American Journal of Epidemiology, 2024, 193, 996–1001
https://doi.org/10.1093/aje/kwae001
Advance access publication date February 6, 2024
Original Contribution

Exercise to socialize? Bidirectional relationships between physical activity and loneliness in middle-aged and older American adults

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Abstract

Physical inactivity and loneliness are both associated with health risks and can affect each other through various social and behavioral mechanisms. However, current evidence on this relationship is equivocal and mostly based on cross-sectional data. This longitudinal study aimed to determine whether current levels of physical activity (moderate and vigorous intensity) and loneliness are associated with future respective states of themselves and each other. We used data from waves 6-14 (2002-2018) of the Health and Retirement Study (n = 20 134) in a mixed-effects and random-intercept cross-lagged panel model. Analysis showed that current loneliness and physical activity were associated with each future respective state. Additionally, weekly participation in moderate-intensity, but not vigorous-intensity, physical activity was associated with a lower likelihood of becoming lonely in the future (relative risk [RR] = 0.94; 95% CI, 0.90-0.99). However, changes in physical activity were not associated with deviation from a person's typical level of loneliness (for vigorous intensity, mean deviation [MD] = 0.00; 95% CI: −0.04 to 0.03; for moderate-intensity, MD = 0.01; 95% CI: −0.03 to 0.04). Loneliness was not associated with moderate- or vigorous-intensity physical activity in subsequent waves. This suggests that while lower physical activity levels can be associated with future loneliness, changing levels of physical activity has little impact on loneliness at the individual level.

Key words: physical activity; loneliness; cohort study; middle-aged adults; older adults.

Introduction

Loneliness is a negative emotional state arising from a discrepancy between an individual's expected and actual social relationships.[1] Despite episodic loneliness being a natural part of life, sustained loneliness has been shown to have adverse physical, mental, and behavioral health consequences,[2] including cardiometabolic disease, cognitive impairment, drug use, and higher risk for premature mortality.[3-5] With recent studies identifying the high global prevalence of sustained loneliness,[6] many health professionals advocate for finding solutions to tackle the epidemic of loneliness.[7,8]

Physical activity reduces the risk of noncommunicable diseases[9-11] and can also facilitate interpersonal relationships.[12] Both physical activity and loneliness are important predictors of health, with each having the potential to influence the other. A potential mechanism for the relationship between loneliness and physical activity is related to impaired self-regulation. Loneliness impairs awareness of self-regulatory processes, making individuals less likely to engage in health-promoting behaviors,[13,14] such as having less motivation to participate in physical activity. A systematic review[15] also found that social interactions that occur during physical activity influence an individual's perception of social support and connection. Physical activity can therefore facilitate social interactions through participation in social groups,[16] which present an opportunity to foster a sense of belonging and community membership,[17] potentially reducing rates of loneliness through increased quality or quantity of social connections.

Despite these theorized mechanisms, the temporality, direction, and magnitude of the association between loneliness and physical activity remain unclear. The currently equivocal evidence on physical activity and loneliness mostly comes from cross-sectional studies.[12] The small number of longitudinal studies mostly examined unidirectional relationships only, not considering the potential bidirectional relationship between loneliness and physical activity.[12,18] These studies have identified that loneliness has the potential to negatively influence an individual's motivation and engagement in physical activity, but less evidence

Received: March 19, 2023. **Accepted:** February 1, 2024

has been identified for how physical activity may potentially affect loneliness.[12,18] Although a recent study by Jennen et al.[19] explored the bidirectional relationship between physical activity and loneliness, and found no significant associations between the two, this study focused exclusively on adolescents and young adults, and the data collection period spanned 6 days only.

Older adults are at risk for both loneliness and physical inactivity. Aging is often related to both passive and active pruning of social capital[20] and declines in physical activity levels. If there is indeed a bidirectional relationship between loneliness and physical activity, it may offer opportunities for simultaneously addressing both issues, to improve the physical, mental, and social well-being of older adults.

Using data from a large population cohort of middle-aged and older Americans, the Health and Retirement Study, we aimed to identify: (1) whether current levels of physical activity and loneliness are associated with future respective states at the population level, and (2) whether increased physical activity or loneliness lead to changes for individuals in the following years.

Methods

The reporting of this study follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies. Full details can be found in Table S1 (available at https://doi.org/10.1093/aje/kwae001). We used data from the US Health and Retirement Study (HRS), a nationally representative biennial longitudinal study of adults over the age of 50 years. National representativeness was ensured through stratified, multistage probability design for each cohort, and updated sample weights across each HRS wave.[21] Additional birth cohorts were added to the sample in 1998, 2004, 2010, and 2016 (Figure S1).[22] The HRS collects a wide variety of information, including sociodemographic characteristics, medical history, and current health status. Further details of the HRS have been provided elsewhere.[21] For this study, we used data from waves 6 (2002) to 14 (2018) of the HRS, using sociodemographic data from wave 6 onwards and loneliness and physical activity data from wave 7 (2004) onwards ($n = 20\,134$). We did not use data from earlier waves due to a shift in the physical activity questions. Wave 15 (2020) was also excluded because of a change in the loneliness question. Missing data for each variable across all waves ranged from 37.5% to 50.0%, with 43.0% missing data overall. Refer to Table S2 for more details.

The HRS was approved by the University of Michigan's Institutional Review Board.[22] Participants were provided with study information and notice of confidentiality statements, with verbal consent and written authorization for data linkage purposes (social security information, biomarker and physical measure collection, proxy respondents for vulnerable populations) obtained prior to each interview.[21]

Measures

Physical activity

Physical activity was measured using the question, "How often do you take part in sports or activities that are vigorous/… moderately energetic/… mildly energetic," with examples of activities for each intensity level: eg, running or jogging for vigorous-intensity, walking at a moderate pace or dancing for moderate-intensity, and vacuuming or laundry for light-intensity physical activity. Variations of this frequency-based questionnaire have been widely used in cohort studies on aging.[23] We did not include light-intensity physical activity in our analysis as the activities classified as light-intensity were mainly household chores, providing limited opportunities for social interaction. Provided response categories were frequency options including "Every day," ">1 per week," "1 per week," "1-3 per month," and "Never." We then dichotomized the responses based on the distribution and meaningful interpretation of the data into those who reported at least weekly participation in moderate- or vigorous-intensity physical activity and those who did not.

Loneliness

Loneliness was measured using a single-item measure adapted from the Center for Epidemiological Studies Depression Scale (CES-D)[24]: "Much of the time during the past week… You felt lonely: (1) Yes; (2) No." Although scale measures of loneliness are preferable, single-item measures have been shown to have good content validity[25] and convergent validity with scale measures of loneliness.[26]

Correlates of physical activity and loneliness

We considered a range of sociodemographic characteristics as covariates using Lim et al.'s conceptual model of loneliness[2]: sex (male/female), race/ethnicity (Hispanic, White/Caucasian, Black/African American, other), birth cohort (the Greatest Generation [born 1901-1927], the Silent Generation [born 1928-1945], Baby Boomers [born 1946-1964]), educational level (less than high school, high school/General Educational Development certificate, some college, college or higher), employment status (working, retired, unemployed), marital status (married/partnered, single/divorced/separated, widowed), birthplace (United States, outside the United States), and religion (religious, not religious). We also included the CES-D scale score (all items except for the loneliness question), body mass index (BMI, calculated as the person's weight in kilograms divided by their height in meters squared, used as a continuous variable), living alone, and having living children. Finally, we included the following participant health information as covariates as they are likely to potentially affect physical activity and loneliness: high blood pressure, cancer, lung disease, heart problems, stroke, psychological problems, and arthritis.

Analysis

We limited our analysis to participants without existing functional limitations that would inhibit their ability to be physically active, based on their reported difficulties with "getting out of bed" or "walking across the room" based on the Activities of Daily Living Scale adopted by the HRS.[27]

We first calculated unweighted, descriptive statistics of the sample, presented as numbers and percentages across a range of sociodemographic variables. To assess overall associations at the population level, we fitted a series of random-intercept mixed-effects models, one for each of the 3 outcomes, with the outcome at time $t + 1$ regressed on loneliness and physical activity at time t. These models were conducted using robust Poisson mixed models to estimate relative risk (RR) and their 95% CIs (Appendix S1).

We then examined the mix of stable and changing parts of loneliness and physical activity, considering each individual's average loneliness/physical activity over the course of the study (ie, their "trait" loneliness/physical activity), and examining whether changing their observed loneliness/physical activity in a given wave (ie, change in "state") was associated with deviation from that average. We did this using a 3-way random intercept cross-lagged panel model (RI-CLPM)[28] between

loneliness, vigorous-intensity physical activity, and moderate-intensity physical activity, with 3 correlated latent variables for each variable (Appendix S1). Because the target estimand was the average association between each measure at time t and time $t + 1$, coefficients were constrained to be constant across waves. However, the relationship between the observed and latent variables was allowed to vary (Figures S2 and S3). Results of the RI-CLPM are reported as mean deviation (MD) and their 95% CIs.

Both the random-intercept mixed models and RI-CLPM models controlled for time-varying (ie, CES-D score sans loneliness item, BMI, employment status, marital status, living alone, having living children, high blood pressure, cancer, lung disease, heart problems, stroke, psychological problems, and arthritis) and time-constant (ie, sex, race/ethnicity, birth cohort, education, religion, birthplace) confounding. To reduce the risk of bias due to attrition and incomplete responses, all analyses were conducted using multiple imputation, using M = 50 imputations to be conservative (Appendix S2).[29] All models controlled for the sampling unit and stratum from the complex sample design. There is no evidence of multicollinearity in our analysis (Table S3). We conducted all analyses using Stata, version 17.0,[30] and R, version 4.2.1.[31] Mixed model results are reported as RRs while RI-CLPM results are reported as MDs, that is, how much each person deviates from their overall "mean" due to changes in the exposure.

Results

At wave 6 (2002; n = 20 134), the unweighted sample included 56.4% female participants, with the majority born in the United States (83.1%). Participants were predominantly White/Caucasian (61.7%), married/partnered (68.9%), and of the Baby Boomer generation (born 1946-1964) (61.9%). Approximately half were working (49.4%), with 44.2% retired and 6.4% unemployed. Detailed unweighted sociodemographic characteristics are provided in Table 1.

Table 1. Sample baseline characteristics of the participants in this study, Health and Retirement Study Wave 6, United States, 2002.

	n = 20 134	
	No.	%
Sex		
Male	8780	43.6
Female	11 354	56.4
Race/ethnicity		
White/Caucasian	12 423	61.7
Black/African American	3761	18.7
Hispanic	2964	14.7
Other	986	4.9
Birth cohort		
Greatest Generation (1901-1927)	689	3.7
Silent Generation (1928-1945)	6398	34.4
Baby Boomers (1946-1964)	11 496	61.9
Education		
Less than high school	2912	14.5
High school graduate/GED	6503	32.3
Some college	5336	26.5
College and above	5383	26.7
Employment status		
Working	5924	49.4
Retired	5291	44.2
Unemployed	769	6.4
Marital status		
Married/partnered	8352	68.9
Single/divorced/separated	2124	17.5
Widowed	1645	13.6
Born in United States		
Yes	16 728	83.1
No	3406	16.9
Religious		
Yes	17 773	88.3
No	2361	11.7

Abbreviation: GED, General Educational Development test.

Random-intercept generalized linear mixed model

Figure 1 identifies that participants who reported loneliness at time t were twice as likely to continue experiencing loneliness at the time ($t + 1$) (RR = 2.04; 95% CI, 1.89-2.20) compared with those who were not lonely at time t. Participants who reported at least weekly participation in vigorous-intensity physical activity at time t were 68% more likely to report at least weekly participation in vigorous-intensity physical activity at $t + 1$ (95% CI, 1.64-1.72) and 10% more likely to report at least weekly participation in moderate-intensity physical activity (95% CI, 1.09-1.12) at $t + 1$. Similarly, those who participated in moderate-intensity physical activity at t were 28% more likely to continue to participate in moderate-intensity physical activity (95% CI, 1.26-1.29), and they were 19% more likely to participate in vigorous-intensity physical activity at $t + 1$ (95% CI, 1.16-1.22). Conversely, participation in moderate-intensity physical activity at t was also associated with a 6% decrease in the likelihood of experiencing future loneliness at $t + 1$ (95% CI, 0.90-0.99).

Random-intercept cross-lagged panel model

Similar to the mixed-effects model, Figure 2 demonstrates that when controlling for loneliness across the course of all waves, being lonely at time t is associated with a higher deviation in the probability of being lonely at time $t + 1$ than would otherwise be expected for that person (MD = 0.06; 95% CI, 0.002-0.11). Individuals who participated in vigorous-intensity physical activity also had a higher probability of reporting at least weekly participation in vigorous-intensity physical activity (MD = 0.11; 95% CI, 0.07-0.15) and moderate-intensity physical activity (MD = 0.16; 95% CI, 0.13-0.19) in the future than expected for that individual. Those who participated in moderate-intensity physical activity were also more likely to participate in physical activity of moderate (MD = 0.08; 95% CI, 0.04-0.11) and vigorous intensity (MD = 0.16; 95% CI, 0.12, 0.20) than would normally be expected in the future. In contrast to the random-intercept generalized linear mixed model, in the random-intercept cross-legged panel model, there were no significant relationships between loneliness and subsequent levels of physical activity and vice versa.

Discussion

To our knowledge, this is one of the largest studies of its kind to examine the bidirectional relationships between loneliness and intensity-specific physical activity, and the first study to examine the bidirectional relationship in the middle-aged or older adult population. While considering an individual's long-term pattern of loneliness, we found that despite the loneliness and physical activity remaining relatively stable over time, those who participated in higher levels of moderate-intensity physical activity are less likely to be lonely 2 years later, but they will not deviate away from their expected loneliness status. This suggests that while moderate activity is associated with lower population-level risk of

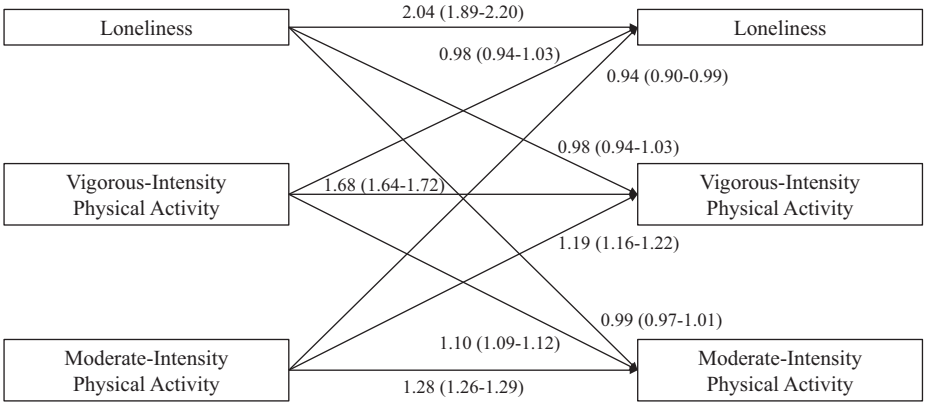

Figure 1. Results from the fully adjusting random-intercept generalized linear mixed model, using data from the Health and Retirement Study, United States, 2002-2018. Results reported as risk ratios (95% confidence intervals), estimated from 3 random-intercept, robust Poisson generalized linear mixed models. Models controlled for depression, body mass index, living alone, having living children, employment status, marital status, high blood pressure, cancer, lung disease, heart problems, stroke, psychological problems, and arthritis.

loneliness, it has little impact at the individual level, with those lonelier over time likely to remain so even if they increase their levels of physical activity. This finding suggests that although moderate-intensity physical activity was found to be associated with future loneliness, we have no evidence to conclude that loneliness could be reduced simply through improving physical activity and vice versa.

Several observational, particularly cross-sectional studies on the relationship between physical activity and loneliness found an inverse association. A systematic review[12] reported that despite the potential for using physical activity as a means to reduce loneliness, the quality of social relationships within these physical activity settings was found to be a potential moderator or mediator of this effect. Therefore, not all physical activities are the same in terms of their potential effects on promoting social well-being and reducing loneliness. Thus, not being able to consistently capture the potentially diverse social context of physical activity may have contributed to the equivocal findings in the current literature. In our study we only found moderate-intensity physical activity to be associated with future loneliness state. This may be because activities typically captured as vigorous-intensity physical activity, at least in terms of the examples provided (eg, running, swimming, cycling), may be more "solo" in nature, as compared with moderate-intensity physical activity (eg, walking and dancing), which may include more opportunities for social interactions. This implies that, as expected, when it comes to fostering social connections, the context of physical activity may matter more than the activities themselves.

Contrary to our findings, other studies have identified associations between loneliness and physical activity.[32,33] However, these studies, unlike ours, used a different estimation method that does not account for the stability of the constructs. Although McMullan et al.[32] found walking to be prospectively associated with lower rates of loneliness, this reduction was only true for loneliness measured by the UCLA Loneliness Scale and not for direct self-reported measures ("how often do you feel lonely?"). Our study only used a direct single-item question, finding no associations for the most part, which was consistent with McMullan's findings. These different findings according to loneliness measures are not unexpected as scale measures are inherently more sensitive when it comes to capturing variation. Luo and Waite[33] found bidirectional relationships between loneliness and physical activity, identifying significant negative associations across 3 waves of the Chinese Longitudinal Healthy Longevity Survey. However, this study recorded physical activity using a single dichotomous question regarding whether or not individuals regularly participated in exercise (physical activity performed during leisure time for the purpose of health and fitness), rather than the broader construct of physical activity, as captured in the HRS. In addition to different measures, different cultural contexts may have also contributed to the observed differences between our studies.

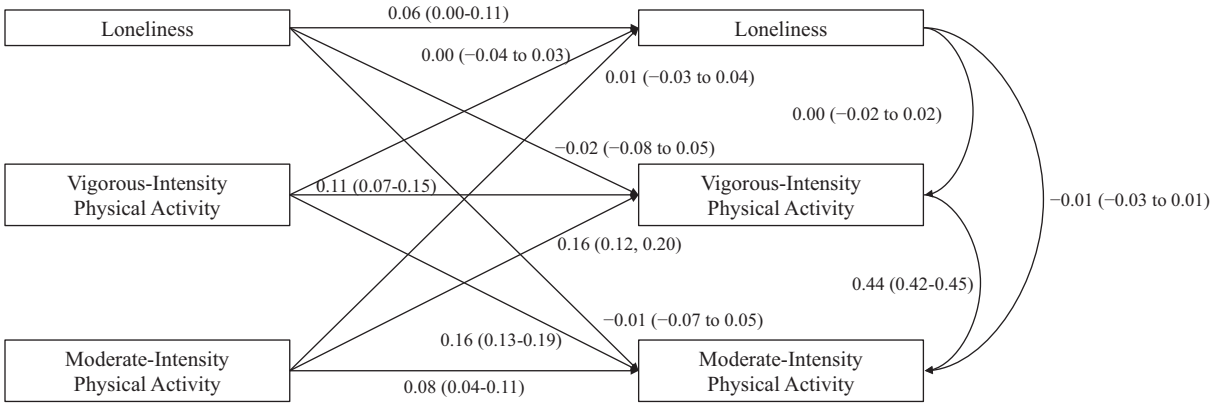

Figure 2. Results from the fully adjusting random-intercept cross-lagged panel model (RI-CLPM), using data from the Health and Retirement Study, United States, 2002-2018. Results reported as mean differences (95% confidence intervals), estimated from RI-CLPM models. Model controls for depression, body mass index, living alone, having living children, employment status, marital status, high blood pressure, cancer, lung disease, heart problems, stroke, psychological problems, and arthritis.

