Health Science Reports

WILEY

Health Science Reports
Open Access

ORIGINAL RESEARCH OPEN ACCESS

Joint Pain and Leisure-Time Physical Activity: Cross-Sectional Findings From the Cardiovascular Health Study

Kailyn Witonsky[1] | Xiaonan Zhu[2] | Andrea L. Rosso[1] | Anne Newman[1] | Caterina Rosano[1]

[1]Department of Epidemiology, School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania, USA | [2]Model Development, BNY Mellon Center, Pittsburgh, Pennsylvania, USA

Correspondence: Kailyn Witonsky (krw85@pitt.edu)

Received: 17 July 2023 | **Revised:** 11 December 2024 | **Accepted:** 20 December 2024

Funding: This research was supported by the National Heart, Lung, and Blood Institute contracts HHSN268201200036C, HHSN268200800007C, HHSN268201800001C, N01HC55222, N01HC85079, N01HC85080, N01HC85081, N01HC85082, N01HC85083, N01HC85086 (Grant Nos. U01HL080295, R01HL087652, R01HL105756, R01HL103612, R01HL120393, and U01HL130114); National Institute on Aging (Grant Nos. R01AG023629, T32 AG055381).

Keywords: age | epidemiology | exercise | pain

ABSTRACT

Background: Joint pain is common and limits leisure-time physical activity (LTPA) in older adults. However, some older adults with pain are also physically active. Psychosocial factors that may indicate external engagement (such as social network) and internal drive (such as feeling able to "get going") are emerging as predictors of LTPA and may explain why some older adults with pain are physically active.

Methods: We investigated the cross-sectional association of psychosocial factors with LTPA (kcal/week) in adults over the age of 64 with pain in their back, hips, knees and/or feet from the Cardiovascular Health Study. Psychosocial factors included: social network score from the Lubben Social Network scale and three questions from the Center of Epidemiologic Studies Depression Scale (CES-D): perceived effort, difficulty getting going, and trouble concentrating. Separate multivariable ordinal regression models estimated the association between these indicators and LTPA, while controlling for demographics and other contributors of LTPA: number of medications, number of pain sites, body mass index, gait speed, digit substitution symbol test, brain white matter hyperintensities, and mood.

Results: Among 902 participants (65% female, 14% Non-White) with joint pain and complete data, higher social network score, and no self-reported "difficulty getting going" were associated with higher levels of LTPA, independent of covariates. Associations with perceived effort or trouble concentrating were not statistically significant.

Conclusions: Our research suggests that some older adults with pain are physically active and psychosocial factors related to external engagement and internal drive might be important targets to support LTPA. Studies should investigate the role of psychosocial states on LTPA among older adults with pain.

Impact Statement: We certify that this work is novel.

The potential impact of this research on clinical care includes the following: Resiliency factors such as psychosocial factors may be more important targets to promote leisure-time physical activity in older adults with pain than specific pain reduction strategies.

Summary

- Pain characteristics were not associated with leisure-time physical activity, but psychosocial variables were, independent of covariatesWhy does this paper matter?
- Lower leisure-time physical activity is not an inevitable result of joint pain and psychosocial factors might be important targets to support leisure-time physical activity in this vulnerable population.

1 | Introduction

Pain is highly prevalent for older adults; musculoskeletal pain impacts over 40% of US adults over 60 years old [1, 2], has an increasing prevalence [3], and, when chronic, has no effective treatment [4]. Persistent pain commonly leads to lower physical activity in older adults [5, 6], which can have detrimental impacts such as reduced quality of life [7], and higher risk of disability [8], dementia [9], and depression [10]. Promoting leisure-time physical activity (LTPA) in older adults with pain may protect against these detrimental consequences.

While pain often leads to lower LTPA in older adults, it does not always. Some older adults have higher levels of LTPA. Previous research suggests that pain characteristics, like pain severity, do not fully explain lower LTPA among those with musculoskeletal pain [11]. A recent exercise and education clinical trial intervention ($n = 17{,}454$) in patients with osteoarthritis pain, found that 33% of participants with low levels of baseline physical activity reached and *maintained* moderate physical activity levels for up to a year after the end of the trial, *independent of pain reduction* [12]. That is, one-third of the cohort increased physical activity even though their pain did not change. This suggests that physical activity in the presence of persistent pain is not rare, does not depend on lowering pain levels, and can be modified. Uncovering the determinants of LTPA among older adults with pain is important to develop more specific strategies to improve LTPA among this high-risk group and potentially delay the onset of physical disability.

Drivers of LTPA and healthy living include both internal and external drivers. One example of an external driver of LTPA is social engagement, for example through a robust social network [13]. Social support can also protect against some of the negative consequences of persistent pain [14, 15]. An example of an internal driver of LTPA includes feeling able to initiate and maintain activity. This can include feeling able to concentrate and able to get going. The feeling of being able to "keep going," has been previously found to be a key factor in older adults with chronic pain who report being in good health [16]. However, most previous studies were not specific to older adults and lacked a thorough characterization of other contributors of LTPA. For example, subclinical brain abnormalities like white matter hyperintensities are related to aging and have been associated with pain-related disability [17] and with lower physical activity [18]. It is feasible that white matter hyperintensities and small vessel disease are confounders of pain and LTPA, but this has largely not been investigated. There is a need for research with older adults specifically, as older adults have the highest pain prevalence, with worse outcomes, including premature death and accelerated cognitive decline [4]. There are also several age-related changes that may be important in pain. Older adults, for example those over 60, often have chronic low grade inflammation, delayed wound healing, and changes in function in peripheral and central nerve physiology related to nociception and pain processing [4, 19, 20]. Aging can lead to diminished function in both the peripheral and central nervous systems, resulting in the seemingly paradoxical experience of a higher pain threshold (e.g. reduced sensitivity to acute pain) [21] alongside an impaired ability to tolerate intense pain [22]—phenomena commonly observed in older adults.

