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Associations of Pain Intensity and Frequency With Loneliness, Hostility, and Social Functioning: Cross-Sectional, Longitudinal, and Within-Person Relationships

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Abstract

Background The current studies investigated associations between pain intensity and pain frequency with loneliness, hostility, and social functioning using cross-sectional, longitudinal, and within-person data from community-dwelling adults with varying levels of pain.

Method Secondary analysis of preexisting data was conducted. Study 1 investigated cross-sectional (baseline data: $n = 741$) and longitudinal (follow-up data: $n = 549$, observed range between baseline and follow-up: 6–53 months) associations. Study 2 tested within-person associations using daily diaries across 30 days from a subset of the participants in Study 1 ($n = 69$).

Results Cross-sectionally, pain intensity and frequency were associated with higher loneliness ($\beta_{intensity} = 0.16$, $\beta_{frequency} = 0.17$) and worse social functioning ($\beta_{intensity} = -0.40$, $\beta_{frequency} = -0.34$). Intensity was also associated with higher hostility ($\beta = 0.11$). Longitudinally, pain intensity at baseline predicted hostility ($\beta = 0.19$) and social functioning ($\beta = -0.20$) at follow-up, whereas pain frequency only predicted social functioning ($\beta = -0.21$). Within people, participants reported higher hostility ($\gamma = 0.002$) and worse social functioning ($\gamma = -0.013$) on days with higher pain, and a significant average pain by daily pain interaction was found for loneliness. Pain intensity did not predict social well-being variables on the following day.

Conclusion Pain intensity and frequency were associated with social well-being, although the effects were dependent on the social well-being outcome and the time course being examined.

Keywords Acute pain · Biopsychosocial · Community-dwelling adults · Social well-being

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Introduction

In both humans and animals, the social environment influences how pain is perceived and expressed [1–5]. For example, pain is rated less intensely when experienced in the presence of a close social partner than alone [1, 6] but more intensely when experienced in the context of a familiar dyad experiencing similar pain [7]. These studies provide evidence that the social context influences pain outcomes and are complemented by cross-sectional research showing that patients with chronic pain report worse social well-being than those without chronic pain [e.g., 8, 9]. Yet, research has focused more on how social factors influences pain than on how pain influences social well-being. Furthermore, little work has examined the association between pain and social well-being in nonclinical or community-dwelling samples, and little is known about which aspects of pain (intensity or frequency) are associated with social outcomes in this population. The

current paper aimed to investigate if pain intensity or frequency predicted social well-being in community-dwelling adults using cross-sectional, longitudinal, and within-person data.

Social well-being is a complex construct and refers to how people function in their social world. It can include both subjective and objective components [10]. Because subjective measures of social well-being are often better predictors of health outcomes than objective predictors [10, 11], we chose three subjective facets of social well-being to investigate in the current study. Two of them (loneliness and hostility) assessed how people perceived their interpersonal relationships with others in their social network; one of them (social functioning) assessed how health and psychological functioning influenced social activities. We chose to focus on these three facets of social well-being because (1) of their potential to be influenced by pain in the moment and over time, (2) of literature supporting their role in influencing subsequent pain outcomes, and (3) data were available for each cross-sectionally, longitudinally, and within-people. The three facets will be referred to as "components of social well-being" hereafter, although they admittedly represent a small part of the broader social well-being construct.

Loneliness and Pain

Loneliness, or the discrepancy between desired and perceived connection with others [12], has been linked with higher pain intensity in fibromyalgia patients ($r = 0.35$ [13]) and in community-dwelling younger and older adults [14–16]. Among community-dwelling older adults with acute pain, loneliness predicted pain intensity above and beyond social network size or perceived affiliation, but no relationship existed between loneliness and pain intensity in adults with chronic pain [16]. Additionally, lonelier breast cancer survivors reported higher pain intensity than less lonely survivors [17]. Loneliness longitudinally predicted pain seven years later in older adults with chronic lower back pain [15], and social isolation predicted pain interference in patients with persistent pain, although pain did not predict social isolation [18]. In adults with fibromyalgia, within-person increases in loneliness predicted subsequent pain intensity [13, 19]. Cumulatively, cross-sectional, longitudinal, and within-person evidence suggests that loneliness influences pain.

Hostility and Pain

Like loneliness, hostility has also been associated with higher pain intensity. Hostility—unfriendliness, antagonism, or opposition to others in a social group—has been positively correlated with pain in cross-sectional studies [20, 21]. In pain-free undergraduates, a pain manipulation increased aggressive behavior for those high in state hostility, suggesting that the hostility-pain relationship may be bidirectional [22]. Individuals with musculoskeletal and vulvar pain reported higher pain intensity up to several hours after they perceived hostility from their spouses [23, 24]. However, whether pain intensity of frequency predict hostility over longer periods of time remains untested.

Social Functioning and Pain

People may withdraw from social activities when in pain. Social functioning refers to how well people maintain social activities like visiting family, friends, neighbors, or other groups in the face of physical or emotional problems [25]. Cross-sectionally, an extensive body of literature suggests that pain is negatively correlated with social functioning (e.g., $r = -0.48$ [e.g., 9, 26–28]), but longitudinal data exploring the temporal nature of these associations remains scarce.

Summary of the Literature on Pain and Social Outcomes

In summary, evidence suggests that loneliness, hostility, and social functioning influence pain, but whether pain influences these components of social well-being remains an important yet understudied question in community-dwelling adults. Many community-dwelling adults do not have chronic pain, defined as pain that persists beyond the normal healing time (generally taken to be 3–6 months), but instead experience episodes of acute pain with known etiology. Examining relationships between pain and social well-being in community-dwelling adults is important because it can (1) increase the generalizability of results beyond chronic pain samples, (2) provide an unrestricted range in pain frequency/intensity in which to study their relationship with social well-being, and (3) reveal that the negative consequences of pain are more ubiquitous than previously imagined. In this population, there are two characteristics of pain that may be particularly important: intensity, which refers to how salient the pain is, and frequency, which refers to how often pain occurs. Frequency can be examined by the number of days pain occurs, or by comparing those with frequent pain to those with infrequent pain.