Taking our findings together with the existing literature, it appeared that the association between physical activity and loneliness remained equivocal and it is likely to depend on the measures of physical activity and loneliness, the analytical techniques (eg, whether or not long-term stability of loneliness or physical activity was accounted for), and possibly the social and cultural context. In fact, a meta-analysis of randomized controlled trials[34] of physical activity interventions on loneliness found a lack of effects overall, while some specific studies, such as a quasi-experimental study using group exercises as an intervention to alleviate loneliness,[35] found promising supportive evidence. Kahlbaugh et al.[36] also emphasized the importance of shared social experiences, noting that shared mutual interests towards an activity play an important role in determining overall satisfaction and effect on loneliness, in comparison with simply doing an activity together with no shared enjoyment. Overall, these studies suggest that while the heterogeneous literature base from either observational or interventional studies could not provide solid evidence on whether physical activity interventions could be harnessed for reducing loneliness, specific components, such as social experiences and the context of physical activity, may be critical.

Strengths and limitations

A major strength of our study is that we examined bidirectional longitudinal associations for 20 134 middle-aged or older adults across 16 years, making this the largest study of its kind. We also used 2 models testing average associations across the population at a point in time and average associations within individuals over time. Testing 2 types of models adds robustness, with the potential to observe causality. The HRS also utilizes a large population-representative sample after weighting. Therefore, our analysis was well-powered with good external validity.

This study has several limitations. First, typical for large cohort studies, physical activity measures are self-reported and based on frequency only, which could potentially introduce response bias. However, there is evidence to show that self-reports of physical activity intensity do have strong associations with more objective measures for moderate- and vigorous-intensity physical activity,[37] and one may expect that the reporting bias remains similar within individuals over time. Furthermore, the physical activity questionnaire from the HRS does not capture types or relevant social context of physical activity. Second, loneliness was measured using a single-item question, which may lead to social desirability bias related to the stigma and negative connotations associated with the term "lonely." Furthermore, using a dichotomized response category for loneliness (yes/no) may potentially introduce bias through the oversimplification of a complex experience. However, there is no evidence that such bias is differential across participants with different levels of physical activity. Third, the HRS also shifts the interview mode every second wave (phone vs face-to-face), which could potentially introduce response bias as a result of interviewer and social desirability bias. However, a previous study on the HRS found no differences in reported loneliness between the phone and face-to-face based interviews, as both were interviewer-administered.[38] Fourth, due to the temporary nature of episodic loneliness and the biennial frequency of the HRS surveys, it is not possible to identify whether there were changes in loneliness state within the 2 years between waves (eg, an individual starting off as lonely, becoming not lonely, and then becoming lonely again within the 2 years). Finally, residual confounding is still likely due to unmeasured or insufficiently measured confounders.

Conclusion

The findings of this study indicate that low participation in physical activity may be associated with future loneliness, but loneliness is not associated with physical activity participation. Furthermore, current loneliness does not relate to future participation in physical activity when the long-term stability of loneliness is taken into account. Therefore, it is not possible to conclude whether physical inactivity or loneliness interventions can be used as a means of treating the other. Despite this, loneliness and physical activity are associated with each future respective state, indicating the habitual nature of both exposures. Future research should consider using a scale measure of loneliness and better capturing the social context of physical activity. Physical inactivity and loneliness remain important dual public health issues; however, more evidence is needed to harness the potential relationships between the two to promote active and social connected lifestyles.

Supplementary material

Supplementary material is available at *American Journal of Epidemiology* online.

Funding

None declared.

Conflict of interest

The authors declare no conflicts of interest.

Data availability

This study used data from the Health and Retirement Study. Publicly available data products can be obtained through the Health and Retirement Study Data Portal (https://hrsdata.isr.umich.edu/).

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