In this study, we investigated whether psychosocial factors were related to LTPA among adults over 64 years old with pain in their back, hips, knees, and/or feet. We hypothesized that older adults with more robust social networks and who feel better able to initiate and maintain behavior would have more LTPA, and that pain characteristics related to pain location, number of pain sites, and painkiller use would modify these associations. Since brain small vessel disease has also been shown to influence physical activity and pain, we also test the potential influence of this confounder.

2 | Methods

This cross-sectional study utilizes data from years 1992 and 1993 of the Cardiovascular Health and Cognition Study (CHS-CS), an ancillary study designed to investigate the prevalence of mild cognitive impairment and dementia. This sample was recruited from the larger CHS study: a community-based study of 5888 adults over 64 years old from four regions of the United States.

2.1 | Study Participants

Participants were recruited in 1989 and 1990 from four different US regions via Medicare eligibility lists and supplemental recruitment of minority participants was included in 1992 and 1993 [23]. Eligibility criteria for CHS included that participants (1) did not have active cancer, (2) were mobile without the use of a wheelchair, and (3) were not planning to move locations within 3 years. Additionally, participants received a magnetic resonance imaging (MRI) brain scan if they were willing and eligible (e.g., without metal implants, pacemakers, etc.) between 1991 and 1994. Of the 5888 older adults in this study, 2703 participants had complete MRI and mobility data at year 5 of data collection. Of the 2703 participants with complete data, 919 (34%) older adults reported pain in one or more of the following locations: back, hip, knee, feet. An additional 17 people were excluded from the analysis: 14 people had missing digit-symbol substitution task, 2 people had missing mood related predictors, and 1 person had missing medication information. The final analytical sample included 902 older adults, all with back, hip, knee, and/or foot pain. All participants provided written informed consent, and all four sites received institutional review board approval. The Institutional Review Board approval protocol number is MOD22060162-006.

2.2 | Pain

Joint pain was based on a self-reported yes/no question for each location: "Have you had pain in your bones or joints in the last year?" If endorsed, participants were then asked about each location: "Have you had pain in your [pain location] in the last year?" This was assessed separately for back, hips, knees, and feet. It is important to note that this question cannot distinguish between different pain etiology (e.g., musculoskeletal or neuropathic).

2.3 | Outcome: LTPA

LTPA was assessed as a series of self-reported questions via the CHS Physical Activity Form adapted from the NCHS Health Interview Survey Health Promotion and Disease Prevention Supplement and the Paffenbarger Questionnaire [24, 25]. During the year 5 follow-up interview trained interviewers collected information on 18 specific physical activities and general movement behaviors in older adults. Activities included walking, mowing and raking the lawn, gardening, hiking, jogging, biking, exercise machines, dancing, aerobics, bowling, golf, calisthenics, swimming, other activities, stair climbing and sedentary habits. Participants were asked about each activity, frequency, duration, and the number of months performed over the past year. From this, average energy expenditure during LTPA over the last 2 weeks could be estimated. This variable represents moderate activity for leisure and transportation.

The LTPA distribution is skewed right and zero-inflated, with 183 (20%) of the sample reporting no exercise over the 2 weeks before the survey. Because the sample is zero-inflated, the LTPA variable cannot be transformed adequately to meet the assumption of normality. As such, five groups of roughly equivalent sample size were created using sample specific quintiles for multivariate ordinal regression. The five LTPA groups were (1) 0 kCal ($n = 183$); (2) 1–349 kCal ($n = 184$); (3) 350–849 kCal ($n = 185$); (4) 850–1799 kCal ($n = 179$); (5) 1800–9905 kCal ($n = 183$). National recommendations for physical activity in older adults include 150 min/week of moderate exercise or 75 min/week of intense exercise [26]. The fifth LTPA group corresponds with this recommendation (~2000 kcal/2 weeks) and the other LTPA groups allow granularity in this analysis.

2.4 | Psychosocial Factors

We used the following variables as predictors of LTPA in this sample of older adults with joint pain: (1) social network score from questions extracted from the Lubben Social Network scale [12] and three single-item questions from the Center of Epidemiologic Studies Depression Scale (CES-D): (2) perceived effort, (3) difficulty getting going, and (4) trouble concentrating.

2.4.1 | Social Network Score

The Lubben Social Network Scale [27] is a validated measure of social support that was adapted from the Berkman-Syme Social Network Index for use with older populations. This measure was calculated as a sum of 10 questions, each with a possible score of 0–5; cumulative possible scores range from 0 to 50; higher values indicate more support. This scale has been used previously and captures a range and depth of social interactions by considering frequency of contact and depth of connection among relatives, friends, confidantes, and dependents. It also assessed if a person lived alone.

2.4.2 | Mood Related Factors

The mood related variables were single questions extracted from the CES-D, worded as follows:

I had trouble keeping my mind on what I was doing.

I felt that everything I did was an effort.

I could not get "going."

Participants responses ranged from 0 (*rarely/none*) to 3 (*most of the time*). To facilitate interpretation, binary variables were created with '1' representing the rarely/none answer and '0' representing any endorsement above 0. This binarization did not impact significance, direction, or the magnitude of the effect size.