The Current Studies

The current studies had three aims. The first aim was to examine the cross-sectional associations between pain intensity and frequency with loneliness, hostility, and social functioning in community-dwelling midlife adults with varying levels of pain (Study 1). The second aim was to examine these relationships longitudinally (Study 1). The third aim was to examine whether within-person changes in pain intensity predicted concurrent and next-day levels of loneliness, hostility, and social functioning (Study 2). This third aim was included because between-person associations do not necessarily

correspond to how people cope with increases in pain relative to their own baseline levels [29]. It was predicted that pain intensity and frequency would each be associated with higher loneliness, higher hostility, and worse social functioning cross-sectionally and longitudinally. It was also predicted that greater within-person deviations in pain would predict worse social outcomes on the same day and on the following day.

Study 1

Study 1 examined cross-sectional and longitudinal relationships between pain and loneliness, hostility, and social functioning over a period of 6 to 53 months.

Methods

Participants

The current study is a secondary analysis of data from a larger study of resilience in mid-life. An a priori power analysis was conducted for the parent study; for the current study, a post hoc power analysis using GPower revealed sufficient power to detect small effects in longitudinal analysis ($r \leq 0.12$) and in correlational analyses ($r \leq 0.10$).

Participants were 741 community-dwelling adults living in the Phoenix, Arizona, metropolitan area who completed a baseline visit (described below). Age, gender, education, and relationship status of the sample are provided in Table 1. Ethnic composition of the total sample was 73.6% white, 3.1% African American, 2.9% Asian American, American Indian, or Alaska Native, 12% more than one race, and 8.4% missing.

Of the total sample, 549 participants (74.09%) also completed a follow-up phone interview over the phone approximately 6–53 months following their baseline visit. Table 1 provides demographic characteristics of the follow-up sample at baseline. Those who completed the follow-up data were slightly older than those who did not ($M = 54.15$ vs. 52.51, respectively, $t(738) = 2.71$, Cohen's $d = 0.23$, $p = 0.007$), but did not differ on baseline pain intensity ($t(739) = 0.66$, $d = 0.06$, $p = 0.51$), pain frequency ($t(739) = -0.31$, $d = 0.02$, $p = 0.76$), loneliness ($t(739) = 1.33$, $d = 0.10$, $p = 0.19$), hostility ($t(738) = 1.70$, $d = 0.13$, $p = 0.12$), or social functioning ($t(739) = 1.01$, $d = 0.08$, $p = 0.31$).

Table 1 Demographic characteristic of study samples at baseline

	Study 1			Study 2
	Full sample ($n = 741$)	Frequent pain subsample[a] ($n = 312$)	Follow-up subsample ($n = 549$)	Daily diary subsample ($n = 69$)
% female	54.5	58.8	54.9	65.2
Mean age (SD)	53.73 (7.25)	54.05 (6.91)	54.15 (7.29)	54.23 (6.53)
Pain intensity (SD)	2.62 (1.39)	3.64 (1.17)	2.64 (1.38)	3.74 (1.04)
Pain frequency in days/month (SD)	9.19 (12.22)	21.07 (10.51)	9.11 (12.16)	20.75 (10.42)
Loneliness (SD)	0.90 (1.20)	1.13 (1.33)	0.87 (1.18)	1.00 (1.31)
Hostility (SD)	1.35 (0.67)	1.38 (0.73)	1.32 (0.63)	1.29 (0.57)
Social functioning (SD)	82.73 (24.60)	74.40 (28.41)	83.27 (24.61)	75.54 (29.03)
Education				
Less than high school	6.6%	5.5%	4.6%	8.9%
High school or GED	16.4%	18.1%	7.9%	5.9%
Some college	27.3%	33.1%	35.2%	35.3%
Graduated college	30.7%	27.6%	32.6%	35.2%
Professional degree	18.1%	15.6%	19.7%	14.7%
Relationship status				
Married	50.8%	48.2%	50.7%	47.1%
Divorced or separated	23.2%	26.9%	24.0%	26.5%
Unmarried but in a committed relationship	12.7%	13.1%	11.9%	13.1%
Single and never married	7.3%	7.5%	8.0%	5.9%
Widowed	5.3%	4.3%	5.4%	7.4%

BL baseline, FU follow-up, SD standard deviation

[a] Frequent pain subsample only includes participants who scored "1" on the dichotomous pain frequency variable (i.e., pain "every week," "several times a week," or "daily")

Procedure

All procedures were approved by the Arizona State University Institutional Review Board, and all participants provided informed consent. Participants were required to be 40 to 65 years of age, English- or Spanish-speaking, and primarily residing in the Phoenix metropolitan area. Because the parent study aimed to examine the influence of community characteristics on resilience, purposive sampling was employed to ensure sampling from diverse neighborhoods. Upon study enrollment, participants completed questionnaires and a phone interview to assess pain and social well-being. Participants were compensated for agreeing to participate in the study ($10), completing questionnaires ($30), and completing the phone interview ($30). Data were collected from July 2007 to February 2012.

Over the course of the study, the follow-up interview was added to track social functioning over time. Consequently, the length of time from completion of the original study to the follow-up phone assessment varied substantially (M = 20 months, median = 11 months; observed range = 6–53 months). All participants who indicated interest in participating in future studies were contacted for this follow-up assessment. Of the 741 original participants, 192 declined to provide follow-up data (see "Participants" section). Individuals received $30 for participation in the follow-up phone assessment. Follow-up data were collected between March and December 2012.

Measures

Pain Location At baseline, participants reported the extent to which they experienced pain over the past 4 weeks in 22 distinct body locations on a 0 = "none" to 3 = "severe" scale. Mean pain score for each of the 22 body sites were computed for descriptive purposes only.

