

# Are Formal and Informal Home Mindfulness Practice Quantities Associated With Outcomes? Results From a Pilot Study of a Four-Week Mindfulness Intervention for Chronic Pain Management

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## Abstract

**Background:** The association between home mindfulness practice quantity in standard length mindfulness-based interventions (MBIs) and chronic pain outcomes is variable. Few studies focus on abbreviated MBIs (< 8 weeks) and distinguish between formal guided practices and informal practices in daily life.

**Objectives:** To characterize home mindfulness practice and explore associations between home practice quantity and pre-to-post-outcome changes after an MBI for chronic pain.

**Methods:** In this single-arm study, 21 adults with chronic pain (mean age = 54 years, 81% White, mean pain duration = 7 years) completed an MBI with four weekly group sessions. Pre and post self-report measures of pain intensity/interference, physical function, depression, anxiety, positive affect, sleep disturbance (all PROMIS measures), and pain acceptance, catastrophizing, perceived stress and mindfulness were completed, along with daily surveys of formal (mindfulness of breath, body scan) and informal (breathing space, mindfulness of daily activities) practice. Bivariate correlations and multivariable regression models were used to assess the association between days and minutes of practice and change in outcomes.

**Results:** On average, formal practice was completed on 4.3 days per week and 13.5 minutes per day. Informal practice was completed on 3.5 days per week and 8.6 minutes per day. Formal practice was not significantly correlated with outcomes (Spearman's  $\rho = |.01|$ – $|.32|$ ), whereas informal practice was correlated with multiple outcomes ( $\rho = |.04|$ – $|.66|$ ). Number of days practiced informally was associated with improved pain interference, physical function, sleep disturbance, and catastrophizing ( $p$ 's  $\leq .05$ ). Number of minutes practiced informally was associated with improved pain interference, anxiety, positive affect, and catastrophizing ( $p$ 's  $\leq .05$ ).

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**Conclusion:** Informal home practice quantity, but not formal practice quantity, is associated with improved outcomes during an abbreviated MBI for chronic pain. For these MBIs, it is important to evaluate the distinct roles of formal and informal practice.  
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## Keywords

mindfulness, mindfulness intervention, chronic pain, home practice, engagement, adherence

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## Introduction

Mindfulness-based interventions (MBIs) such as mindfulness-based stress reduction (MBSR)<sup>1</sup> and mindfulness-based cognitive therapy (MBCT)<sup>2</sup> are efficacious for improving patient-reported outcomes such as pain interference, pain intensity, and psychological distress for people living with chronic pain.<sup>3-5</sup> Mindfulness can be defined as the awareness that emerges from self-regulating one's attention to present-moment experience with an orientation of curiosity and openness, even when an experience is unpleasant or unwanted.<sup>6,7</sup> Engagement in mindfulness practices is presumed to be a critical behavioral mechanism for the beneficial effects of MBIs. Participants of standardized 8-week MBIs are encouraged to engage in guided or unguided mindfulness meditation practices (e.g., mindfulness of breathing, walking meditation, or body scan) for 45 minutes per day, 6 days per week and to practice bringing mindful attention to daily activities (e.g., eating, brushing teeth).<sup>1,2</sup> Thus, mindfulness practices can be separated into formal and informal types, with formal practice referring to setting aside time to engage in mindfulness meditation, and informal practice referring to purposefully being mindful during daily life experiences or activities.<sup>8</sup>

Studies that have evaluated the association between mindfulness practice engagement and MBI outcomes have found variable results. A meta-analysis of 28 trials of either MBSR or MBCT in a variety of healthy and clinical populations found a small but significant association ( $R = .26$ ) between home practice engagement and post-treatment outcomes.<sup>9</sup> Most included studies reported on psychological outcomes ( $n = 19$ ), with fewer reporting on physical outcomes ( $n = 6$ ) or targeting chronic pain populations specifically ( $n = 2$ ).<sup>9</sup>

A recent systematic review examined adherence to home meditation practices in third-wave psychotherapies for participants with chronic pain.<sup>10</sup> Nine of the included studies, which primarily evaluated 8-week MBCT or MBSR programs, examined the relationship between quantity of home meditation practice and health outcomes. Seven out of 9 studies found significant associations between amount of home practice completion and at least one health outcome measured. However, there was inconsistency across studies in the outcomes measured and the method of assessing home

practice. Most studies measured formal practice or did not distinguish between formal and informal practice.<sup>10</sup>

Brief mindfulness interventions lasting fewer than 8 weeks and with shorter daily practice recommendations are becoming more common to increase accessibility and scalability of mindfulness interventions.<sup>11</sup> There is minimal research examining whether the reduced home practice quantity as part of brief MBIs for chronic pain are associated with intervention outcomes. Thus, the purpose of this article is (1) to characterize the frequency, duration, and types of home practice completed by adults with chronic nonmalignant pain who enrolled in a study of a 4-week mindfulness intervention for chronic pain management and (2) to explore whether frequency and duration of formal and informal home mindfulness practice is associated with changes in pain-related and psychosocial outcomes from pre- to post-intervention.

## Methods

This post-hoc analysis used data from a single-arm pilot feasibility trial of a 4-week mindfulness intervention for adults with chronic pain. The methods and primary and secondary outcomes of the pilot study ( $N = 23$ ) are described in detail elsewhere.<sup>12</sup> Briefly, the results demonstrated that the intervention delivery was feasible and acceptable, and participants reported significant pre- to post-intervention changes in 9 out of the 11 outcomes measured.<sup>12</sup> The University of North Carolina (UNC) at Chapel Hill Institutional Review Board approved all study procedures.

## Participants

Participants were eligible if they were (1) adults aged 18 and older with chronic nonmalignant pain, defined as having daily or almost daily pain for at least 3 months' duration, (2) English-speaking, (3) had any medical provider for pain management, (4) reported pain bothersomeness  $>3$  on a 0-10 scale and/or pain interference with general activities  $>2$  on a 0-10 scale in the past 7 days. Participants were excluded if they reported (1) history of psychotic disorder, (2) history of psychiatric hospitalization in the past 2 years, (3) a score  $>4$  on the Alcohol Use Disorders Identification Test

or >2 on the Drug Abuse Screening Test, (4) previously completed a mindfulness course or had a current, regular mindfulness meditation practice. Twenty-one out of 23 enrolled participants were included in the analyses. Data from two participants were excluded, because one participant withdrew from the study after one session and one participant completed only two daily practice surveys out of 20.

### Measures

All measures were self-completed by participants online using Research Electronic Data Capture (REDCap)<sup>13</sup> surveys. Outcome measures were administered before treatment and 1 week after treatment (four weeks post-baseline). The pre-treatment survey requested information about demographics (age, gender, race, ethnicity, education, income), chronic pain duration, pain conditions, number of chronic pain sources, and current pain medications.

Daily online REDCap surveys assessed participants' mindfulness practice for 20 days from the day following Session 1 through the day of Session 4, the final session. Each survey asked if participants completed any of the assigned mindfulness practices that day (yes/no), and if yes, which practice/s and for how many minutes. The response options changed each week as new mindfulness practices were assigned.

Patient-Reported Outcomes Measurement Information System (PROMIS) adult short-form scales included Pain Interference 6b, Physical Function 4a, Depression 4a, