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# Social Activity Diversity as a Lifestyle Factor to Alleviate Loneliness and Chronic Pain

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## Abstract

**Objective:** This study examined whether social activity diversity, a novel concept indicating an active social lifestyle, is associated with lower subsequent loneliness, and decreased loneliness is further associated with less chronic pain over time.

**Methods:** 2,528 adults from the Midlife in the United States Study ($M_{age}$=54yrs) provided data at baseline (2004–2009) and 9 years later. Social activity diversity was operationalized by Shannon's entropy that captures the variety and evenness of engagement across 13 social activities (0–1). Participants reported feelings of loneliness (1–5), presence of any chronic pain (yes/no), the degree of chronic pain-related interference (0–10), and the number of chronic pain locations. Indirect associations of social activity diversity with chronic pain through loneliness were evaluated, adjusting for sociodemographics, living alone, and chronic conditions.

**Results:** Higher social activity diversity at baseline (*B*=−0.21, *95%CI*=[−0.41, −0.02]) and an increase in social activity diversity over time (*B*=−0.24, *95%CI*=[−0.42, −0.06]) were associated with lower loneliness 9 years later. An increase in loneliness was associated with 24% higher risk of any chronic pain (*95%CI*=[1.11, 1.38]), greater chronic pain-related interference (*B*=0.36, *95%CI*=[0.14, 0.58]), and 17% increase in the number of chronic pain locations (*95%CI*=[1.10, 1.25]) at the follow-up, after controlling for corresponding chronic pain at baseline and covariates. Social activity diversity was not directly was associated with chronic pain, but there were indirect associations through its association with loneliness.

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Declarations of interest

None.

**Conclusion:** Diversity in social life may be associated with decreased loneliness, which in turn, may be associated with less chronic pain, two of the prevalent concerns in adulthood.

### Keywords

Active lifestyles; activity diversity; social activities; social isolation; pain; loneliness

## Introduction

There is under-recognized evidence that chronic pain is affected by adverse social experiences. Social isolation—defined as being objectively detached from society [1] and loneliness—defined as unpleasant subjective experience that occurs when a person's social relationships are deficient or unsatisfying [2] are two of the negative social experiences important for health. Neuroimaging research has demonstrated that experiences of social isolation predominantly activate the dorsal anterior cingulate cortex and anterior insula—regions known to have a role in the distressing experience of chronic pain [3]. Experiences of loneliness also activate these chronic pain related neural regions [4,5]. There is a shared mechanism between loneliness and chronic pain, yet it is still unknown whether and how to cut the vicious cycle between loneliness and chronic pain. For example, is there an association between lifestyle and loneliness that may then impact chronic pain? To answer this question, we determined whether a novel concept of social activity diversity is associated with lower loneliness and thereby lower chronic pain. Social activity diversity is defined as broad and even engagement across a range of social activities, encompassing social meetings, volunteering at different places, and interactions and exchange of emotional support with multiple social partners. This concept captures diversity in social events, social places, and social partners. Previous work has shown the importance of diversity in daily activities in mental, emotional, and cognitive functioning [6–8]. Building on this work, the goal of this study was to examine whether social activity diversity is associated with loneliness over time, and whether change in loneliness is associated with subsequent chronic pain.

### Social Activity Diversity as a Means to Decrease Loneliness

According to the social integration of health theory [9–12], engagement in a variety of social roles and activities provides broader opportunities to build psychosocial resources, which helps maintain overall health and well-being. Our concept of social activity diversity is particularly relevant to test the possible impact of positive social life on health and well-being, because it captures the variety and evenness of social activities, both of which can add more nuances. The following example illustrates this concept: Person A engaged in six different social activities out of a possible list of seven (higher variety); among the six, three activities occurred only once, one occurred every day, and the remaining two occurred two times a week (lower evenness). In contrast, Person B engaged in six different social activities (higher variety) and all the activities occurred three times a week (higher evenness). In this example, Person B has a higher social activity diversity than Person A, because the activities are inclusive and equally distributed across days. While previous research has focused on the importance of variety, there has been less attention to evenness. Evenness conveys additional information that each of the engaged

activities is not random (e.g., occurring just once) but deliberately chosen by the individual (e.g., occurring in similar frequency with other activities). There is growing evidence that shows the importance of diversity in daily activities in psychological well-being, cognitive functioning, larger hippocampal volume, and rich and balanced emotional experiences [6–8,13]. Furthermore, variety in social activities is found to be more important for cognitive function than variety in cognitive (e.g., reading books, using a computer) or physical (e.g., brisk walking, exercise) activities [14]. A hypothesized mechanism whereby social activity is more important for health than other domains of activities (e.g., cognitive or physical) is through its buffering effect on stress and negative emotions.

While social isolation has been associated with incidence of chronic pain and chronic pain-related interference [15,16], we know little about whether a positive aspect of social life, social activity diversity, is associated with less chronic pain. Social activity diversity may relate to social isolation, but it has its own unique features as well. For example, individuals who live alone may still be able to extend their social activities with friends, neighbors, and family members. Some people may also choose to narrow their social activities, and for these people, limited social activities may not necessarily degrade their health, such as increasing chronic pain. In this sense, there is a lack of rationale to expect that social activity diversity is directly associated with chronic pain. We need additional mechanism that may link social activity diversity to chronic pain.

## Loneliness as a Mechanism Linking Social Activity Diversity and Chronic Pain

The social integration of health theory [9–12] suggests that the health benefit of social activity diversity may be conveyed through increased psychosocial resources, such as increased social network and getting more social support, which may buffer emotional stress and contribute to lowering feelings of loneliness. Loneliness is closely related to chronic pain. While most evidence is based on cross-sectional data, few existing studies show bidirectional relationships. Specifically, more feelings of loneliness increase the odds of subsequently reporting chronic pain [17,18] or are predicted by baseline chronic pain [18]. We posit that the expected negative association of loneliness with chronic pain may weaken by social activity diversity. For example, individuals who engage in social activities with greater diversity may have opportunities to meet multiple social partners and thus may feel less lonely. This psychosocial experience may be associated with perceiving less chronic pain.

Considering the mechanism of loneliness is important, because objective (e.g., living alone, small social network size, a lack of social activities) and subjective (e.g., loneliness, quality of social network) aspects of social life often do not agree with each other and can have differential effects on health. For example, prior research suggests that subjective loneliness and network quality best predict mental health; contrarily, network size and living alone best predict physical and cognitive health [19]. In a study examining chronic pain, subjective loneliness was higher but objective social isolation (assessing marital/cohabitating status and contacts with children and family members) was lower in those with musculoskeletal pain [20]. When both loneliness and objective social isolation (living alone) were examined as independent predictors of mortality, the effect size of loneliness was higher than that

of living alone [21]. This latter study suggests that loneliness may provide additional information on the potential impact of social life on health. Extending this idea, the health benefit of social activity diversity may manifest only when accompanying decreased feelings of loneliness. This motivates us to examine the indirect association of social activity diversity with chronic pain through feelings of loneliness.

### Present Study

The current study had three specific aims. First, we tested the longitudinal relationship between social activity diversity and loneliness. Studies often use single measures of social activity (e.g., volunteering), lacking comprehensive understanding of contribution of other social activities. We created a novel measure of social activity diversity that captured both the variety and evenness of engagement across multiple social activities. We hypothesized that higher social activity diversity at baseline and an increase in social activity diversity over time would be associated with less feelings of loneliness at a follow-up after adjusting for baseline loneliness (H1). While those with higher social activity diversity at baseline may not have room to further improve (i.e., ceiling effect), there may be some individuals who change from lower diversity to higher diversity. Specifically, persons whose social activity diversity increases over time may represent a selected group which behaves differently than an age-related stereotype, because previous studies report age-related decrease in activity diversity in general [6,22]. Second, we tested whether an increase in loneliness over time would be associated with more chronic pain at a follow-up after adjusting for baseline levels of loneliness and corresponding chronic pain outcome (H2). Third, integrating the three variables together, we hypothesized that higher social activity diversity at baseline and an increase in social activity diversity over time would be indirectly associated with less chronic pain at a follow-up via a decrease in feelings of loneliness (H3).