Pain Frequency At baseline, participants reported how often during the past 4 weeks they experienced physical pain or discomfort lasting for more than a few minutes. Item responses were "never" (32.3% of the sample), "less than once a month" (7.0%), "once a month" (9.0%), "twice a month" (9.6%), "every week" (8.2%), "several times a week" (10.8%), and "daily" (23.1%). This ordinal variable, with unequal intervals between consecutive units on the scale (i.e., the difference between "never" and "less than once a month" was unequal to the difference between "several times a week" and "daily"), was converted into a continuous variable by assigning numerical values representing number of days of pain as follows: "never" = 0 days, "less than once a month" = 0.5 day, "once a month" = 1 day, "twice a month" = 2 days, "every week" = 4 days, "several times a week" = 15 days, and "daily" = 30 days.

Additionally, a dichotomous pain frequency variable was created to differentiate those with frequent pain at baseline ("every week," "several times a week," and "daily"; n = 312; coded 1) from those with infrequent or no pain at baseline ("twice a month" or less; coded 0), as those with pain ≥ 2 days per week are more likely to have negative pain-related impact in daily activities than those with less frequent pain [30]. Of the 312 in the frequent pain subsample, 231 (74.04%) completed follow-up data.

Pain Intensity A single item from the SF-36 was used at baseline and follow-up to assess pain intensity [25]. The item asked participants to rate the severity of their pain over the past 4 weeks using a scale of 1 = "none" to 6 = "severe." The single item was chosen over the bodily pain subscale because the latter confounds pain intensity and pain interference and would therefore contaminate predictions of social functioning.

Loneliness Loneliness was assessed at baseline and follow-up using a single item that asked participants to report "how much during the past 4 weeks have you felt lonely?" using a scale ranging from 1 = "all of the time" to 6 = "none of the time." The item was reverse-scored so that higher values indicated more loneliness.

Hostility Hostility was assessed at baseline and follow-up using a single item from the Positive and Negative Affect Schedule (PANAS) [31]. Participants reported how much they felt "hostile" during the past seven days using a scale from 1 = "very slightly/not at all" to 5 = "extremely." Single-item hostility measures have previously been used to predict pain outcomes [23].

Social Functioning The SF-36 social functioning subscale was used at baseline and follow-up to assess social functioning [25]. The subscale consisted of two items that assessed how much physical or emotional problems interfered with social activities. Scores ranged from 0 to 100 and were scored such that higher scores indicated better social functioning. Reliability for the social functioning subscale in the current sample was $\alpha = 0.85$ at baseline and $\alpha = 0.87$ at follow-up.

Data Analysis

Prior to data analysis, potential outliers on all study variables were flagged using a criterion of ± 4 SD [32]. Three outliers were found for the baseline hostility variable; no outliers were found for other variables. Exclusion of outliers did not substantively change results, and outliers represented plausible values of hostility, so subsequent models include all data points. Missing data analysis revealed that one participant did not provide baseline or follow-up hostility data; all other

variables had complete data available. Descriptive statistics and bivariate correlations were computed for all variables.

The first aim of Study 1 was to test whether pain intensity or frequency was cross-sectionally associated with components of social well-being. To do this, pain intensity was used as the single explanatory variable for loneliness, hostility, and social functioning in separate linear regressions. Pain intensity models were run twice, once with the full sample and a second time only including participants with frequent pain (i.e., 1 on the dichotomous pain frequency variable). Models were then repeated with continuous pain frequency as the single explanatory variable, and independent sample *t* tests were used to compare components of social well-being between those with frequent pain and those without.

The second aim of Study 1 was to examine whether pain intensity or frequency was longitudinally associated with components of social well-being. Using hierarchical regression, the first step contained the social well-being variable at baseline as the single explanatory variable of the social well-being variable at follow-up. The second step added pain intensity at baseline. This two-step approach was used to compute the additional variance explained by adding the pain variable. Separate pain intensity models were run for the full sample and for the frequent pain subsample. Models were repeated with continuous pain frequency as the explanatory variable and again with dichotomous pain frequency as the explanatory variable. Time between baseline and follow-up was entered as a covariate in all models. Its inclusion did not substantively change any results so only unadjusted models are presented below. Analyses were conducted using SPSS version 22 (IBM Corp., 2015).

Results

Descriptive Pain Outcomes

Table 2 describes the sites of pain and average pain per site of the sample. The most frequently endorsed pain sites were lower back, neck, and knees. The sites with the highest pain intensity were ankles, buttocks, and hips. One-hundred-seventy-nine (24.2%) participants did not report pain at any site; 83 (11.2%) reported pain at one site, 93 (12.6%) reported pain at two sites, and the remainder (52%) reported pain at three or more sites.

Descriptive Statistics and Cross-Sectional Associations

Tables 1 and 3 provide descriptive statistics, bivariate correlations, and test-retest correlations among study variables for the

Table 2 Pain sites of the full sample

Area	*n* (%) of full sample endorsing pain in area	Mean pain of those who endorsed pain in area (SD, observed range)
Neck	232 (31.3)	1.66 (0.71, 1–3)
Chest	43 (6.6)	1.58 (0.72, 1–3)
Upper back	150 (20.4)	1.73 (0.72, 1–3)
Lower back	318 (42.9)	1.74 (0.75, 1–3)
Buttocks	51 (6.9)	1.88 (0.76, 1–3)
Abdomen/stomach	72 (9.7)	1.72 (0.77, 1–3)
Right shoulder	122 (16.6)	1.66 (0.72, 1–3)
Left shoulder	121 (16.3)	1.61 (0.71, 1–3)
Right upper arm	54 (7.6)	1.70 (0.78, 1–3)
Left upper arm	46 (6.5)	1.74 (0.79. 1–3)
Right elbow	58 (7.8)	1.69 (0.70, 1–3)
Left elbow	49 (6.6)	1.59 (0.75, 1–3)
Right hand	94 (12.7)	1.71 (0.72, 1–3)
Left hand	89 (12.1)	1.67 (0.68, 1–3)
Right hip	99 (13.5)	1.82 (0.69, 1–3)
Left hip	102 (14.0)	1.82 (0.83, 1–3)
Right knee	168 (22.8)	0.38 (0.82, 1–3)
Left knee	164 (22.1)	0.37 (0.78, 1–3)
Right ankle	63 (8.5)	1.69 (0.75, 1–3)
Left ankle	58 (8.0)	1.69 (0.73, 1–3)
Right foot	72 (10.0)	1.76 (0.74, 1–3)
Left foot	75 (10.1)	1.81 (0.79, 1–3)

