 0.001$). On the reverse pathway, Time-1 physical activity predicted Time-2 sense of purpose in life ($\beta = 0.05$, 95% $CI = [0.015, 0.082]$, $p < 0.001$). The size of the association between sense of purpose in life and subsequent activity levels did not differ from the size of the association between physical activity and subsequent sense of purpose in life ($\beta_{\text{diff}} = 0.05$, 95% CI = [−0.004, 0.101], $p = 0.069$). Adding the extensive set of controls reduced the size of the associations for both sense of purpose in life predicting activity ($\beta = 0.06$, 95% $CI = [0.010, 0.100]$, $p = 0.017$) and activity predicting sense of purpose in life ($\beta = 0.04$, 95% CI = [0.005, 0.071], $p = 0.024$) although the associations remained significant (Table S6).

Across datasets, perceived health was positively associated with future levels of both sense of purpose in life and physical activity. BMI and age were negatively associated with future physical activity, while education was positively associated with sense of purpose in life. Among psychosocial covariates, positive affect was a consistent predictor of sense of purpose in life in both datasets, while depression predicted physical activity only in MIDUS.

Discussion

Consistent with the hypotheses, sense of purpose in life predicted greater levels of self-reported engagement in physical activity over four years in a large, representative sample of older adults (HRS). The size of the association was small (between 0.07 and 0.09 standard deviations depending on the model) but remained similar in an independent national dataset (MIDUS) with a nine-year follow-up (0.06 to 0.10 standard deviations). Supporting the generalizability of the results, the datasets used samples with different age profiles ($M_{age} = 68$ in HRS and $M_{age} = 56$ in MIDUS) and employed different measures of activity: leisure time activity in HRS and a more comprehensive measure of activity at work, home (i.e., chores), and leisure time in MIDUS.

The results were also supportive of the second hypothesis and showed that self-reported physical activity levels predicted sense of purpose in life over four years. This association remained consistent in the two datasets that covered different follow-up periods and age profiles. Compared to the opposite pathway from sense of purpose in life to activity, the size of the association from activity to sense of purpose in life was slightly but not significantly lower: 0.05 to 0.06 standard deviations in HRS and 0.04 to 0.05 standard deviations in MIDUS.

It is worth noting that sense of purpose in life was uniquely associated with physical activity while controlling for other measures of psychological well-being (positive and negative affect) and mental illness measures (anxiety and depression). These variables did not show consistent associations with subsequent physical activity. These findings highlight the unique predictive value of sense of purpose in life as an aspect of psychological well-being.

The current research contributes to an emerging body of evidence that highlights sense of purpose in life as a predictor of long-term activity behaviors (Kim et al., 2020). Past research has found a positive link between sense of purpose in life and health outcomes and longevity (e.g., Hill & Turiano, 2014; Kim et al., 2013; Windsor et al., 2015). The current findings suggest that sustained activity could explain why sense of purpose in life may be linked to long-term health and longevity—although other health behaviors such as sleep (Hill et al., 2017; Kim et al., 2014) and biological pathways (Friedman & Ryff, 2012) may also be driving these outcomes. Future studies can explore these mechanisms.

By showing a prospective association between physical activity behaviors and future levels of sense of purpose in life, the findings contribute to two literatures: i) emerging research examining health behaviors as a contributor to sense of purpose in life (Chen et al., 2020), and ii) the more established literature on the well-being benefits of physical activity where most studies have focused on positive feelings (Zhang & Chen, 2019), depression (Schuch et al., 2018), and anxiety (McDowell et al., 2019). The present research suggests that for older adults who tend to experience lower levels of sense of purpose in life (Springer et al., 2011), physical activity may be a positive contributor to this valuable psycho-social resource.

Limitations and future directions

Our findings highlight a prospective, bidirectional relationship between sense of purpose in life and physical activity, a health behavior that is challenging to promote (Rhodes & Brujin, 2013). Because of this, activity promotion may not be an attractive means of cultivating sense of purpose in life. However, the current results can be informative for future efforts to increase physical activity. Studies have reported increases in sense of purpose in life among individuals who participated in a 45-min reflection on life goals (Bundick, 2011), an 8-week positive psychology training (Friedman et al., 2017) and a web-based exercise that guided people to use their personal strengths for two weeks (Forest et al., 2012). Future studies can examine whether such interventions may have impacts on physical activity.

Given that the average effect size observed in physical activity interventions is 0.27 (Rhodes et al., 2017), the associations between sense of purpose in life and physical activity uncovered in this study can be considered small (0.06 to 0.10 standard deviations), suggesting that interventions on sense of purpose in life may have limited impacts on physical activity. However, our study captures long-term effects over four to nine years and among the least active population group, older adults (Sallis et al., 2016), therefore, the current effect sizes could also indicate meaningful improvements in physical activity. Intervention studies with multi-year follow-ups are needed to determine the clinical significance of the findings.

Note that in the present research, the size of the associations between physical activity and some of its most established predictors such as BMI (0.05 to 0.07 standard deviations) or perceived health (0.07 standard deviations) were comparable to the size of the associations between sense of purpose in life and physical activity (0.06 to 0.10 standard deviations), which may support the practical value of the findings.

Despite showing a prospective association between sense of purpose in life and activity behaviors, it was not within the scope of the study to explore the psychological mechanisms that can explain this link. To better understand why sense of purpose in life may contribute to activity participation, future studies can examine the role of i) motivational processes (Ajzen, 1991; Fishbein & Ajzen, 2005) (i.e., individuals with a higher sense of purpose in life having more intentions to stay healthy and/or exercise) or ii) post-motivational processes (Sniehotta et al., 2005) (i.e., individuals with a higher sense of purpose of in life executing activity goals better).

Recent research has highlighted that significant methodological improvements can be made in observational data analysis when multi-wave longitudinal data is present (VanderWeele et al., 2016). The present research employed cross-lagged panel models with an extensive set of controls, employing a rigorous approach to longitudinal analysis. Although this approach helps address reverse causality and important sources of unobserved heterogeneity, it is still possible that an unobserved factor is related to baseline predictors and future changes in the outcomes, thereby creating a bias in the estimates.

Another limitation of our study is the self-report measurement of physical activity. Studies show that physical activity is generally over-estimated in self-reported data (Troiano et al., 2008). However, the physical activity measures in MIDUS were shown to be conservative compared to national statistics (Cotter & Lachman, 2010). Note that as long as misreporting is stable across people, our estimates would remain unbiased, and if misreporting is person-specific but stable over time, our inclusion of baseline physical activity should help to eliminate potential bias due to misreporting. Biases may arise if misreporting of future physical activity is correlated with baseline sense of purpose in life. However, given our model, this would have to occur even as we condition on baseline physical activity, making the misreporting concern less likely.

Conclusion

As life expectancy increases, the proportion of older adults in the population is expected to rise (Medina, Sabo, & Vespa, 2020). However, later stages of life are marked by a more sedentary lifestyle (Sallis et al., 2016) and tend to show declines in certain aspects of psychological well-being, such as sense of purpose in life (Springer et al., 2011). Using rigorous longitudinal methods, the current study finds a positive, reciprocal relationship between two critical outcomes among middle-aged and older adults, sense of purpose in life and physical activity. These findings suggest that sense of purpose in life and physical activity participation may operate as an upward spiral that leads to greater health, well-being, and longevity at later stages of life. Randomized intervention studies can provide causal evidence on this hypothesis to better understand the means of improving the quality and quantity of life among middle-aged and older adults.

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Declarations

Conflict of interest Ayse Yemiscigil and Ivo Vlaev declare that they have no conflict of interest.

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