## Methods

### Participants and Procedure

Data for the current study were drawn from the Midlife in the United States Study (MIDUS). Comprehensive details of the design and sample can be found elsewhere [23]. This study used the MIDUS core and Milwaukee samples collected between 2004 and 2006 (M2) and approximately 9 years later between 2013 and 2015 (M3). MIDUS II Milwaukee (MIL) was conducted for the purposes of enhancing the racial diversity by enriching the sample with African American participants. During the M2 phase, 4,963 individuals completed the main survey. Out of 4963 individuals who participated in M2, 931 individuals did not complete self-administered questionnaire (SAQ) that included questions on social activities and chronic pain. In MIL, all 592 participants completed the SAQ. Combining M2 and MIL, 4,633 people provided SAQ data. There were missing data on loneliness ($n = 56$), any chronic pain ($n = 89$), race ($n = 5$), and education ($n = 6$). As the percentage with missing data was small (3%), we used complete cases in our analyses. Further, 293 participants who did not provide data on any activities were excluded; we imputed missingness in social activities to zero if they provided valid responses to other activities. Among 4,184 participants who provided complete data at M2, 2,528 participants were reassessed at M3,

consisting of our final analytic sample. Those who provided longitudinal data ($n = 2,528$) were younger, female, more educated, had fewer chronic conditions, and reported lower feelings of loneliness, greater social activity diversity, lower likelihood of any chronic pain, lower pain interference, and fewer pain locations, compared to those who dropped out ($n = 1,656$). However, the two groups did not differ in race.

The MIDUS study protocol was approved by the University of Wisconsin-Madison Institutional Review Board (IRB). Written informed consent was received for all MIDUS participants. The current study was exempt from an IRB review due to our use of publicly available, de-identifiable data.

## Measures

**Social activity diversity—**Social activities were measured by 13 items across three domains - attending meetings, volunteer work, and giving emotional support to social partners. For attending meetings, participants were asked three questions to indicate how many times per month they spent in meetings with three different types of groups (i.e., unions or other professional groups, sports groups, and any other social groups). We considered each incident frequency as an hour-long meeting to approximate hours spent in attending meetings. For volunteer work, four questions asked how many hours per month they spent doing volunteer work at four different places (i.e., healthcare related, school related, political organizations, and any other volunteer work). For giving emotional support, six questions asked about how many hours they spent giving emotional support such as giving advice to different groups of people (i.e., spouse or partner, parents, in-laws, children or grandchildren, other family members or close friends, and anyone else). Hours spent in these 13 activities were related to each other but internal consistency was not very high ($\alpha = .61$ and .48 at M2 and M3, respectively), indicating that each provided relevant and unique information about one's social life. We created social activity diversity using Shannon's (1948) entropy, which captures both the number (variety) and proportion (evenness) of activity engagement. The frequency of each activity type was measured in hours. The sum and proportion of each activity type was calculated for each participant. The formula for calculating social activity diversity is expressed as:

$$Social\ Activity\ Diversity_i = -\left(\frac{1}{\ln(m)}\right)\sum_{j=1}^{m} p_{ij}\ln p_{ij}$$

where $m = 13$ is the number of social activities, and $p_{ij}$ is the proportion of individual $i$'s reported frequency of each activity type to their total activity frequency, $j = 1$ to $m$. Social activity diversity scores could range from 0 to 1 and higher scores indicated greater diversity.

**Loneliness—**We used one item asking, "During the past 30 days, how much of the time did you feel lonely?" Responses were initially coded as 1 (all the time) to 5 (none of the time). We reverse coded the item such that higher scores represent more frequency of loneliness. This loneliness measure resembles an item included in the Center for Epidemiological Studies Depression Scale (CES-D). Similar single-item loneliness measurements have been shown in previous studies to be sensitive [24] and to correlate

well with UCLA Loneliness Scale [25]. This measure has been used in previous studies and has demonstrated internal validity predicting mortality [21,26]. We treated loneliness as continuous, following a simulation study that shows the appropriateness of Likert data with parametric approaches especially with larger samples [27]. In our data, loneliness had a relatively normal distribution (skewness < 2, kurtosis < 3). We also conducted supplemental analyses with a dichotomous loneliness variable (some of the time/most of the time/all the time vs. none of the time/a little of the time).

**Chronic pain—**We assessed the presence of any chronic pain, chronic pain-related interference, and the number of chronic pain locations. First, the presence of any chronic pain was measured by asking, "Do you have chronic pain, that is do you have pain that persists beyond the time of normal healing and has lasted from anywhere from a few months to many years? Responses were coded yes (= 1) or no (= 0). If participants responded yes, then we administered a 5-item version of the Brief Pain Inventory scale [28], a reliable and valid instrument used to assess chronic pain-related interference [29]. Participants reported the degree to which their chronic pain interfered with (1) general activity, (2) mood, (3) relations, (4) sleep, and (5) enjoyment. For example, the item asking chronic pain-related pain interference with general activity read, "On a scale of 0 (did not interfere) to 10 (completely interfered), circle the number below that best describes how much, during the past week, your chronic pain interfered with your general activity." We used the mean of the five items ($\alpha$=.91 and .92 at M2 and M3, respectively). Chronic pain-related interference was not measured in M2 MIL due to data collection error. Lastly, the number of chronic pain locations was measured by nine items: (1) head, (2) neck, (3) back, (4) arms/hands, (5) legs/feet, (6) shoulders, (7) hips, (8) knees, and (9) other (specify). Responses to each item were coded as yes (= 1) or no (= 0). We calculated the sum of the nine items to indicate the number of chronic pain locations.

## Statistical Analysis

We used descriptive statistics to examine sample characteristics and correlations between the variables. To test H1 (social activity diversity → loneliness) and H2 (loneliness → chronic pain), we used multiple regression models in SAS v.9.4. In our analyses, M2 served as baseline and M3 served as follow-up assessment. Each chronic pain outcome (i.e., any chronic pain, chronic pain-related pain interference, and the number of chronic pain locations) was modeled separately. PROC LOGISTIC was used for the binary outcome of any chronic pain. PROC GLM was used for the continuous variable of chronic pain-related interference. PROC GENMOD (with Poisson distribution) was used for the count outcome of the number of chronic pain locations. To test H3 (social activity diversity → loneliness → chronic pain), we used SAS PROCESS macro that can test the indirect association of social activity diversity with chronic pain through loneliness based on the bootstrapping method [30]. In all models, we set the number of bootstrap samples to 10,000. The bootstrapping method produces a bias-corrected confidence interval for the indirect association. A significant indirect effect was assumed if bootstrap 95% confidence intervals (CI) for the indirect path did not include zero. A significant indirect effect indicates a significant mediation by loneliness.

All models adjusted for baseline levels of corresponding chronic pain outcome and standard sociodemographic characteristics, including age (in years), sex (0=*female*, 1=*male*), race (0=*non-White*, 1=*White*), and education (1=*no school/some grade school* to 12=*Ph.D. or other professional degree*). We also adjusted for living alone condition (0=*having at least one household member living with the respondent*, 1=*having no household member living with the respondent*). Lastly, to rule out health-related confounds, we adjusted for the number of chronic conditions (sum of 30 conditions experienced or been treated in the past 12 months, including depression, joint/bone diseases, and diabetes), as was done in previous studies [22,31].

## Results

Table 1 shows sample characteristics at baseline and correlations among the variables at baseline and at the 9-year follow-up. Appendix Table 1 shows the results of difference tests comparing the levels of social activity diversity, loneliness, and chronic pain variables between baseline and the follow-up.

### Social Activity Diversity and Loneliness

Table 2 shows the longitudinal association of social activity diversity with loneliness. Social activity diversity at baseline and change in social activity diversity over time were associated with loneliness at the 9-year follow-up. That is, those who had higher social activity diversity at baseline (*B*=−0.21, *95% CI*=[−0.41, −0.02]; see Figure 1) and those who increased social activity over time (*B*=−0.24, *95% CI*=[−0.42, −0.06]) had lower feelings of loneliness 9 years later. These associations persisted after controlling for baseline levels of loneliness, sociodemographic characteristics including living alone, and chronic conditions. Thus, H1 that higher social activity diversity at baseline and an increase in social activity diversity over time would be associated with more feelings of loneliness at a follow-up was fully supported.

### Loneliness and Chronic Pain

Table 3 shows longitudinal association of loneliness with three chronic pain outcomes. Change in loneliness was positively associated with all three chronic pain outcomes at the follow-up, adjusting for baseline levels of loneliness and corresponding chronic pain outcome. Beginning with any chronic pain, individuals who increased loneliness (*Exp(B)*=1.24, *95% CI*=[1.11, 1.38]) had a 24% higher risk of having any chronic pain 9 years later. Similarly, among those with any chronic pain, those who increased loneliness (*B*=0.36, *95% CI*=[0.14, 0.58]) exhibited greater chronic pain-related interference 9 years later. Lastly, the number of chronic pain locations was also predicted by loneliness. Specifically, one unit increase in loneliness over time (*Exp(B)*=1.17, *95% CI*=[1.10, 1.25]) was associated with a 17% increase in the number of chronic pain locations 9 years later. Figure 2 shows the associations between increase in loneliness and chronic pain outcomes at the follow-up. Again, all these associations remained significant after controlling for sociodemographic characteristics, living alone, and chronic conditions. Thus, H2 that an increase in loneliness over time would be associated with more chronic pain at a follow-up was also fully supported.