Table 3 Bivariate correlations among study variables in the full sample and frequent pain subsample (shown in parentheses)

	1	2a	2b	3a	3b	4a	4b	5a	5b
1. BL pain frequency—continuous	1	0.63* (0.31*)	0.48* (0.27*)	0.17* (0.08)	0.18* (0.18*)	0.07 (0.08)	0.12* (0.01)	− 0.34* (− 0.23*)	− 0.36* (− 0.27*)
2a. BL pain intensity		1	0.52* (0.48*)	0.16* (0.11**)	0.17* (0.14**)	0.11* (0.13**)	0.22* (0.22*)	− 0.40* (− 0.41*)	− 0.37* (− 0.41*)
2b. FU pain intensity			1	0.25* (0.29*)	0.28* (0.33*)	0.11* (0.17**)	0.23* (0.28*)	− 0.44* (− 0.44*)	− 0.57* (− 0.61*)
3a. BL loneliness				1	0.58* (0.61*)	0.26* (0.25*)	0.21* (0.30*)	− 0.42* (− 0.41*)	− 0.31* (− 0.32*)
3b. FU loneliness					1	0.20* (0.22*)	0.24* (0.32*)	− 0.33* (− 0.31*)	− 0.44* (− 0.49*)
4a. BL hostility						1	0.36* (0.31*)	− 0.23* (− 0.25*)	− 0.13* (− 0.16**)
4b. FU hostility							1	− 0.22* (− 0.25*)	− 0.28* (− 0.33*)
5a. BL social functioning								1	0.51* (0.49*)
5b. FU social functioning									1
n	–	–	549 (231)	–	547 (230)	–	548 (230)	–	549 (231)
Mean	–	–	2.77 (3.49)	–	0.86 (1.04)	–	1.33 (1.44)	–	82.47 (73.65)
SD	–	–	1.36 (1.31)	–	1.17 (1.29)	–	0.67 (0.77)	–	25.33 (29.21)

Values in parenthesis are from the frequent pain subsample. *N*, mean, and SD are presented only for the full sample and the frequent pain subsample at follow-up. These values for the full sample and the frequent pain subsample at baseline are found in Table 1

BL baseline, FU follow-up, SD standard deviation

**Significant at the 0.05 level (two-tailed), *significant at the 0.01 level (two-tailed)

full sample and frequent pain subsample. Cross-sectionally, pain intensity was associated with higher loneliness ($\beta = 0.16$, $t(740) = 4.35$, $p < 0.001$, adjusted $R^2 = 0.03$), higher hostility ($\beta = 0.11$, $t(739) = 2.98$, $p = 0.003$, adjusted $R^2 = 0.011$), and worse social functioning ($\beta = -0.40$, $t(740) = -11.68$, $p < 0.001$, adjusted $R^2 = 0.16$) in the full sample. Similar results were observed for pain intensity predicting higher loneliness ($\beta = 0.11$, $t(311) = 2.01$, $p = 0.045$, adjusted $R^2 = 0.01$), hostility ($\beta = 0.13$, $t(311) = 2.29$, $p = 0.02$, adjusted $R^2 = 0.01$), and worse social functioning ($\beta = -0.41$, $t(311) = -7.90$, $p < 0.001$, adjusted $R^2 = 0.17$) in the frequent pain subsample.

Pain frequency (measured continuously) was also associated with higher loneliness ($\beta = 0.17$, $t(740) = 4.60$, $p < 0.001$, adjusted $R^2 = 0.027$) and worse social functioning ($\beta = -0.34$, $t(740) = -9.78$, $p < 0.001$, adjusted $R^2 = 0.11$), but not higher hostility ($\beta = 0.068$, $t(739) = 1.85$, $p = 0.065$, adjusted $R^2 = 0.003$). Similarly, compared to participants with infrequent pain, those with frequent pain reported higher loneliness ($t(739) = -4.39$, $p < 0.001$, Cohen's $d = 0.32$) and worse social functioning ($t(739) = 8.20$, $p < 0.001$, Cohen's $d = 0.59$), but not higher hostility ($t(739) = -1.16$, $p = 0.23$, Cohen's $d = 0.09$).

Longitudinal Associations of Pain Intensity and Frequency With Components of Social Well-Being

Pain intensity at baseline was significantly associated with higher hostility and worse social functioning at follow-up after controlling for baseline hostility and social functioning (see Table 4). The effects of pain intensity on change in loneliness were small ($\Delta R^2 = 0.003$) and not likely to be of clinical significance, as the unstandardized betas revealed that for every one-point increase in pain intensity, loneliness at follow-up increased by only 0.06 points. Similar results were found in the frequent pain subsample.

Similarly, the continuous baseline pain frequency variable predicted worse social functioning at follow-up, even after controlling for baseline levels of social functioning. Effects were statistically significant but of limited clinical significance for pain frequency predicting future loneliness or hostility (see Tables 4 and 5), as unstandardized betas revealed that for every 1-day increase in pain frequency, loneliness at follow-up increased by 0.008 point and hostility at follow-up increased by 0.005 point. Similar results were obtained when the dichotomous pain frequency variable was used as a predictor with one exception: the relationship between pain frequency and hostility was slightly stronger.

Discussion

Pain Intensity and Social Well-Being

The cross-sectional associations between pain intensity and loneliness, hostility, and social functioning found in Study 1 replicate associations found in chronic pain samples [8, 9, 13, 19, 21, 23, 24]. The magnitude of the associations varied widely, with pain intensity accounting for 1 to 16% of variance in components of social well-being. The largest association, between pain intensity and social functioning, suggests that as pain becomes more intense, it disrupts people's ability to maintain their usual engagement in social and recreational activities. Alternatively, changes in social and recreational activities may make pain more intense. The magnitude of the cross-sectional association between pain intensity and social functioning in Study 1 is similar to what has previously been found between pain intensity and physical health ($r = -0.55$

Table 4 Longitudinal associations of pain at baseline (BL) predicting social outcomes at follow-up in the full and frequent pain samples

Outcome	Sample	Predictor	β	t	p	Adjusted R^2	ΔR^2	Model F (df)
Follow-up loneliness	Full sample	BL loneliness	0.57	15.94	< 0.001	0.331	–	–
		BL pain intensity	0.067	1.88	0.061	0.334	0.003	138.22 (2, 546)
		BL loneliness	0.56	15.90	< 0.001	0.331	–	–
		BL pain freq—cont.	0.079	2.25	0.025	0.336	0.005	139.36 (2, 546)
		BL loneliness	0.57	16.08	< 0.001	0.330	–	–
		BL pain freq—dichot.	0.032	0.91	0.36	0.331	0.001	136.20 (2, 546)
	Frequent pain[a]	BL loneliness	0.60	11.30	< 0.001	0.364	–	–
		BL pain intensity	0.053	0.99	0.32	0.367	0.003	67.48 (2, 229)
Follow-up hostility	Full sample	BL hostility	0.34	8.60	< 0.001	0.126	–	–
		BL pain intensity	0.19	4.73	< 0.001	0.159	0.030	52.42 (2, 546)
		BL hostility	0.35	8.73	< 0.001	0.126	–	–
		BL pain freq—cont.	0.093	2.32	0.021	0.133	0.007	42.70 (2, 546)
		BL hostility	0.35	8.84	< 0.001	0.124	–	–
		BL pain freq—dichot.	0.12	3.04	0.002	0.139	0.015	44.92 (2, 546)
	Frequent pain[a]	BL hostility	0.29	4.61	< 0.001	0.094	–	–
		BL pain intensity	0.18	2.92	0.004	0.123	0.033	16.92 (2, 228)
Follow-up soc. funct.	Full sample	BL social functioning	0.43	10.69	< 0.001	0.255	–	–
		BL pain intensity	− 0.20	− 4.93	< 0.001	0.285	0.030	110.46 (2, 548)
		BL social functioning	0.43	11.35	< 0.001	0.255	–	–
		BL pain freq—cont.	− 0.21	− 5.58	< 0.001	0.294	0.039	115.07 (2, 548)
		BL social functioning	0.46	12.15	< 0.001	0.254	–	–
		BL pain freq—dichot.	− 0.17	− 4.45	< 0.001	0.280	0.026	107.44 (2, 548)
	Frequent pain[a]	BL social functioning	0.39	5.99	< 0.001	0.238	–	–
		BL pain intensity	− 0.22	− 3.35	0.001	0.273	0.035	44.27 (2, 230)

BL loneliness, BL hostility, and BL social functioning were entered in step 1 of all 12 models. Pain intensity or frequency variables were entered in step 2 to examine the change in adjusted R squared from addition of the pain variable. All 12 models were run separately

BL baseline, soc. funct. social functioning, freq—cont. pain frequency using the continuous variable, freq—dichot pain frequency using the dichotomous variable (0 = not frequent pain, 1 = frequent pain)

[a] Frequent pain subsample only includes participants who scored "1" on the dichotomous pain frequency variable (i.e., pain "every week," "several times a week," or "daily")

[33]), pain-related interference with daily activities ($r = 0.55$ [32]), and pain-related disability ($r = 0.35$ [34]) in patients with chronic pain, suggesting that pain intensity may be similarly associated with social and physical dysfunction.

Surprisingly, pain intensity was similarly associated with components of social well-being in the full sample as in the subsample with frequent pain, even though the subsample with frequent pain reported higher pain intensity, loneliness, and social functioning than the full sample. This result stands in contrast to findings that suggest that loneliness is cross-sectionally associated with greater pain intensity and disability in older adults with acute but not with chronic pain [16]. This discrepancy may be related to differences in sample characteristics. The prior study's sample was composed of older adults, whereas the current study's sample was composed of middle-aged adults (age 40–65 at baseline), suggesting that the relationship between loneliness and pain intensity may become stronger as people age. Second, the presence of chronic pain could not be confirmed in the current sample. Although pain chronicity is associated with a higher number of pain sites and more frequent pain [30], it is likely that the frequent pain subsample was relatively high functioning given that they were recruited from the community and were willing to participate in research.

Longitudinally, pain intensity at baseline predicted hostility and social functioning (but not loneliness) after controlling for baseline levels of these variables. The magnitude of these longitudinal associations was small, with most of the variance in the social well-being variables at follow-up being explained by baseline levels of the social well-being variable. These small effects suggest that increases in pain intensity may contribute to hostility and social dysfunction, but given the extant literature, the directionality appears to be stronger for hostility and social dysfunction contributing to increases in pain intensity [18]. This is consistent with prior work finding that social isolation predicted pain interference but that pain interference

Table 5 Summary results of studies

Evidence for relationship?*

	Predictor	Outcome		
		Loneliness	Hostility	Social Functioning
Cross-sectional	Pain intensity	Yes	Yes	Yes
	Pain frequency—continuous	Yes	No	Yes
	Pain frequency—dichotomous	Yes	No	Yes
Longitudinal	Pain intensity	No	Yes	Yes
	Pain frequency—continuous	Negligible	Negligible	Yes
	Pain frequency—dichotomous	No	Yes	Yes
Within-person, same day	Pain intensity	No	Yes	Yes
	Average pain by daily pain interaction	Yes	No	No
Within-person, lagged	Pain intensity	No	No	No

*Evidence for relationship means that predictor explained 1% or more of variance in the outcome and that the statistical inferential test used to model the relationship was statistically significant. Negligible relationships are those in which the predictor explained less than 1% of variance in the outcome, although the test was statistically significant. No relationship means that the test was not statistically significant. Results from all tests are presented in the "Results" section

did not predict social isolation in a large sample of patients with persistent pain [18]. The small longitudinal effects in the current study may also be related to the nature of the community-dwelling sample. Stronger effects might be seen in clinical samples solely comprised of individuals with chronic pain. The small effects also suggest the presence of possible moderating influences. Pain intensity has been linked with negative mood, depression, fatigue, and anger, among other variables—each of which may serve to moderate the longitudinal relationships between pain intensity and social well-being [35–37]. The potential moderating influences of these variables should be tested in future research.

Pain Frequency and Social Well-Being

Cross-sectional effect sizes for pain frequency were similar to those of pain intensity, with frequency accounting for 3 to 11% of the variance in components of social well-being. The similarity in the magnitudes of correlations of pain frequency and intensity with components of social well-being is particularly surprising, given that intensity and frequency were only moderately correlated with one another ($r = 0.63$). The findings suggest that pain intensity and frequency each explain unique variance (albeit small amounts) in social well-being.

Similar to pain intensity, pain frequency prospectively accounted for worse social functioning. In chronic pain samples, there is a restriction of range in pain frequency, as patients often have constant pain. In community samples with varying degrees of pain, how often one has pain matters. Frequently experienced pain may be more damaging to social functioning in the long term than infrequently experienced pain. The mechanisms by which pain frequency interferes with future social functioning merit further exploration. People who experience frequent pain may limit social activities for fear that another painful episode might occur [38]. Alternatively, frequent pain may be perceived as uncontrollable and may negatively influence social activities. A third possibility is that people with frequent pain may have higher disability, fatigue, or poorer sleep, impairing their social functioning over time [21, 27, 32]. These possibilities are not mutually exclusive, and other mechanisms may also exist.

Unexpected Findings and Limitations

Several findings in the longitudinal analysis of the current study were surprising. First, controlling for days between the initial appointment and follow-up did not influence the results; if indeed components of social well-being become progressively worse over time as a function of pain, time should have been associated with worse social outcomes. One possibility is that components of social well-being change after 1 to 12 months following pain onset and then plateau, and that our follow-up window ($M = 20$ months after the initial appointment, SD = 11 months) was unable to capture this change in slope. Additionally, participants in the current study were not recruited at pain onset, so it may be that the effects of pain on social well-being were already established by the time they were recruited. Longitudinal data with more consistently spaced follow-up assessments and with the ability to track people in the transition from acute to chronic pain are needed to understand how components of social well-being change as a function of pain.

Study 1 has important limitations. Cross-sectional analysis cannot be used to speculate about causal processes. The

sample in Study 1 was highly educated and only included people in mid-life (40–65); as such, results may not generalize to all adults in the US population. The follow-up data in Study 1 did not assess pain, so the influence of components of well-being on future pain could not be examined.

Another significant limitation in Study 1 is that the results were based on retrospective aggregates. Whereas aggregates are useful in describing how people generally respond to pain, they do not describe how people respond to pain that differs from their own usual level of pain [39]. For a person who on average experiences pain intensity of 8 out of 10, that level of pain may not interfere with daily activities. In another person who typically experiences no pain, pain intensity of 8 out of 10 would likely be distressing and disruptive. Thus, examinations of within-person fluctuations in pain (rather than aggregate levels) are required to examine how changes in pain predict social well-being.

Study 2: Within-Person Associations

Study 2 used a subset of participants from Study 1 to examine within-person fluctuations in pain intensity. Relationships at the between-person level do not necessarily generalize to the within-person level. For instance, in community-dwelling older adults, within-person fluctuations in pain and executive functioning interact to predict future health, but between-person levels of pain and executive functioning do not [39]. Studying within-person associations is important because they provide insight into how people respond to changes in pain relative to their own usual levels. Study 2 sought to examine how between-person means and within-person deviations in pain intensity predicted loneliness, hostility, and social functioning on both the same day and the next day using daily diary data across 30 days. It was hypothesized that on days when pain was higher than usual, participants would report worse social well-being on the same day and on the following day. Reverse-directionality and cross-level interactions were also examined in Study 2 in exploratory analysis.

Method

Participants

One quarter of the Study 1 sample ($n = 200$) was randomly selected to participate in a study of daily life. Of these participants, 184 provided daily diary data, and 69 reported having recurrent pain. The sample for Study 2 consisted of these 69 participants. Table 1 provides demographic characteristics of Study 2 participants at baseline. The Study 2 sample reported significantly worse baseline social functioning ($t(182) = 3.58$, $d = 0.51$, $p = 0.001$) and marginally more baseline loneliness ($t(182) = 1.93$, $d = 0.28$, $p = 0.055$) than the remainder of the daily diary sample who did not report recurrent pain. The two subsamples did not differ on baseline hostility ($t(182) = 0.15$, $d = 0.019$, $p = 0.88$). Completion rate of the diary dataset was 79.1%.

Procedure

Participants completed daily diaries on a tablet computer for 30 consecutive days. They were trained to use the equipment and were instructed to notify staff immediately if a problem occurred; malfunctioning equipment was replaced as needed. The dates of each entry were verified with built-in software to ensure that entries were not retrospectively entered. After the 30-day period, participants were compensated $3 for every entry for up to $90 in total.