2.5 | Covariates

Demographics including age, gender, and race were self-reported at baseline. Covariates were chosen using a systematic approach that included accounting for potential confounders, as informed by previous literature [12, 28–34], and using statistical variable selection methods. Variables informed from literature included: Body mass index (BMI), a continuous variable calculated from height and weight; gait speed was measured from usual walking speed in meters/second over 4.57 meters. BMI was used as a continuous variable to avoid the loss of information that may occur with categorization. Additional analyses were performed using categorical and squared BMI because both underweight and overweight categories have been associated with pain intensity [35]. White matter hyperintensities were coded as a binary variable and were obtained on 1.5-T (three centers) and 0.35-T (one center) scanners using a standard protocol. These scans were interpreted at a central reading center and were graded from 0 to 9 (least to most burden), as used and published previously [14] by members of our group. A white matter grade of 3+ was coded as WMH being present. The Digit Symbol Substitution Test (DSST) [36] measures processing speed, with higher scores indicating a faster processing speed. Depressive symptoms were measured via a modified version of the CES-D [37] scale, where scores over 10 suggest a depression diagnosis.

Other pain characteristics [29] were pain location, number of pain sites, and painkiller use. Number of pain sites was a summation of the pain locations included in this study (back, hip, knee, feet) and ranged from 1 to 4. Painkiller was classified as taking one or more of the following: aspirin, aspirin-containing medicine, or non-steroidal anti-inflammatory agents. Participants also reported and brought in the containers for medications taken in the 14 days before the clinical visit, this constituted the variable "number of medications."

2.6 | Statistical Analyses

2.6.1 | Variable Selection

We determined the optimal set of variables using background literature [12, 28–31, 38–40] and statistical considerations. Variables were removed for redundancy, collinearity, or lack of information (i.e., a binary yes/no variable with only five 'yes' responses). Three variable selection methods (backward and forward stepwise selection and best subset selection) were used to decrease the likelihood of overfitting. The number of selected variables was chosen via adjusted R^2 and Mallow's Cp. When these numbers did not agree, the smaller number was chosen for a more parsimonious model.

There were no substantial collinearity issues in this dataset. Backward, forward and best subset selection were in agreement to drop the following variables: education level (years), clinic location (Bowman Gray, Davis, Hagerstown, Pittsburgh), marital status, smoking status (never, former, current), alcohol use (number of alcoholic drinks consumed per week), loneliness (extracted from the CES-D as a single scaled self-reported question "feeling lonely" over the past week), caretaker status (coded: 'yes' if yes to any of the following: 'helping someone with things like shopping', 'someone relies on you to do something for them each day', 'caring for someone who is sick or disabled'), diagnoses of arthritis, high blood pressure, and diabetes defined as previously described [41], C-reactive Protein (measured in blood, mg/L), and trouble falling asleep (by a single binary question). Painkiller use (included self-reported use of aspirin or Nonsteroidal Anti-Inflammatory Drugs [NSAIDs]) was dropped because there was substantial overlap with number of medications, and number of medications had more variability. Due to lack of information, Modified Mini-Mental State Examination score (binary, less than 80 indicating likely cognitive impairment [42]) was not included.

2.6.2 | Descriptive Comparisons

Descriptive comparisons were conducted for the ordinal LTPA outcome and each predictor (social network, trouble concentrating, perceived effort, and difficulty getting going), as well as the total CES-D score using bivariate ordinal regression models.

2.6.3 | Ordinal Regression Models

For this analysis, multivariable ordinal regression models estimated the association between LTPA group and each psychosocial variable in unadjusted models (Model 1) and then while controlling for all confounders: demographics (age, sex, race), BMI, gait speed, other pain characteristics (number of medications, number of pain sites) and brain integrity (cognitive function and white matter hyperintensities via MRI) using a cumulative link model (Model 2). An interaction was also tested between each predictor and number of pain sites. A final model included depressive symptoms (Model 3), which was not controlled for in Model 2, since three of the psychosocial variables of interest are extracted from the CES-D. A more conservative model included only those variables that were statistically associated with LTPA in bivariate analyses. Estimates and 95% confidence intervals are presented.

p-values were calculated by comparing the t-value against a standard normal distribution, which is reasonable given the large sample size here. All analyses were completed in R using the R studio interface (Version 2023.03.0 + 386).

3 | Results

Demographic characteristics are shown in Table 1 and Supporting Information S1: Table S3. Briefly, the final sample included 902 participants between the ages of 65–92 (median = 73), all reporting pain in one or more of the following locations at baseline: back, hips, knees, or feet. The sample was predominantly female (65%) and White (86%). Pain characteristics, including the number of pain locations, presence of pain in each of the documented pain locations, and use of pain medication were similar across LTPA groups. Results from forward, backward, and best subset selection were similar. The selected variables for the outcome of LTPA group were gait speed, gender, number of medications, race, age, and BMI. Based on the hypothesis and importance in previous research, the number of pain sites, white matter intensities, and DSST score were also included in the final model.

3.1 | Descriptive Observations

Social network scores and percentage endorsing psychosocial factors across LTPA groups are shown in Table 1. Higher social network score, and less difficulty getting going, less trouble concentrating, and less perceived effort were all independently associated with higher LTPA groups in older adults with back, hip, knee, and/or foot pain in unadjusted analyses (Table 2, Model 1). Significance, magnitude, and direction of the effect was similar regardless of whether the single item CES-D predictors were scaled (0–3) or binary (0 vs. more than 0; Supporting Information S1: Table 4).

3.2 | Social Network Score

Larger social network score was associated with being in a higher LTPA group ($\beta = 0.022$, $p < 0.0091$) while adjusting for demographics (gender, age, race), BMI, gait speed, number of pain sites, number of medications, white matter hyperintensities, and DSST score (Table 2, Model 2). This finding remained significant after controlling for total depressive symptoms ($\beta = 0.020$, $p = 0.021$) (Table 2, Model 3).

3.3 | Psychosocial Factors

Trouble concentrating ($\beta = 0.070$, $p = 0.61$) was not associated with LTPA group when controlling for covariates (Table 2, Models 2 and 3). Greater perceived effort was associated with a

TABLE 1 | Characteristics and prevalence of psychosocial predictors by physical activity group among adults aged 65 years and older all reporting pain in one or more of the following locations: Back, Hip, Knee, Foot ($n = 902$).

	No exercise $n = 183$	**1–349 kCal $n = 184$**	**350–849 kCal $n = 185$**	**850–1799 kCal $n = 179$**	**1800–9905 kCal $n = 171$**	**Total $n = 902$**
Age (years) median	75	73	73	73	73	73
[min, max]	[67, 92]	[66, 91]	[66, 92]	[66, 86]	[65, 89]	[65, 92]
% Female	144 (79%)	140 (76%)	122 (66%)	106 (59%)	75 (44%)	587 (65%)
% Non-White	35 (19%)	39 (21%)	22 (12%)	19 (11%)	11 (6%)	126 (14%)
Depressive symptoms (CES-D), mean (SD)	6.9 (5.5)	6.0 (4.9)	6.5 (5.4)	5.5 (4.9)	4.6 (4.1)	5.9 (5.1)
kCal/2 weeks median	0	180	540	1290	2790	525
[min, max]	[0, 0]	[16, 345]	[364, 844]	[855, 1800]	[1810, 9910]	[0, 9910]
Social network score, mean (SD)	32.0 (7.7)	33.2 (7.5)	33.8 (7.0)	34.1 (7.3)	35.8 (7.2)	33.8 (7.4)
No perceived effort	46%	54%	50%	61%	68%	56%
No difficulty getting going	42%	47%	51%	59%	64%	53%
No trouble concentrating	50%	55%	56%	60%	63%	57%

Abbreviations: CES-D, Centers for Epidemiologic Studies Depression scale; SD, standard deviation.

TABLE 2 | Ordinal regression models of physical activity and psychosocial factors in older adults with back, hip, knee, and/or foot pain ($n = 902$).

	Model 1		**Model 2**		**Model 3**		
	β	***p*-value**	**β**	***p*-value**	**β**	***p*-value**	**1/Odds**
Higher social network score	0.039	< 0.001	0.022	0.0091	0.020	0.021	1.0
No difficulty getting going	0.6	< 0.001	0.38	0.0019	0.36	0.0079	1.4
No trouble concentrating	0.30	0.011	0.15	0.23	0.070	0.61	1.1
No perceived effort	0.49	< 0.001	0.25	0.044	0.20	0.15	1.2
CES-D	−0.048	< 0.001	−0.020	0.1	Not applicable		

Note: Models are using a cumulative link model. **Model 1**: Single, unadjusted predictors; **Model 2:** adjusted by gender, age, race, body mass index, gait speed, number of medications, presence of white matter hyperintensities, digit symbol substitution score, number of pain sites; **Model 3:** Adjusted as in Model 2 with addition of depressive symptoms as measured by CES-D.

higher likelihood of being in a lower LTPA group in the model controlling for covariates ($\beta = 0.25$, $p = 0.044$ Table 2, Model 2) but not when also controlling for total depressive symptoms ($\beta = 0.20$, $p = 0.15$, Table 2, Model 3). Greater difficulty getting going was significantly associated with lower likelihood of being in a higher LTPA group ($\beta = 0.38$, $p = 0.0019$, Table 2, Model 2), and this remained significant after also adjusting for total depressive symptoms ($\beta = 0.36$, $p = 0.0079$, Table 2, Model 3). There was no significant interaction between the predictors and the number of pain sites. More conservative models including only variables with a bivariate association with LTPA yielded similar results (Supporting Information S1: Table S5). Additional analyses using categorical and squared BMI did not impact the model (Supporting Information S1: Table S6).

To aid interpretation, an odds ratio was calculated by exponentiating the regression beta (Table 2). Among older adults who do not have difficulty getting going, the odds of being in one higher LTPA group was 1.4 times that of those who endorse some amount of difficulty getting going.

4 | Discussion

In this cross-sectional analysis of community-dwelling older adults with back, hip, knee, and/or foot pain, higher social network scores and lower difficulty getting going were associated with more LTPA while controlling for other contributors of LTPA and depressive symptoms. Additionally, associations were independent of pain location, number of pain sites, and painkiller use. Taken together, our results indicated that low LTPA is not an inevitable conclusion of pain in older adults. This suggests that targets besides pain reduction, such as psychosocial factors related to external engagement and internal drive should be considered when promoting and supporting LTPA in older adults with pain in their back, hips, knees, and/or feet.

Our findings are in line with previous research that suggests that social networks are protective against some of the adverse effects of pain [43] and that difficulty getting going and perceived effort are associated with somatic complaints and repetitive negative thinking [44]. Difficulty getting going and perceived effort have both been associated with fatigue [45], but difficulty getting going may suggest difficulty in initiating an action rather than sustaining it. While further investigation is needed, psychosocial factors that promote the *initiation* of LTPA may be important as specific intervention targets.

4.1 | Informative Null Findings

Several variables that were initially included were removed during variable selection. Pain-related variables including the specific location of the pain, painkiller use, and CRP, an inflammatory factor commonly elevated in pain [46, 47], were largely similar between groups. This suggests, as also reported by others [11], that factors beyond specific pain characteristics may be important in driving lower LTPA and further supports the idea that low LTPA is not an inevitable conclusion from pain.

Previous research, mostly not specific to older adults, has reported an association between higher LTPA and both better processing speed, as measured by the DSST [48], and white matter integrity [49], in older adults. As such, small vessel disease was an important potential confounder to control for in this analysis. These data suggest that, while averages in the LTPA groups were in the expected directions, there was not sufficient evidence that these factors were important predictors of LTPA in older adults with back, hip, knee, and/or foot pain. While the reason for this is not clear, one potential explanation is that physical activity contributes to neural reserve that lessens the impact of WMH, which has been reported elsewhere [50]. A similar relationship may be present for older adults with joint pain. Since this study is cross-sectional, the direction of the effect cannot be established. Previous research has found pain and LTPA to impact each other bidirectionally [51], and the directionality of this relationship requires additional investigation. Individuals with pain may be more sedentary for multiple reasons, including pain exacerbation with movement, limited strength, flexibility and function, and pain catastrophizing and fear of pain and falling [52, 53].

4.2 | Limitations and Future Directions

There are several limitations in the current study. The analyses included here were cross-sectional and could not examine changes over time or directionality. There is evidence that lower LTPA can exacerbate pain [54, 55] and that pain can have a detrimental impact on brain structure and function [56, 57]. Future studies with repeated measures of pain and LTPA can help address the directionality of pain and LTPA. Secondly, this sample is 86% white; this is a critical limitation, as pain management is highly inequitable and much research, including the current study, does not adequately consider the impact of social determinants of health, like race. While the perception of LTPA is important, as this is likely the same form of information available in a clinical setting like a doctor's office, self-report measures are at greater risk for reporting bias and further research should consider other objective measures of LTPA in conjunction with subjective ones. It is possible that our results may not be entirely generalizable to community-dwelling older adults. Eligibility criteria for the larger study and the MRI would likely lead to the inclusion of participants who are healthier than the average older adult living in the community. The data used in this study were collected 29–32 years ago and may not generalize to contemporary older adults. Since the data for this study was collected, many social and cultural aspects have shifted, pain prevalence has increased, and treatment approaches have generally become more multi-modal. The current study captures variables dealing with self-perception of social network, perceived difficulty getting going, pain and LTPA—which may be less influenced by modern developments. However, the social changes over this timespan are large and their impact is likely complex and difficult to predict. As such, these findings should be replicated in more contemporary cohorts.

While we evaluated the specific locations of pain, the sum of pain locations, and use of painkillers, certain pain characteristics were not available, including pain severity. However, the question captured in this dataset is similar to that asked in many non-specialty clinics and may capture reporting that is aligned with community-based care. Additionally, this variable has been previously associated with critical outcomes including physical functioning [58]. While it is possible pain severity could confound these results, others have found that pain severity is not a large determinant in LTPA, the onset of disability, or pain interference [59, 60]. Research suggests that the number of pain sites may be a more important predictor for physical inactivity [11] and this was included. Finally, the difference between acute and chronic pain is well-documented and our hypothesis aligns particularly well with chronic pain. While the pain question in this study does not distinguish between chronic and acute pain, the prevalence of pain in this study is similar to the prevalence of reporting pain for 3 or more consecutive years in longitudinal work using this same sample (longitudinal pain: 32% of sample, here 33%) [61]. While it is likely that there is heterogeneity in pain duration and etiology, it is unlikely that pain from acute injury makes up the majority of this sample. Thus, while a full characterization of pain should be investigated further, these findings are a valuable starting place given the consistency with established chronic pain characteristics and includes data from over 900 participants with pain assessment scales previously used in epidemiological studies of older adults, thus enabling robust analyses in a segment of the population, community-dwelling older adults, that has often been overlooked in studies of pain. This may provide unique insights into the everyday experience of pain and resilience in older adults.

5 | Conclusion

This study utilized a well-characterized community-dwelling cohort of older adults with many relevant variables that captured various aspects of joint pain. The methodological approach utilized a combination of background literature and variable selection methods. A strength of this approach and dataset and many other population-based studies includes the rich number of variables available that allow for both hypothesis-testing and hypothesis generation. The results of this study underscore the importance of studying psychosocial factors related to external engagement and internal drive among older adults with joint pain and their influence on LTPA.

In clinical practice and in the community, pain is often considered a for-gone conclusion of aging and, as such, is often undertreated and undermanaged [62]. However, there is growing evidence that the consequences of joint pain, while deleterious when undertreated, are not inevitable. The promotion of social network and lessening the feeling of difficulty getting going may be important targets to combat the negative impacts of joint pain in older adults.

Author Contributions

All authors met the criteria for authorship as defined in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals. Kailyn Witonsky and Caterina Rosano prepared the first draft of the manuscript. Andrea Rosso and Anne Newman contributed to study design, interpretation, and revisions of each draft of the manuscript. Kailyn Witonsky completed data analyses with overview and full code review completed by Xiaonan Zhu. All authors have read and approved the final version of the manuscript, Kailyn Witonsky had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis. Caterina Rosano gave feedback and helped design and revise the study design and analysis strategies. She also revised each draft of the paper.

Acknowledgments

Dr. Yenisel Cruz-Almeida and Dr. Michael Gold both provided helpful feedback regarding the interpretation of the results in this manuscript. This work was supported by grant #1 T32 AG055381, from the NIA, NIH, United States Department of Health and Human Services. CHS: This CHS research was supported by NHLBI contracts HHSN268201200036C, HHSN268200800007C, HHSN268201800001C, N01HC55222, N01HC85079, N01HC85080, N01HC85081, N01HC85082, N01HC85083, N01HC85086; and NHLBI grants U01HL080295, R01HL087652, R01HL105756, R01HL103612, R01HL120393, and U01HL130114 with additional contribution from the NINDS. Additional support was provided through R01AG023629 from the NIA. The funders had no role in the study design, analysis, interpretation of the data, or in preparing the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Cardiovascular Health Study data are publicly available upon request: https://chs-nhlbi.org/NewInvest. Peer review of these analyses was conducted to confirm the quality of the shared data. Data access is available through the Cardiovascular Health Study and can be requested at https://biolincc.nhlbi.nih.gov/studies/chs/.

Transparency Statement

The lead author Kailyn Witonsky affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

References

1. T. E. Lehti, M.-O. Rinkinen, U. Aalto, et al., "Prevalence of Musculoskeletal Pain and Analgesic Treatment Among Community-Dwelling Older Adults: Changes From 1999 to 2019," *Drugs & Aging* 38 (2021): 931–937.

2. J. Dahlhamer, J. Lucas, C. Zelaya, et al., "Prevalence of Chronic Pain and High-Impact Chronic Pain Among Adults—United States, 2016," *MMWR. Morbidity and Mortality Weekly Report* 67 (2018): 1001–1006.

3. A. Zajacova, H. Grol-Prokopczyk, and Z. Zimmer, "Pain Trends Among American Adults, 2002–2018: Patterns, Disparities, and Correlates," *Demography* 58 (2021): 711–738.

4. A. F. Domenichiello and C. E. Ramsden, "The Silent Epidemic of Chronic Pain in Older Adults," *Progress in Neuro-Psychopharmacology and Biological Psychiatry* 93 (2019): 284–290.

5. M. Shih, J. M. Hootman, J. Kruger, and C. G. Helmick, "Physical Activity in Men and Women With Arthritis," *American Journal of Preventive Medicine* 30 (2006): 385–393.

6. D. W. Griffin, D. C. Harmon, and N. M. Kennedy, "Do Patients With Chronic Low Back Pain Have an Altered Level And/Or Pattern of Physical Activity Compared to Healthy Individuals? A Systematic Review of the Literature," *Physiotherapy* 98 (2012): 13–23.

7. J. Majlesi, "Patients With Chronic Musculoskeletal Pain of 3–6-Month Duration Already Have Low Levels of Health-Related Quality of Life and Physical Activity," *Current Pain and Headache Reports* 23 (2019): 81.

8. A. Wu, L. March, X. Zheng, et al., "Global Low Back Pain Prevalence and Years Lived With Disability From 1990 to 2017: Estimates From the Global Burden of Disease Study 2017," *Annals of Translational Medicine* 8 (2020): 299.

9. W. Zhao, L. Zhao, X. Chang, X. Lu, and Y. Tu, "Elevated Dementia Risk, Cognitive Decline, and Hippocampal Atrophy in Multisite Chronic Pain," *Proceedings of the National Academy of Sciences* 120 (2023): e2215192120.

10. Silva MRd, F. Ferretti, P. Samira da Silva, F. Tombini, and F. Odanor., "Depressive Symptoms in the Elderly and Its Relationship With Chronic Pain, Chronic Diseases, Sleep Quality and Physical Activity Level," *BrJP* 1 (2018): 293–298.

11. S. Murata, T. Doi, R. Sawa, et al., "Association Between Objectively Measured Physical Activity and the Number of Chronic Musculoskeletal Pain Sites in Community-Dwelling Older Adults," *Pain Medicine* 20 (2019): 717–723.

12. L. Baumbach, D. T. Grønne, N. C. Møller, S. T. Skou, and E. M. Roos, "Changes in Physical Activity and the Association Between Pain and Physical Activity–A Longitudinal Analysis of 17,454 Patients With Knee or Hip Osteoarthritis From the GLA: D® Registry," *Osteoarthritis and Cartilage* 31, 2 (2023): 258–266.

13. T. Prochnow and M. S. Patterson, "Assessing Social Network Influences on Adult Physical Activity Using Social Network Analysis: A Systematic Review," *American Journal of Health Promotion* 36 (2022): 537–558.

14. T. Rosemann, T. Kuehlein, G. Laux, and J. Szecsenyi, "Factors Associated With Physical Activity of Patients With Osteoarthritis of the Lower Limb," *Journal of Evaluation in Clinical Practice* 14 (2008): 288–293.

15. E. J. Bartley, S. Palit, R. B. Fillingim, and M. E. Robinson, "Multisystem Resiliency as a Predictor of Physical and Psychological Functioning in Older Adults With Chronic Low Back Pain," *Frontiers in Psychology* 10 (2019): 1932.

16. J. C. Richardson, J. C. Grime, and B. N. Ong, "'Keeping Going': Chronic Joint Pain in Older People Who Describe Their Health as Good," *Ageing and Society* 34 (2014): 1380–1396.

17. N. Buckalew, M. W. Haut, H. Aizenstein, et al., "White Matter Hyperintensity Burden and Disability in Older Adults: Is Chronic Pain a

Contributor?," *PM & R: The Journal of Injury, Function, and Rehabilitation* 5 (2013): 471–480.

18. E. R. Torres, E. F. Strack, C. E. Fernandez, T. A. Tumey, and M. E. Hitchcock, "Physical Activity and White Matter Hyperintensities: A Systematic Review of Quantitative Studies," *Preventive Medicine Reports* 2 (2015): 319–325.

19. S. J. Gibson and M. Farrell, "A Review of Age Differences in the Neurophysiology of Nociception and the Perceptual Experience of Pain," *The Clinical Journal of Pain* 20 (2004): 227–239.

20. S. P. Singh, J. Guindon, P. H. Mody, et al., "Pain and Aging: A Unique Challenge in Neuroinflammation and Behavior," *Molecular Pain* 19 (2023): 17448069231203090.

21. S. Mullins, F. Hosseini, W. Gibson, and M. Thake, "Physiological Changes From Ageing Regarding Pain Perception and Its Impact on Pain Management for Older Adults," *Clinical Medicine* 22 (2022): 307–310.

22. J. Hackett, K. E. Naugle, and K. M. Naugle, "The Decline of Endogenous Pain Modulation With Aging: A Meta-Analysis of Temporal Summation and Conditioned Pain Modulation," *The Journal of Pain* 21 (2020): 514–528.

23. L. P. Fried, N. O. Borhani, P. Enright, et al., "The Cardiovascular Health Study: Design and Rationale," *Annals of Epidemiology* 1 (1991): 263–276.

24. H. L. Taylor, D. R. Jacobs, B. Schucker, J. Knudsen, A. S. Leon, and G. Debacker, "A Questionnaire for the Assessment of Leisure Time Physical Activities," *Journal of Chronic Diseases* 31 (1978): 741–755.

25. R. S. Paffenbarger, S. N. Blair, I.-M. Lee, and R. T. Hyde, "Measurement of Physical Activity to Assess Health Effects in Free-Living Populations," *Medicine & Science in Sports & Exercise* 25 (1993): 60–70.

26. R. D. Olson, A. Vaux-Bjerke, J. B. Quam, et al. Physical Activity Guidelines for Americans. NADAR! SWIMMING MAGAZINE-Periódico científico em esportes e fitness aquático-natação, pólo aquático, nado sincronizado, saltos ornamentais, travessias aquáticas 2023.

27. J. E. Lubben, "Assessing Social Networks Among Elderly Populations," *Family & Community Health* 11 (1988): 42–52.

28. A. E. Bauman, J. F. Sallis, D. A. Dzewaltowski, and N. Owen, "Toward a Better Understanding of the Influences on Physical Activity," *American Journal of Preventive Medicine* 23 (2002): 5–14.

29. M. A. Koop, I. J. Lutke Schipholt, G. G. M. Scholten-Peeters, and M. W. Coppieters, "Identifying the Most Important Confounders When Assessing the Association Between Low-Grade Systemic Inflammation and Musculoskeletal Pain: A Modified Delphi Study," *Pain Medicine* 22 (2021): 2661–2669.

30. Å. Degerstedt, H. Alinaghizadeh, C. A. Thorstensson, and C. B. Olsson, "High Self-Efficacy–A Predictor of Reduced Pain and Higher Levels of Physical Activity Among Patients With Osteoarthritis: An Observational Study," *BMC Musculoskeletal Disorders* 21 (2020): 380.

31. B. Aydemir, C. H. Huang, and K. C. Foucher, "Gait Speed and Kinesiophobia Explain Physical Activity Level in Adults With Osteoarthritis: A Cross-Sectional Study," *Journal of Orthopaedic Research* 41 (2023): 2629–2637.

32. N. M. Maldonato, R. Sperandeo, G. Caiazzo, et al., "Keep Moving Without Hurting: The Interaction Between Physical Activity and Pain in Determining Cognitive Function at the Population Level," *PLoS One* 13 (2018): e0197745.

33. N. Thanoo, A. L. Gilbert, S. Trainor, et al., "The Relationship Between Polypharmacy and Physical Activity in Those With or at Risk of Knee Osteoarthritis," *Journal of the American Geriatrics Society* 68 (2020): 2015–2020.

34. L. Ray, R. B. Lipton, M. E. Zimmerman, M. J. Katz, and C. A. Derby, "Mechanisms of Association Between Obesity and Chronic Pain in the Elderly," *Pain* 152 (2011): 53–59.

35. D. M. Higgins, E. Buta, A. A. Heapy, et al., "The Relationship Between Body Mass Index and Pain Intensity Among Veterans With Musculoskeletal Disorders: Findings From the Msd Cohort Study," *Pain Medicine* 21 (2020): 2563–2572.

36. D. Wechsler WAIS-R: Manual: Wechsler adult intelligence scale-revised. (No Title) 1981.

37. E. M. Andresen, J. A. Malmgren, W. B. Carter, and D. L. Patrick, "Screening for Depression in Well Older Adults: Evaluation of a Short Form of the CES-D," *American Journal of Preventive Medicine* 10 (1994): 77–84.

38. X. Zhao, H. Huang, and C. Du, "Association of Physical Fitness With Cognitive Function in the Community-Dwelling Older Adults," *BMC Geriatrics* 22 (2022): 868.

39. F. Montero-Cuadrado, L. Barrero-Santiago, R. Llamas-Ramos, and I. Llamas-Ramos, "Musculoskeletal Pain in Family Caregivers: Does a Therapeutic Physical Program in Primary Care Work? A Randomized Controlled Trial," *International Journal of Environmental Research and Public Health* 20 (2022): 185.

40. G. D. Miller, B. J. Nicklas, and R. F. Loeser, "Inflammatory Biomarkers and Physical Function in Older, Obese Adults With Knee Pain and Self-Reported Osteoarthritis After Intensive Weight-Loss Therapy," *Journal of the American Geriatrics Society* 56 (2008): 644–651.