### Indirect Associations of Social Activity Diversity with Chronic Pain through Loneliness

In our data, social activity diversity was not directly associated with any of the chronic pain outcomes before or after considering loneliness (Appendix Table 2). However, there was evidence that social activity diversity was indirectly associated with chronic pain through change in loneliness. Appendix Table 3 shows the summary of results testing these indirect associations. When any chronic pain was the outcome, individuals who had higher social activity diversity at baseline had decreased feelings of loneliness, and decreased loneliness was further associated with a lower risk of having any chronic pain at the 9-year follow-up (*Indirect effect*=−0.04, *Boot SE*=0.03, *Boot 95% CI*=[−0.11, −0.01]). Moreover, individuals who increased social activity diversity over the 9 years exhibited a decrease in feelings of loneliness, and decreased loneliness was associated with a lower risk of having any chronic pain at the follow-up (*Indirect effect*=−0.05, *Boot SE*=0.03, *Boot 95% CI*=[−0.12, −0.01]). For chronic pain-related interference and the number of chronic pain locations, the indirect paths were only significant for those who increased social activity diversity over time. Specifically, individuals who increased social activity diversity had decreased feelings of loneliness, and decreased loneliness was associated with lower chronic pain-related interference (*Indirect effect*=−0.18, *Boot SE*=0.12, *Boot 95% CI*=[−0.51, −0.01]) and fewer chronic pain locations (*Indirect effect*=−0.05, *Boot SE*=0.02, *Boot 95% CI*=[−0.11, −0.01]) 9 years later. Thus, H3 that higher social activity diversity at baseline and an increase in social activity diversity over time would be indirectly associated with less chronic pain at a follow-up via a decrease in feelings of loneliness was partially supported.

### Supplemental Analyses

Although our focus is to examine whether and how social activity diversity is related to chronic pain, it is also possible that chronic pain may limit one's resources and ability to engage in diverse social activities. Thus, we also explored this reverse directionality. Neither baseline nor change in chronic pain was associated with subsequent social activity diversity. However, our results supported the reverse indirect pathway through increased feelings of loneliness (Appendix Table 4). Compared to those who did not have chronic pain at both times, those who developed new chronic pain at follow-up reported increased feelings of loneliness over 9 years. Further, those who increased the number of chronic pain locations reported increased feelings of loneliness. Increased loneliness was then associated with lower social activity diversity at the follow-up.

We further conducted sensitivity analyses treating loneliness as a dichotomous variable. Fourteen percent of the participants who responded feeling lonely "some of the time", "most of the time", or "all the time" were coded as 1, and the rest who responded feeling lonely "none of the time" or "a little of the time" were coded as 0. These results were consistent with the main results (Appendix Tables 5 and 6). Lastly, we additionally controlled for participant's total annual income (including wage, pension, and social security income), given that income may be related to social activity diversity and loneliness. Although 88 participants did not provide income data (n=2,440), results generally remained consistent (Appendix Tables 7 and 8).

## Discussion

This study shows that “diversity” in social activities is indirectly associated with less chronic pain through lower feelings of loneliness. While most studies have focused on negative aspects of social life (e.g., social isolation), the current study shows how a positive aspect of social life has potential to alleviate loneliness and chronic pain, which are two of the most significant public health concerns [32–34]. Overall, findings from this study support the social integration of health theory [9–12] by showing the health benefit of social activity diversity by decreasing feelings of loneliness and indirectly decreasing chronic pain. To the best of our knowledge, this is one of the first studies that tested longitudinal associations between social activity diversity, loneliness, and chronic pain.

Previous studies have reported that a lack of social activities is associated with poor health [21,26,35–40]. Another line of literature has shown that engaging in leisure or physical activities is associated with a lower risk of chronic pain [41,42]. Linking these two lines of literature with the social integration of health theory, the current study asked a novel question: whether “diversity” in social activities matters for chronic pain. Our results showed that higher social activity diversity at baseline and an increase in social activity diversity over time were associated with lower feelings of loneliness at a follow-up. Decreased feelings of loneliness over time, in turn, were associated with less chronic pain outcomes at a follow-up. Social activity diversity was not significantly and directly associated with subsequent chronic pain. However, an increase in social activity diversity was indirectly associated with less chronic pain at a follow-up through decreased feelings of loneliness. While our data with only two time points cannot fully determine the temporal order between these variables, our findings suggest that loneliness is a critical mechanism whereby social activity diversity is associated with chronic pain. In other words, if someone engaged in social activities with greater diversity but it did not involve decreased feelings of loneliness, then it may mean that the diverse social activities were not voluntarily sought by the individual and thus did not link to decrease chronic pain. These findings add to the literature considering subjective and objective aspects of social life [19–21] by showing how feelings of loneliness provide additional information on the potential indirect benefit of social activity diversity in decreasing chronic pain.

Note also that the indirect pathways linking social activity diversity and chronic pain were mostly supported when examining change in social activity diversity. These results signify a possibility of a behavioral intervention designed to increase diversity in social activities to improve health, especially to alleviate loneliness and chronic pain. For example, an intervention that assigns participating older adults to novel social activities (e.g., physical activity groups, volunteer opportunities) and helps them to expand their social activity repertoire may increase social activity diversity and bring health benefits. There are existing programs that promote volunteering in older adults and show the efficacy of the programs in improving health, like Experience Corps [43,44]. We need to test the impact of additional behavioral intervention programs to promote diversity in social activities, considering preferences of today’s older adults.

Overall, our results indicate the utility of our new measure of social activity diversity, by showing its direct association with loneliness and indirect associations with multiple chronic pain outcomes. Importantly, the associations were independent of living alone, chronic conditions, as well as sociodemographic differences. Taken together, findings suggest that those with greater social activity diversity tend to feel less lonely, and these people experience less chronic pain. These findings suggest that an active social life may have indirect benefits in alleviating chronic pain [3,45], by lowering feelings of loneliness.

## Limitations and Future Directions

There are several strengths of this study, including its focus on a positive aspect of social life, use of multiple chronic pain outcomes, consideration of loneliness as a mechanism, and longitudinal analyses in a large sample of US adults. However, there are also limitations in this study that may be overcome in future studies. First, our measure of social activity diversity was less than ideal. Although the 13 activities used in this study captured three key domains of adult social lives - attending meetings, volunteer work, and giving emotional support to family, friends, and others, they did not represent all possible social activities. There may be differences in participant ability to precisely report the frequency of their engagement in the activities (e.g., social meeting vs. providing emotional support). We also did not take into account potential overlaps in the activities (e.g., providing emotional support during volunteer work). Future studies may want to use a more extensive list of social activities, minimizing potential response bias and considering overlaps in the engaged activities. Second, we used one item measure of loneliness, thus were unable to capture the multidimensional nature of loneliness (e.g., emotional, social). Although this item has been widely used in previous studies [21,26], future research could use a validated loneliness scale that includes multiple items. Third, the MIDUS sample was relatively healthy, highly educated, and included a small percentage of racial minorities. Future research could examine whether findings from this study are replicated in a more diverse (and chronic pain-prone) sample of adults, considering potential differences in social activity engagement and the meaning of loneliness across racial/ethnic groups [46,47] and examining specific chronic pain types (e.g., back pain, knee pain, etc.). It may also be important to examine the relationships in non-US samples, because individualism moderates the relationship between loneliness and health outcomes, with the smallest effects being observed in the most individualistic countries like US [48]. Fourth, we used only two time points as our main variables were only assessed in M2 and M3. Future research may want to use three or more time points to fully examine the mediation pathways. Lastly, this study used observational data, thus a causal inference cannot be drawn.

## Conclusion

This study shows the potential, indirect benefit of an active social life in alleviating chronic pain through lowering feelings of loneliness. Social activity diversity may be associated with less chronic pain by providing broader opportunities to build psychosocial resources and thus by lowering loneliness. Given that social activities tend to decrease with advancing age, future studies are warranted to test whether a community-based activity intervention can reduce loneliness and chronic pain in late adulthood. Such interventions may need to incorporate various and new social activities that today’s older adults may enjoy, considering

recent lifestyle changes, technology development, and differences by sex, race/ethnicity, and education levels.

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Data and documentation for all MIDUS projects are available to other researchers at the Inter-university Consortium for Political and Social Research (ICPSR). In addition to the publicly-available data at ICPSR, a MIDUS-Colectica Portal (midus.colectica.org) contains rich searchable metadata, links to helpful documentation, and the ability to download customized datasets. Analytic methods specific to the current study are available upon request from the corresponding author. The current study was not preregistered with an analysis plan in an independent, institutional registry.