Measures

Pain Each night, participants reported "what number between 0 and 100 best describes [his/her] average level of physical pain," with anchors of 0 = "no pain" to 100 = "pain as bad as it can be." The intraclass correlation (ICC) for pain across all days was 0.65, indicating that about 2/3 of the variance in pain was stable individual differences, and 1/3 was fluctuations within people over time.

Loneliness Each night, participants reported the extent to which they felt lonely that day using a single-item scale, with response options ranging from 1 = "not at all" to 5 = "very much." The ICC for loneliness across all days was 0.64.

Hostility Each night, participants reported how much they felt "hostile" that day on a single-item scale from ranging from 1 = "very slightly/not at all" to 5 = "extremely." The ICC for hostility across all days was 0.55.

Social Functioning Each night, participants reported "to what extent have [their] physical health or emotional problems interfered with [their] normal social activities with family, friends, neighbors, or groups" with anchors of 1 = "not at all" to 5 = "extremely." The variable was reverse-scored so that higher scores represent better functioning. The ICC for social functioning across all days was 0.56.

Data Analysis

All analyses used the linear mixed modeling package LME4 in R, and *r*-squared estimates were computed using the r2glmm package. This analytic approach controls for clustering of observations in hierarchical datasets (e.g., daily diaries), thereby allowing for analysis of daily-level variables without biasing *p* values. For all analyses, daily predictors were

centered using the cluster (person) mean and person-level predictors (e.g., average levels of daily pain aggregated across the 30-day period) were centered on the grand mean. For daily variables, a value of 0 indicated a typical level of pain, positive numbers indicated more pain than usual for that person, and negative numbers indicated less pain than usual for that person. These centered predictors were entered as simultaneous predictors of loneliness, hostility, and social function on both the same day (Eq. 1) and on the following day, while controlling for the current day's pain (Eq. 2), while also controlling for average levels of pain intensity across the 30-day period (a person-level variable):

$$Y_{ij} = \gamma_{00} + \gamma_{01} \times \text{daily pain} + \gamma_{10} \times \text{average pain} + u_{0j} + r_{ij} \quad (1)$$

$$Y_{ij} = \gamma_{00} + \gamma_{01} \times \text{previous day's pain} + \gamma_{02} \times \text{daily pain} + \gamma_{10} \times \text{average pain} + u_{0j} + r_{ij} \quad (2)$$

Random slopes were estimated for the effects of daily pain on each outcome (allowing variability between individuals in estimating the effects of daily pain), along with random intercepts, as likelihood ratio tests revealed that random effect models were a better fit for the data than fixed effect models. Cross-level interaction terms were estimated between average pain levels over the 30-day period with daily pain levels to determine whether these daily relationships varied significantly between participants who reported different levels of pain intensity on average across the 30-day period (Eq. 3) [40].

$$Y_{ij} = \gamma_{00} + \gamma_{01} \times \text{daily pain} + \gamma_{10} \times \text{average pain} + \gamma_{11} \times \text{daily pain} \times \text{average pain} + u_{0j} + r_{ij} \quad (3)$$

In cases of significant interaction terms, simple slopes were estimated for grand mean (level-2) scores in 30-day average pain for the entire sample, as well as average daily pain scores 1 standard deviation above and below the grand mean.

As a secondary step, and as a means of comparing our results to the results of Study 1, we also examined the relationships between these variables at the individual mean level using aggregated daily variables for each participant (Eq. 4):

$$\beta_{0j} = \gamma_{00} + \gamma_{10} \times \text{average pain} + u_{0j} \quad (4)$$

For significant daily effects, r^2 variance estimates were computed to address the relative size of each estimated effect [41].

Results

Results of the hierarchical models revealed that there were no lagged associations between pain intensity on 1 day and ratings of loneliness, hostility, or overall social functioning on the next day ($p > 0.05$ in all cases). When these paths were reversed, no social variable was found to predict pain intensity on the next day ($p > 0.05$ in all cases).

However, same-day associations revealed that on days when pain was higher than people's personal average, participants reported higher hostility ($\gamma = 0.003$, $SE = 0.001$, $p = 0.007$, $r^2 = 0.005$) and worse social functioning ($\gamma = -0.015$, $SE = 0.002$, $p < 0.001$, $r^2 = 0.068$), but not loneliness ($p = 0.23$; see Table 6). Regarding the effects of aggregated (i.e., between-person) scores, individuals with higher average levels of daily pain intensity reported worse social functioning ($\gamma = 0.031$, $SE = 0.003$, $p < 0.001$, $r^2 = 0.35$) and higher

Table 6 Summary table of same-day associations between pain intensity, loneliness, hostility, and social functioning

	Loneliness	Hostility	Social function
Level 1			
Intercept	1.62 (0.104)**	1.21 (0.062)**	1.76 (0.065)**
Daily pain intensity	0.003 (0.002)	0.003 (0.001)*	0.016 (0.002)**
Level 2			
Average pain intensity	0.009 (0.005)	0.006 (0.002)*	0.031 (0.003)**
Interaction	− 0.0002 (0.00008)*	0.00001 (0.00006)	0.000 (0.000)
Variance components			
Level-1 slope	0.00004	0.00003	0.0001
Level-2 intercept	0.713	0.249	0.251
Residual	0.390	0.190	0.494
Number of parameters	8	8	8
R^2	0.034	0.039	0.393
− 2 log likelihood	− 1640.5	− 1068.7	− 1781.2

**$p < 0.01$, *$p < 0.05$

average levels of hostility ($\gamma = 0.006$, SE = 0.003, $p = 0.039$, $r^2 = 0.033$), but pain intensity was not significantly related to average levels of loneliness ($\gamma = 0.008$, $SE = 0.005$, $p = 0.087$, $r^2 = 0.025$).

Of note, a significant average pain-by-daily pain interaction was found for daily levels of loneliness (interaction $\gamma = -0.0002$, SE = 0.00007, $p = 0.047$), suggesting that the magnitude of the relationship between daily pain intensity and loneliness decreased as average pain increased. The relationship of daily pain and daily loneliness was strongest at lower levels of average pain (see Fig. 1). The interactions of daily and average pain levels were not significant for hostility (interaction $\gamma = 0.00001$, SE = 0.00005, $p = 0.81$) or social functioning (interaction $\gamma = 0.0002$, SE = 0.00001, $p = 0.056$).

Discussion

Within-person associations allow for the examination of how people respond to pain when it is higher or lower than their usual levels. When daily pain was higher than usual, people reported being more hostile and having worse social functioning. Exploratory analysis revealed that for loneliness, daily pain interacted with average pain such that the relationship of daily pain and daily loneliness was strongest at lower levels of average pain (see Fig. 1). For those with higher average pain intensity, there appeared to be a ceiling effect on loneliness. This complements results from Study 1 and previous work that finds loneliness to be cross-sectionally associated with greater pain intensity and disability in those with acute but not with chronic pain [16]. In cross-sectional studies pain intensity may be unrelated to loneliness because those with chronic pain are already at high levels of loneliness. These results suggest that interventions aimed at promoting social well-being should target individuals before changes in loneliness have taken place. The effectiveness of such early interventions presents an important area for future research.

Importantly, there was no evidence of lagged effects; that is, pain intensity did not appear to affect levels of social well-being, nor did these relationships emerge when the models were tested in reverse. The lack of support for lagged effects suggests that pain-related disruption in components of social well-being may be brief, lasting only for perhaps minutes or hours but not days. Alternatively, the effects of pain intensity on components of social well-being from 1 day to the next may be insignificant in and of themselves but may, over time, accumulate to produce significant changes. The longitudinal analyses in Study 1 provide only partial support for this hypothesis, as longitudinal effects of pain intensity were found for social functioning and hostility but not for loneliness. These findings suggest that pain may change how people function in their social networks before it changes perceptions of interpersonal functioning. Future work should continue to explore the time course over which pain may (or may not) shape individual components of social well-being.

Study 2 had several important limitations that should be noted. First, daily diaries were only examined in the frequent pain subsample and as such the within-person associations between pain frequency and the components of social well-being were not examined. Second, the daily diaries utilized single-item measures to assess the constructs of interest. Third, because pain chronicity was not directly assessed or verified, results cannot be expected to generalize to chronic pain samples. Despite these shortcomings, there are notable aspects of study 2 that add to the literature. Results highlight the importance of assessing within-person deviations in pain and average levels of pain, as each may uniquely contribute to components of social well-being at the moment. Additional

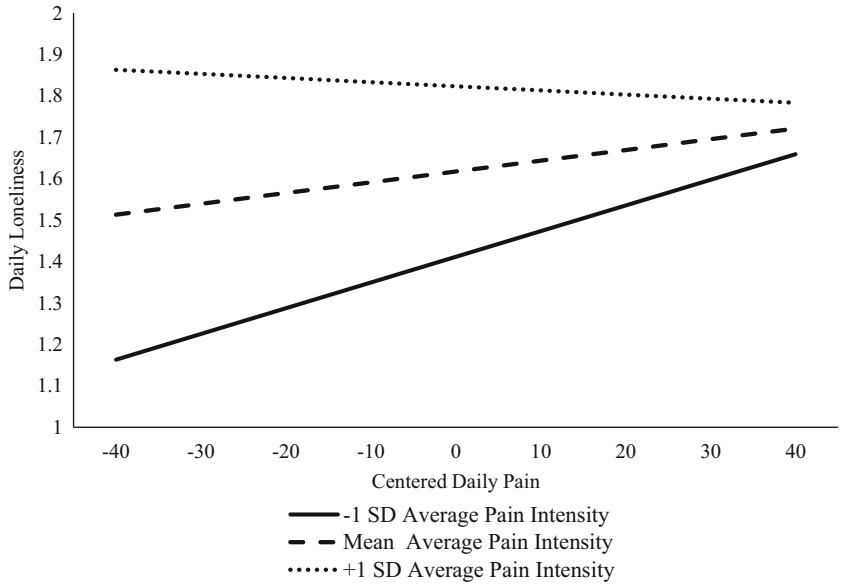

Fig. 1 Interactions of average pain by daily pain predicting daily loneliness

strengths of Study 2 include the relatively long assessment period (30 days of data) and the ability to test cross-level interactions between daily and average levels of pain.

General Discussion

Higher pain intensity was associated with worse social well-being in both cross-sectional data and aggregated daily-diary data. However, contrary to the study hypotheses, support for pain intensity influencing later social well-being was limited. The longitudinal associations between pain intensity and social well-being were small or not statistically significant, and the lagged associations between daily pain intensity and next-day social well-being were nonsignificant. Results were largely similar for pain frequency. Overall, comparing results from both of our studies with those in the literature, it appears that that social variables may be stronger predictors of pain than vice versa in community-dwelling adults, although more work is needed to definitively answer this question in light of the current studies' limitations.

Nevertheless, the results from both studies contribute to the literature on pain and social well-being in several important ways. They are among the first studies to examine the role of pain as a predictor of social well-being in community-dwelling adults. The sample was demographically diverse, with good generalizability to middle-aged, community-dwelling adults in the general population. Additionally, these were the first studies to examine three social outcomes simultaneously, and the first to examine pain as a longitudinal and within-person predictor of components of social well-being. Further, these were the first studies to examine the effects of pain frequency on components of social well-being in a community-dwelling sample. Unique relationships between pain intensity and frequency were found for some outcomes while similar relationships were found for others, suggesting that they each should be examined when assessing the interrelationships between pain and social well-being.

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Compliance with Ethical Standards

Disclaimer The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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