41. D. G. Ives, A. L. Fitzpatrick, D. E. Bild, et al., "Surveillance and Ascertainment of Cardiovascular Events," *Annals of Epidemiology* 5 (1995): 278–285.

42. C. TengEL, "The Modified Mini-Mental State (3MS) Examination," *Journal of Clinical Psychiatry* 48 (1987): 314–318.

43. S. Musich, S. S. Wang, L. Slindee, S. Kraemer, and C. S. Yeh, "Association of Resilience and Social Networks With Pain Outcomes Among Older Adults," *Population Health Management* 22 (2019): 511–521.

44. J. Everaert, H. Benisty, R. Gadassi Polack, J. Joormann, and G. Mishne, "Which Features of Repetitive Negative Thinking and Positive Reappraisal Predict Depression? An In-Depth Investigation Using Artificial Neural Networks With Feature Selection," *Journal of Psychopathology and Clinical Science* 131 (2022): 754–768.

45. H.-J. Kuo, Y.-C. Huang, and A. A. García, "Fatigue, Pain, Sleep Difficulties, and Depressive Symptoms in Mexican Americans and Chinese Americans With Type 2 Diabetes," *Journal of Immigrant and Minority Health* 22 (2020): 895–902.

46. K. Macphail, "C-Reactive Protein, Chronic Low Back Pain And, Diet and Lifestyle," *International Musculoskeletal Medicine* 37 (2015): 29–32.

47. P. Morris, K. Ali, M. Merritt, J. Pelletier, and L. G. Macedo, "A Systematic Review of the Role of Inflammatory Biomarkers in Acute, Subacute and Chronic Non-Specific Low Back Pain," *BMC Musculoskeletal Disorders* 21 (2020): 142.

48. L. Hu, L. Smith, K. R. Imm, S. E. Jackson, and L. Yang, "Physical Activity Modifies the Association Between Depression and Cognitive Function in Older Adults," *Journal of Affective Disorders* 246 (2019): 800–805.

49. D. A. Raichlen, Y. C. Klimentidis, P. K. Bharadwaj, and G. E. Alexander, "Differential Associations of Engagement in Physical Activity and Estimated Cardiorespiratory Fitness With Brain Volume in Middle-Aged to Older Adults," *Brain Imaging and Behavior* 14 (2020): 1994–2003.

50. D. A. Fleischman, J. Yang, K. Arfanakis, et al., "Physical Activity, Motor Function, and White Matter Hyperintensity Burden in Healthy Older Adults," *Neurology* 84 (2015): 1294–1300.

51. T. J. Davis, D. J. Hevel, G. F. Dunton, and J. P. Maher, "Bidirectional Associations Between Physical Activity and Pain Among Older Adults: An Ecological Momentary Assessment Study," *Journal of Aging and Physical Activity* 1 (2022): 1–9.

52. B. Stubbs, S. Patchay, A. Soundy, and P. Schofield, "The Avoidance of Activities Due to Fear of Falling Contributes to Sedentary Behavior Among Community-Dwelling Older Adults With Chronic Musculoskeletal Pain: A Multisite Observational Study," *Pain Medicine* 15 (2014): 1861–1871.

53. C. Hicks, P. Levinger, J. C. Menant, et al., "Reduced Strength, Poor Balance and Concern About Falls Mediate the Relationship Between Knee Pain and Fall Risk in Older People," *BMC Geriatrics* 20 (2020): 94.

54. A. O'Neill, K. O'Sullivan, and K. McCreesh, "Lower Levels of Physical Activity Are Associated With Pain Progression in Older Adults, a Longitudinal Study," *European Journal of Pain* 25 (2021): 1462–1471.

55. R. Gordon and S. Bloxham, "A Systematic Review of the Effects of Exercise and Physical Activity on Non-Specific Chronic Low Back Pain." *Healthcare* (MDPI, 2016), 22.

56. S. H. Park, A. K. Baker, V. Krishna, S. C. Mackey, and K. T. Martucci, "Altered Resting-State Functional Connectivity Within Corticostriatal and Subcortical-Striatal Circuits in Chronic Pain," *Scientific Reports* 12 (2022): 12683.

57. Y. Cruz-Almeida, R. B. Fillingim, J. L. Riley, et al., "Chronic Pain Is Associated With a Brain Aging Biomarker in Community-Dwelling Older Adults," *Pain* 160 (2019): 1119–1130.

58. W. H. Ettinger, L. P. Fried, T. Harris, et al., "Self-Reported Causes of Physical Disability in Older People: The Cardiovascular Health Study," *Journal of the American Geriatrics Society* 42 (1994): 1035–1044.

59. L. H. P. Eggermont, S. G. Leveille, L. Shi, et al., "Pain Characteristics Associated With the Onset of Disability in Older Adults: The Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly Boston Study," *Journal of the American Geriatrics Society* 62 (2014): 1007–1016.

60. A. Ezzati, C. Wang, M. J. Katz, et al., "The Temporal Relationship Between Pain Intensity and Pain Interference and Incident Dementia," *Current Alzheimer Research* 16 (2019): 109–115.

61. S. M. Thielke, H. Whitson, P. Diehr, et al., "Persistence and Remission of Musculoskeletal Pain in Community-Dwelling Older Adults: Results From the Cardiovascular Health Study," *Journal of the American Geriatrics Society* 60 (2012): 1393–1400.

62. R. Borsheski and Q. L. Johnson, "Pain Management in the Geriatric Population," *Missouri Medicine* 111 (2014): 508–511.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.