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## Appendix Table 1.: Results of difference tests comparing the levels of main variables between baseline and the 9-year follow-up

| | Baseline | | | Follow-up | | | Difference Tests | |
|---|---|---|---|---|---|---|---|---|
| | *M or %* | *SD* | *Range* | *M or %* | *SD* | *Range* | *T-test or* $\chi^2$ | *P-value* |
| Social activity diversity | 0.48 | 0.19 | 0–0.98 | 0.45 | 0.20 | 0–0.88 | 7.13 | <.001 |
| Loneliness | 1.50 | 0.81 | 1–5 | 1.51 | 0.86 | 1–5 | −0.60 | 0.546 |
| Having any chronic pain (vs. no) | 34% | | | 38% | | | 7.93 | 0.005 |
| Chronic pain-related interference[1] | 2.94 | 2.37 | 0–10 | 3.41 | 2.71 | 0–10 | −3.85 | <.001 |
| Number of chronic pain locations | 0.86 | 1.55 | 0–9 | 1.01 | 1.68 | 0–9 | −3.29 | 0.001 |

*Notes.* $n$=2,528.

[1]Those who had any chronic pain at baseline ($n$=776) and at the follow-up ($n$=458) answered questions on pain interference. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error.

## Appendix Table 2.: Results of the longitudinal associations of social activity diversity with chronic pain outcomes before or after considering loneliness

| | Risk of any chronic pain at follow-up | | | Chronic pain-related interference at follow-up | | | | The number of chronic pain locations at followup | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Exp(B)* | *P-value* | *95% CI* | *B* | *SE* | *P-value* | 95% CI | *Exp(B)* | *P-value* | 95% CI |
| **Before Controlling for Loneliness (Baseline and Change)** | | | | | | | | | | |
| Social activity diversity at baseline | 1.08 | 0.801 | [0.61, 1.89] | −0.88 | 0.70 | 0.209 | [−2.5, 0.49] | 1.08 | 0.582 | [0.83, 1.39] |
| Social activity diversity at baseline | 0.92 | 0.744 | [0.55, 1.54] | −0.58 | 0.61 | 0.338 | [−1.78, 0.61] | 1.03 | 0.828 | [0.81, 1.29] |
| **After Controlling for Loneliness (Baseline and Change)** | | | | | | | | | | |
| Social activity diversity at baseline | 1.21 | 0.511 | [0.68, 2.15] | −0.74 | 0.70 | 0.289 | [−2.11, 0.63] | 1.10 | 0.461 | [0.85, 1.43] |
| Change in social activity diversity | 0.99 | 0.978 | [0.59, 1.67] | −0.34 | 0.61 | 0.576 | [−1.53, 0.85] | 1.09 | 0.468 | [0.86, 1.38] |

*Note*. $n$=2,528; $n$ = 458 were used in the model for pain interference who had any chronic pain at both time points. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error; $n$=2,491 were used in the model for the number of chronic pain locations due to missing responses. The models controlled for baseline levels of corresponding chronic pain outcome and all covariates.

## Appendix Table 3.: Results of the indirect associations of social activity diversity with chronic pain outcomes through change in loneliness

| Indirect paths | *Indirect Effect* | *Boot SE* | *Boot 95% CI* |
|---|---|---|---|
| Social activity diversity at baseline → Any chronic pain at follow-up | −0.04 | 0.03 | [−0.11, −0.01] |
| Change in social activity diversity → Any chronic pain at follow-up | −0.05 | 0.03 | [−0.12, −0.01] |
| Social activity diversity at baseline → Chronic pain-related interference at follow-up | −0.03 | 0.11 | [−0.29, 0.17] |
| Change in social activity diversity → Chronic pain-related interference at follow-up | −0.18 | 0.12 | [−0.51, −0.01] |
| Social activity diversity at baseline → Number of chronic pain locations at follow-up | −0.04 | 0.02 | [−0.11, −0.01] |
| Change in social activity diversity → Number of chronic pain locations at follow-up | −0.05 | 0.02 | [−0.11, −0.01] |

*Note*. $n$=2,528; $n$=458 were used in the model for pain interference who had any chronic pain at both time points; $n$=2,491 were used in the model for the number of pain locations due to missing responses. Grey highlights indicate significant indirect paths. All models adjusted for sociodemographic characteristics (i.e., age, sex, race, and education), living alone, chronic conditions, and baseline levels of loneliness and corresponding chronic pain outcome.

## Appendix Table 4.: Results of the indirect associations of chronic pain with social activity diversity through change in loneliness

| Indirect paths | *Indirect Effect* | *Boot SE* | *Boot 95% CI* |
|---|---|---|---|
| Having any chronic pain at baseline → Social activity diversity at follow-up | −0.001 | 0.001 | [−0.002, −0.0000] |
| No pain to any chronic pain (vs. no pain throughout) → Social activity diversity at follow-up | −0.001 | 0.001 | [−0.003, −0.0002] |
| Chronic pain-related interference at baseline → Social activity diversity at follow-up | −0.001 | 0.001 | [−0.002, 0.0002] |
| Change in chronic pain-related interference → Social activity diversity at follow-up | −0.001 | 0.001 | [−0.003, −0.0000] |
| Number of chronic pain locations at baseline → Social activity diversity at follow-up | 0.0003 | 0.0002 | [−0.001, −0.0000] |
| Change in the number of chronic pain locations → Social activity diversity at follow-up | −0.001 | 0.0003 | [−0.002, −0.0002] |

*Note*. $n$=2,528; $n$=458 were used in the model for chronic pain-related interference who had any chronic pain at both time points; $n$=2,491 were used in the model for the number of chronic pain locations due to missing responses. Grey highlights indicate significant indirect paths. All models adjusted for sociodemographic characteristics (i.e., age, sex, race, and education), living alone, chronic conditions, and baseline levels of loneliness and corresponding chronic pain outcome.

## Appendix Table 5.: Results of the longitudinal association of social activity diversity with feeling lonely[1]

| | **Feeling Lonely at follow-up** | | |
|---|---|---|---|
| | ***Exp(B)*** | ***P-value*** | ***95% CI*** |
| Intercept | 10.63 | <.001 | [7.72, 14.63] |
| **Social activity diversity at baseline** | **3.42** | **0.002** | **[1.56, 7.48]** |
| **Change in social activity diversity** | **2.85** | **0.003** | **[1.42, 5.72]** |
| Feeling Lonely at baseline | 0.17 | <.001 | [0.13, 0.23] |
| Age (in years) | 1.02 | 0.011 | [1, 1.03] |
| Men (vs. Women) | 0.94 | 0.655 | [0.73, 1.22] |
| Non-Hispanic white (vs. non-whites) | 0.94 | 0.709 | [0.69, 1.29] |
| Education | 1.03 | 0.343 | [0.97, 1.08] |
| Living alone (vs. no) | 0.87 | 0.580 | [0.53, 1.44] |
| Number of chronic conditions | 0.87 | <.001 | [0.84, 0.92] |
| *Model fit statistics* | $2LL$ = 1790.88<br>$\chi^2$ = 267.77, $p$ < .001 | | |

*Note*. $n$=2,528. The main variables of interest are bolded.

[1] Loneliness was dichotomized, such that feeling lonely some of the time, a little of the time, and all the time were coded as 1 and feeling lonely a little of the time and none of the time were coded as 0.

## Appendix Table 6.: Results of the longitudinal associations of feeling lonely[1] with chronic pain outcomes

| | Risk of any chronic pain at follow-up | | | Chronic pain-related interference at follow-up | | | | The number of chronic pain locations at follow-up | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Exp(B)* | *P-value* | *95% CI* | *B* | *SE* | *P-value* | 95% CI | *Exp(B)* | *P-value* | 95% CI |
| Intercept | 0.33 | <.001 | [0.26, 0.41] | 2.85 | 0.42 | <.001 | [2.03, 3.67] | 0.89 | 0.025 | [0.81, 0.99] |
| Feeling Lonely at baseline | 1.16 | 0.313 | [0.87, 1.55] | 0.18 | 0.29 | 0.540 | [−0.39, 0.75] | 1.04 | 0.482 | [0.93, 1.16] |
| **Feeling lonely at follow-up** | **1.42** | **0.009** | **[1.09, 1.85]** | **0.67** | **0.26** | **0.010** | **[0.16, 1.17]** | **1.41** | **<.001** | **[1.27, 1.55]** |
| Corresponding chronic pain at baseline | 3.39 | <.001 | [2.81, 4.08] | 0.43 | 0.05 | <.001 | [0.34, 0.52] | 1.26 | <.001 | [1.24, 1.29] |
| Age (in years) | 1.00 | 0.347 | [0.99, 1] | 0.02 | 0.01 | 0.034 | [−0.04, −0.002] | 1.00 | 0.529 | [0.99, 1] |
| Men (vs. Women) | 1.06 | 0.547 | [0.88, 1.27] | 0.26 | 0.21 | 0.222 | [−0.68, 0.16] | 1.00 | 0.953 | [0.92, 1.09] |
| Non-Hispanic white (vs. nonwhites) | 1.11 | 0.405 | [0.87, 1.41] | 0.27 | 0.41 | 0.511 | [−0.54, 1.07] | 0.84 | 0.001 | [0.76, 0.93] |
| Education | 0.99 | 0.433 | [0.95, 1.02] | 0.08 | 0.04 | 0.059 | [−0.16, 0.003] | 0.96 | <.001 | [0.95, 0.98] |
| Living alone (vs. no) | 0.70 | 0.088 | [0.46, 1.06] | 0.08 | 0.51 | 0.874 | [−1.09, 0.93] | 0.97 | 0.711 | [0.8, 1.16] |
| Number of chronic conditions | 1.20 | <.001 | [1.15, 1.26] | 0.14 | 0.04 | 0.001 | [0.06, 0.22] | 1.08 | <.001 | [1.07, 1.1] |
| *Model fit statistics* | $2LL = 2956.45$ $\chi^2 = 394.48$, $p < .001$ | | | $R^2 = 0.34$ $F = 26.03$, $p < .001$ | | | | $LL = -1823.59$ $\chi^2 = 5101.26$, $p < .001$ | | |

*Note*. $n$=2,528; $n$ = 458 were used in the model for pain interference who had any chronic pain at both time points. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error; $n$=2,491 were used in the model for the number of chronic pain locations due to missing responses. The main variable of interest is bolded.

[1] Loneliness was dichotomized, such that feeling lonely some of the time, a little of the time, and all the time were coded as 1 and feeling lonely a little of the time and none of the time were coded as 0.

## Appendix Table 7.: Results of the longitudinal association of social activity diversity with loneliness, additionally controlling for income

| | Loneliness at follow-up | | | |
|---|---|---|---|---|
| | *B* | *SE* | *P-value* | 95% CI |
| Intercept | 1.44 | 0.04 | <.001 | [1.36, 1.52] |
| **Social activity diversity at baseline** | **−0.20** | **0.10** | **0.052** | **[−0.39, 0,002]** |
| **Change in social activity diversity** | **−0.23** | **0.09** | **0.013** | **[−0.41, −0.05]** |
| Loneliness at baseline | 0.42 | 0.02 | <.001 | [0.38, 0.46] |
| Age (in years) | 0.00 | 0.00 | 0.032 | [−0.006, 0] |
| Men (vs. Women) | 0.05 | 0.03 | 0.103 | [−0.01, 0.12] |

| | Loneliness at follow-up | | | |
|---|---|---|---|---|
| | ***B*** | ***SE*** | ***P-value*** | **95% CI** |
| Non-Hispanic white (vs. non-whites) | 0.05 | 0.04 | 0.216 | [−0.03, 0.13] |
| Education | −0.003 | 0.01 | 0.638 | [−0.02, 0.01] |
| Income[1] | −0.000001 | 0.0000004 | 0.006 | [−0.000002, −0.0000003] |
| Living alone (vs. no) | 0.02 | 0.07 | 0.727 | [−0.11, 0.16] |
| Number of chronic conditions | 0.04 | 0.01 | <.001 | [0.03, 0.06] |
| *Model fit statistics* | | | $R^2 = 0.22$<br>$F = 68.16$, $p < .001$ | |

*Note*. $n$=2,528; $n$=2,440 were used in the analysis due to missing values in income data. The main variables of interest are bolded.

[1] Income was measured by asking, "Please fill in the letter representing the amount of pre-tax income you earned in the last calendar year for (1) personal earning income, (2) pension income, and (3) social security income." Responses were coded as original dollar values. We summed up responses to the three items to reflect the respondent's total annual income.

## Appendix Table 8.: Results of the longitudinal associations of loneliness with chronic pain outcomes, additionally controlling for income

| | Risk of any chronic pain at follow-up | | | Chronic pain-related interference at follow-up | | | | The number of chronic pain locations at follow-up | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***Exp(B)*** | ***P-value*** | ***95% CI*** | ***B*** | ***SE*** | ***P-value*** | **95% CI** | ***Exp(B)*** | ***P-value*** | **95% CI** |
| Intercept | 0.35 | <.001 | [0.27, 0.44] | 2.93 | 0.41 | <.001 | [2.11, 3.74] | 0.93 | 0.145 | [0.84, 1.03] |
| Loneliness at baseline | 1.25 | 0.001 | [1.1, 1.43] | 0.36 | 0.14 | 0.013 | [0.08, 0.64] | 1.14 | <.001 | [1.08, 1.2] |
| **Change in loneliness** | **1.22** | **0.001** | **[1.09, 1.37]** | **0.33** | **0.12** | **0.004** | **[0.11, 0.56]** | **1.16** | **<.001** | **[1.11, 1.22]** |
| Corresponding chronic pain at baseline | 3.47 | <.001 | [2.87, 4.19] | 0.42 | 0.05 | <.001 | [0.33, 0.52] | 1.25 | <.001 | [1.23, 1.28] |
| Age (in years) | 1.00 | 0.224 | [0.99, 1] | 0.02 | 0.01 | 0.031 | [−0.04, −0.002] | 1.00 | 0.243 | [0.99, 1] |
| Men (vs. Women) | 1.08 | 0.443 | [0.89, 1.31] | 0.22 | 0.23 | 0.324 | [−0.67, 0.22] | 1.02 | 0.593 | [0.94, 1.12] |
| Non-Hispanic white (vs. nonwhites) | 1.08 | 0.519 | [0.85, 1.38] | 0.29 | 0.41 | 0.478 | [−0.52, 1.11] | 0.84 | 0.001 | [0.76, 0.93] |
| Education | 0.99 | 0.688 | [0.95, 1.03] | 0.08 | 0.05 | 0.079 | [−0.17, 0.009] | 0.97 | <.001 | [0.95, 0.98] |
| Income[1] | 1.00 | 0.459 | [1, 1] | −0.000002 | 0.000003 | 0.548 | [−0.000008, 0.000004] | 1.00 | 0.067 | [1, 1] |
| Living alone (vs. no) | 0.66 | 0.051 | [0.43, 1] | −0.06 | 0.55 | 0.916 | [−1.14, 1.02] | 0.93 | 0.462 | [0.77, 1.13] |
| Number of chronic conditions | 1.21 | <.001 | [1.15, 1.27] | 0.13 | 0.04 | 0.002 | [0.05, 0.22] | 1.09 | 0.145 | [1.07, 1.11] |
| *Model fit statistics* | $2LL = 2827.84$<br>$\chi^2 = 402.62$, $p < .001$ | | | $R^2 = 0.34$<br>$F = 22.54$, $p < .001$ | | | | $LL = -1753.58$<br>$\chi^2 = 4878.44$, $p < .001$ | | |

*Note*. $n$=2,528; $n$ = 458 were used in the model for pain interference who had any chronic pain at both time points. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error; $n$=2,491 were used in the model for the number of chronic pain locations due to missing responses. The main variable of interest is bolded.

[1] Income was measured by asking, "Please fill in the letter representing the amount of pre-tax income you earned in the last calendar year for (1) personal earning income, (2) pension income, and (3) social security income." Responses were coded as original dollar values. We summed up responses to the three items to reflect the respondent's total annual income.

## References


[1]. Huisman M, van Tilburg TG, Social exclusion and social isolation in later life, Handb. Aging Soc. Sci (2021) 99–114. 10.1016/B978-0-12-815970-5.00007-3.

[2]. Peplau L, Perlman D, Perspectives on loneliness, in: Peplau L, Perlman D (Eds.), Loneliness A Sourceb. Curr. Theory, Res. Ther, John Wiley and Sons, New York, 1982.

[3]. Eisenberger NI, The pain of social disconnection: Examining the shared neural underpinnings of physical and social pain, Nat. Rev. Neurosci 13 (2012) 421–434. 10.1038/nrn3231. [PubMed: 22551663]

[4]. Ferris LJ, Jetten J, Hornsey MJ, Bastian B, Feeling Hurt: Revisiting the Relationship Between Social and Physical Pain, Rev. Gen. Psychol 23 (2019) 320–335. 10.1177/1089268019857936.

[5]. Eisenberger NI, Social pain and the brain: Controversies, questions, and where to go from here, Annu. Rev. Psychol 66 (2015) 601–629. 10.1146/annurev-psych-010213-115146. [PubMed: 25251482]

[6]. Lee S, Koffer RE, Sprague BN, Charles ST, Ram N, Almeida DM, Activity diversity and its associations with psychological well-being across adulthood, Journals Gerontol. Ser. B 73 (2018) 985–995. 10.1093/geronb/gbw118.

[7]. Lee S, Urban-Wojcik EJ, Charles ST, Almeida DM, Rich and balanced experiences of daily emotions are associated with activity diversity across adulthood, Journals Gerontol. Ser. B (2021). 10.1093/GERONB/GBAB144.

[8]. Lee S, Charles ST, Almeida DM, Change is good for the brain: activity diversity and cognitive functioning across adulthood, J. Gerontol. Psychol. Sci 76 (2021) 1036–1048. 10.1093/geronb/gbaa020.

[9]. Berkman LF, Glass T, Brissette I, Seeman TE, From social integration to health: Durkheim in the new millennium, Soc. Sci. Med 51 (2000) 843–857. 10.1016/S0277-9536(00)00065-4. [PubMed: 10972429]

[10]. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand S-LT, Walters EE, Zaslavsky AM, Short screening scales to monitor population prevalences and trends in non-specific psychological distress, Psychol. Med 32 (2002) 959–976. DOI: 10.1017/S0033291702006074. [PubMed: 12214795]

[11]. Pillemer K, Moen P, Glasgow N, Wethington E, Social integration in the second half of life, Johns Hopkins University Press, Baltimore, MD, 2010.

[12]. Cohen S, Lemay EP, Why would social networks be linked to affect and health practices?, Heal. Psychol 26 (2007) 410–417. 10.1037/0278-6133.26.4.410.

[13]. Urban-Wojcik EJ, Lee S, Grupe DW, Quinlan L, Gresham L, Hammond A, Charles ST, Lachman ME, Almeida DM, Davidson RJ, Schaefer SM, Diversity of daily activities is associated with greater hippocampal volume, Cogn. Affect. Behav. Neurosci 22 (2022) 75–87. 10.3758/S13415-021-00942-5/TABLES/3. [PubMed: 34599488]

[14]. Jeon S, Lee S, Charles ST, Not just how much, but how many: Overall and domain-specific activity variety and cognitive functioning in adulthood, J. Gerontol. Psychol. Sci 77 (2022) 1229–1239. 10.1093/geronb/gbac053.

[15]. Karayannis NV, Baumann I, Sturgeon JA, Melloh M, Mackey SC, The impact of social isolation on pain interference: a longitudinal study, Ann. Behav. Med 53 (2019) 65–74. 10.1093/abm/kay017. [PubMed: 29668841]

[16]. Yamada K, Wakaizumi K, Kubota Y, Murayama H, Tabuchi T, Loneliness, social isolation, and pain following the COVID-19 outbreak: data from a nationwide internet survey in Japan, Sci. Rep 11 (2021) 18643. 10.1038/s41598-021-97136-3. [PubMed: 34545110]

[17]. Powell VD, Kumar MBBS N, Galecki AT, Kabeto MM, Clauw DJ, Williams DA, Hassett PsyD A, Silveira MJ, Victoria Powell CD, Bad company: Loneliness longitudinally predicts the symptom cluster of pain, fatigue, and depression in older adults, J. Am. Geriatr. Soc (2022). 10.1111/JGS.17796.

[18]. Loeffler A, Steptoe A, Bidirectional longitudinal associations between loneliness and pain, and the role of inflammation, Pain 162 (2021) 930. 10.1097/J.PAIN.0000000000002082. [PubMed: 32960533]

[19]. Beller J, Wagner A, Disentangling loneliness: Differential effects of subjective loneliness, network quality, network size, and living alone on physical, mental, and cognitive Health, J. Aging Health 30 (2018) 521–539. 10.1177/0898264316685843. [PubMed: 28553795]

[20]. Smith TO, Dainty JR, Williamson E, Martin KR, Association between musculoskeletal pain with social isolation and loneliness: analysis of the English Longitudinal Study of Ageing., Br. J. Pain 13 (2019) 82–90. 10.1177/2049463718802868. [PubMed: 31019689]

[21]. Teguo MT, Simo-Tabue N, Stoykova R, Meillon C, Cogne M, Amiéva H, Dartigues JF, Feelings of loneliness and living alone as predictors of mortality in the elderly: The PAQUID Study, Psychosom. Med 78 (2016) 904–909. 10.1097/PSY.0000000000000386. [PubMed: 27583712]

[22]. Lee S, Koffer R, Drewelies J, Adults older than age 55 engage in less diverse activities than those 18 years ago, Journals Gerontol. Ser. B (2023) gbad047. 10.1093/geronb/gbad047.

[23]. Ryff CD, Krueger RF, Approaching human health as an integrative challenge: Introduction and overview, Oxford University Press, New York, 2018. 10.1093/oxfordhb/9780190676384.001.0001.

[24]. Shiovitz-Ezra S, Ayalon L, Use of Direct Versus Indirect Approaches to Measure Loneliness in Later Life, 10.1177/0164027511423258. 34 (2011) 572–591. 10.1177/0164027511423258.

[25]. Ong AD, Uchino BN, Wethington E, Loneliness and Health in Older Adults: A Mini-Review and Synthesis, Gerontology 62 (2016) 443–449. 10.1159/000441651. [PubMed: 26539997]

[26]. Yu B, Steptoe A, Chen LJ, Chen YH, Lin CH, Ku PW, Social isolation, loneliness, and all-cause mortality in patients with cardiovascular disease: A 10-year follow-up study, Psychosom. Med 82 (2020) 208–214. 10.1097/PSY.0000000000000777. [PubMed: 31842061]

[27]. DeWees TA, Mazza GL, Golafshar MA, Dueck AC, Investigation Into the Effects of Using Normal Distribution Theory Methodology for Likert Scale Patient-Reported Outcome Data From Varying Underlying Distributions Including Floor/Ceiling Effects, Value Heal 23 (2020) 625–631. 10.1016/J.JVAL.2020.01.007.

[28]. Cleeland CS, Ryan K, The brief pain inventory, Pain Res. Gr 20 (1991) 143–147.

[29]. Raichle KA, Osborne TL, Jensen MP, Cardenas D, The reliability and validity of pain interference measures in persons with spinal cord injury, J. Pain 7 (2006) 179–186. 10.1016/j.jpain.2005.10.007. [PubMed: 16516823]

[30]. Hayes AF, Introduction to mediation, moderation, and conditional process analysis: A regression-based approach, Second edi, The Guilford Press, New York, NY, 2017.

[31]. Urban-Wojcik EJ, Mumford JA, Almeida DM, Lachman ME, Ryff CD, Davidson RJ, Schaefer SM, Emodiversity, health, and well-being in the Midlife in the United States (MIDUS) daily diary study, Emotion 22 (2022) 603–615. 10.1037/emo0000753. [PubMed: 32271048]

[32]. Domenichiello AF, Ramsden CE, The silent epidemic of chronic pain in older adults, Prog. Neuro-Psychopharmacology Biol. Psychiatry 93 (2019) 284–290. 10.1016/J.PNPBP.2019.04.006.

[33]. Cacioppo S, Capitanio JP, Cacioppo JT, Toward a neurology of loneliness, Psychol. Bull 140 (2014) 1464–1504. 10.1037/a0037618. [PubMed: 25222636]

[34]. Dahlhamer JM, Lucas J, Zelaya C, Nahin R, Mackey S, Debar L, Kerns R, Von Korff M, Porter L, Helmick C, Prevalence of chronic pain and high-impact chronic pain among adults — United States, 2016, Morb. Mortal. Wkly. Rep 67 (2018) 1001–1006. 10.15585/mmwr.mm6736a2.

[35]. Berkman LF, Syme SL, Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents, Am. J. Epidemiol 109 (1979) 186–204. 10.1093/oxfordjournals.aje.a112674. [PubMed: 425958]

[36]. Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D, Loneliness and social isolation as risk factors for mortality: a meta-analytic review, Perspect. Psychol. Sci 10 (2015) 227–237. 10.1177/1745691614568352. [PubMed: 25910392]

[37]. House JS, Landis KR, Umberson D, Social relationships and health, Science (80-. ) 241 (1988) 540 LP – 545. 10.1126/science.3399889.

[38]. Cohen S, Brissette I, Skoner D, Doyle W, Social integration and health: The case of the common cold, J. Soc. Struct 1 (2000) 1–7.

[39]. Pressman SD, Cohen S, Barkin A, Miller GE, Rabin BS, Treanor JJ, Loneliness, social network size, and immune response to influenza vaccination in college freshmen, Heal. Psychol 24 (2005) 297–306. 10.1037/0278-6133.24.3.297.

[40]. Fingerman KL, Ng YT, Huo M, Birditt KS, Charles ST, Zarit S, Functional limitations, social integration, and daily activities in late life, Journals Gerontol. Ser. B 76 (2021) 1937–1947. 10.1093/geronb/gbab014.

[41]. Micheletti JK, Bláfoss R, Sundstrup E, Bay H, Pastre CM, Andersen LL, Association between lifestyle and musculoskeletal pain: Cross-sectional study among 10,000 adults from the general working population, BMC Musculoskelet. Disord 20 (2019) 1–8. 10.1186/S12891-019-3002-5/TABLES/2. [PubMed: 30611236]

[42]. Shiri R, Lallukka T, Rahkonen O, Leino-Arjas P, Excess body mass and leisure time physical activity in the incidence and persistence of chronic pain, Pain Med 21 (2020) 3094–3101. 10.1093/PM/PNAA102. [PubMed: 32374375]

[43]. Rebok GW, Carlson MC, Barron JS, Frick KD, McGill S, Parisi JM, Seeman T, Tan EJ, Tanner EK, Willging PR, Fried LP, Experience Corps®: A civic engagement-based public health intervention in the public schools, in: Hartman-Stein PE, La Rue A (Eds.), Enhancing Cogn. Fit. Adults A Guid. to Use Dev. Community-Based Programs, Springer, New York, 2011: pp. 469–487. 10.1007/978-1-4419-0636-6_27.

[44]. Varma VR, Tan EJ, Gross AL, Harris G, Romani W, Fried LP, Rebok GW, Carlson MC, Effect of community volunteering on physical activity: A randomized controlled trial, Am. J. Prev. Med 50 (2016) 106–110. 10.1016/j.amepre.2015.06.015. [PubMed: 26340864]

[45]. Solé E, Racine M, Tomé-Pires C, Galán S, Jensen MP, Miró J, Social factors, disability, and depressive symptoms in adults with chronic pain, Clin. J. Pain 36 (2020) 371–378. 10.1097/AJP.0000000000000815. [PubMed: 32040011]

[46]. Compernolle EL, Finch LE, Hawkley LC, Cagney KA, Momentary loneliness among older adults: Contextual differences and their moderation by gender and race/ethnicity, Soc. Sci. Med 285 (2021) 114307. 10.1016/J.SOCSCIMED.2021.114307. [PubMed: 34375898]

[47]. Peek MK, O'neill GS, Networks in later life: An examination of race differences in social support networks, Int. J. Aging Hum. Dev 52 (2001) 207–229. [PubMed: 11407487]

[48]. Beller J, Wagner A, Loneliness and Health: The Moderating Effect of Cross-Cultural Individualism/Collectivism, J. Aging Health 32 (2020) 1516–1527. 10.1177/0898264320943336. [PubMed: 32723203]

## Highlights

- An active social lifestyle has potential to alleviate loneliness and chronic pain
- A new measure of social activity diversity captures an active social lifestyle
- Social activity diversity is associated with lower subsequent loneliness
- Decreased loneliness is further associated with less chronic pain over time

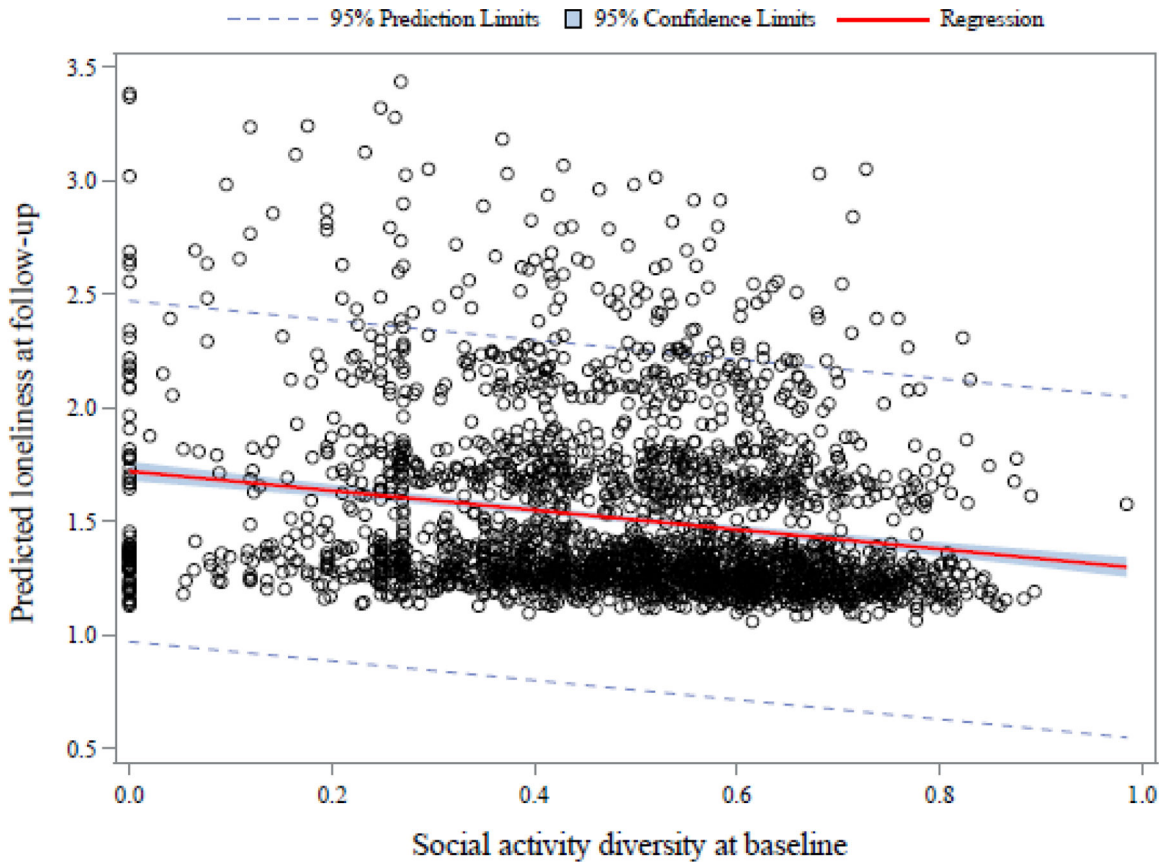


**Figure 1.**
Longitudinal association of social activity diversity with loneliness.

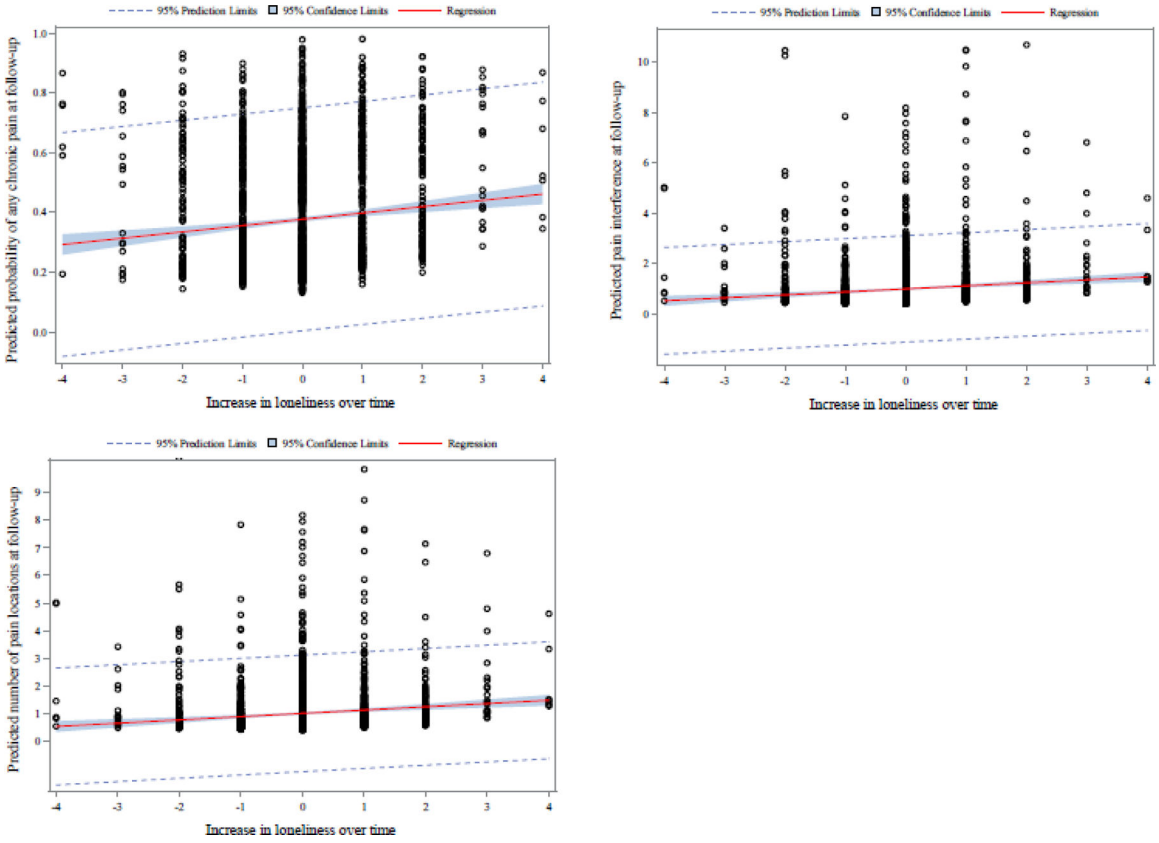


**Figure 2.**
Longitudinal associations of loneliness with chronic pain outcomes.

**Table 1.**

Correlations among variables

| | *M or %* | *SD* | *Range* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age | 53.94 | 10.95 | 30–83 | | -- | -- | -- | -- | -- | **−0.17** | **−0.05** | 0.03 | **−0.12** | 0.03 |
| 2. Men (vs. women) | 43% | | | 0.03 | | -- | -- | -- | -- | −0.03 | **−0.06** | **−0.04** | **−0.13** | **−0.08** |
| 3. Non-Hispanic white (vs. non-whites) | 82% | | | **0.13** | **0.08** | | -- | -- | -- | −0.005 | −0.04 | 0.003 | **−0.19** | **−0.09** |
| 4. Education[1] | 7.49 | 2.52 | 1–12 | −0.03 | **0.13** | **0.20** | | -- | -- | **0.21** | **v0.07** | **−0.07** | **−0.25** | **−0.14** |
| 5. Living alone (vs. not) | 5% | | | **−0.08** | 0.03 | −0.01 | **0.10** | | -- | **−0.09** | **0.05** | −0.02 | −0.01 | −0.01 |
| 6. Number of chronic conditions | 2.36 | 2.42 | 0–30 | **0.15** | **−0.18** | **−0.12** | **−0.15** | 0.04 | | **−0.11** | **0.23** | **0.28** | **0.33** | **0.38** |
| 7. Social activity diversity | 0.48 | 0.19 | 0–0.98 | **−0.05** | 0.01 | **0.13** | **0.23** | **−0.09** | **−0.12** | | **−0.10** | −0.03 | **−0.11** | **−0.05** |
| 8. Loneliness | 1.50 | 0.81 | 1–5 | **−0.11** | **−0.13** | **−0.09** | **−0.09** | **0.08** | **0.28** | **−0.15** | | **0.15** | **0.29** | **0.20** |
| 9. Having any chronic pain (vs. no) | 34% | | | **0.08** | **−0.05** | **0.06** | **−0.08** | −0.01 | **0.31** | **−0.06** | **0.11** | | -- | **0.77** |
| 10. Chronic pain-related interference[2] | 2.94 | 2.37 | 0–10 | **−0.11** | **−0.11** | −0.01 | **−0.19** | −0.04 | **0.44** | −0.04 | **0.25** | -- | | **0.40** |
| 11. Number of chronic pain locations | 0.86 | 1.55 | 0–9 | **0.11** | **−0.11** | **0.05** | **−0.13** | −0.02 | **0.44** | **−0.07** | **0.13** | **0.78** | **0.38** | |

*Notes.* $n$=2,528. Descriptive statistics of the variables are based on baseline values. Numbers below diagonal are correlations at baseline; numbers above diagonal are correlations at follow-up. Bolded numbers indicate correlation coefficients significant at $p < .05$.

[1]The mean level of education (7.49) corresponded to three or more years of college education (no degree yet).

[2]Those who had any chronic pain at baseline ($n$=776) and at the follow-up ($n$=458) answered questions on chronic pain-related interference. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error.

**Table 2.**

Results of the longitudinal association of social activity diversity with loneliness

| | Loneliness at follow-up | | | |
|---|---|---|---|---|
| | ***B*** | ***SE*** | ***P-value*** | **95% CI** |
| Intercept | 1.46 | 0.04 | <.001 | [1.39, 1.54] |
| **Social activity diversity at baseline** | **−0.21** | **0.10** | **0.034** | **[−0.41, −0.02]** |
| **Change in social activity diversity** | **−0.24** | **0.09** | **0.009** | **[−0.42, −0.06]** |
| Loneliness at baseline | 0.42 | 0.02 | <.001 | [0.38, 0.46] |
| Age (in years) | −0.002 | 0.001 | 0.106 | [−0.005, 0.001] |
| Men (vs. Women) | 0.02 | 0.03 | 0.582 | [−0.04, 0.08] |
| Non-Hispanic white (vs. non-whites) | 0.04 | 0.04 | 0.366 | [−0.04, 0.12] |
| Education | −0.01 | 0.01 | 0.441 | [−0.02, 0.01] |
| Living alone (vs. no) | 0.05 | 0.07 | 0.511 | [−0.09, 0.18] |
| Number of chronic conditions | 0.04 | 0.01 | <.001 | [0.03, 0.06] |
| *Model fit statistics* | | | $R^2 = 0.21$<br>$F = 72.40$, $p < .001$ | |

*Note*. $n$=2,528. The main variables of interest are bolded.

**Table 3.**

Results of the longitudinal associations of loneliness with chronic pain outcomes

| | Risk of any chronic pain at follow-up | | | Chronic pain-related interference at follow-up | | | | The number of chronic pain locations at follow-up | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***Exp(B)*** | ***P-value*** | ***95% CI*** | ***B*** | ***SE*** | ***P-value*** | **95% CI** | ***Exp(B)*** | ***P-value*** | **95% CI** |
| Intercept | 0.35 | <.001 | [0.28, 0.44] | 2.94 | 0.41 | <.001 | [2.14, 3.75] | 0.94 | 0.182 | [0.85, 1.03] |
| Loneliness at baseline | 1.26 | <.001 | [1.1, 1.43] | 0.38 | 0.14 | 0.008 | [0.1, 0.65] | 1.16 | <.001 | [1.1, 1.22] |
| **Change in loneliness** | **1.24** | **<.001** | **[1.11, 1.38]** | **0.36** | **0.11** | **0.001** | **[0.14, 0.58]** | **1.17** | **<.001** | **[1.12, 1.22]** |
| Corresponding chronic pain at baseline | 3.40 | <.001 | [2.82, 4.09] | 0.42 | 0.05 | <.001 | [0.33, 0.52] | 1.26 | <.001 | [1.24, 1.29] |
| Age (in years) | 1.00 | 0.362 | [0.99, 1.00] | −0.02 | 0.01 | 0.030 | [−0.04, −0.002] | 1.00 | 0.497 | [0.99, 1] |
| Men (vs. Women) | 1.06 | 0.525 | [0.88, 1.27] | −0.27 | 0.21 | 0.199 | [−0.69, 0.15] | 0.99 | 0.903 | [0.91, 1.08] |
| Non-Hispanic white (vs. non-whites) | 1.10 | 0.422 | [0.87, 1.40] | 0.30 | 0.41 | 0.470 | [−0.51, 1.10] | 0.85 | 0.001 | [0.77, 0.94] |
| Education | 0.98 | 0.408 | [0.95, 1.02] | −0.09 | 0.04 | 0.045 | [−0.17, −0.002] | 0.96 | <.001 | [0.94, 0.98] |
| Living alone (vs. no) | 0.69 | 0.078 | [0.45, 1.04] | −0.14 | 0.51 | 0.779 | [−1.15, 0.87] | 0.97 | 0.743 | [0.8, 1.17] |
| Number of chronic conditions | 1.20 | <.001 | [1.15, 1.25] | 0.13 | 0.04 | 0.001 | [0.05, 0.22] | 1.08 | <.001 | [1.06, 1.09] |
| *Model fit statistics* | $2LL$ = 3350.93<br>$\chi^2$ = 401.38, $p$ < .001 | | | $R^2$ = 0.35<br>$F$ = 26.64, $p$ < .001 | | | | $LL$ = −1820.54<br>$\chi^2$ = 5052.67, $p$ < .001 | | |

*Note.* $n$=2,528; $n$ = 458 were used in the model for pain interference who had any chronic pain at both time points. The chronic pain-related interference scale was not measured in M2 MIL (Milwaukee African American sample) due to data collection error; $n$=2,491 were used in the model for the number of chronic pain locations due to missing responses. The main variable of interest is bolded.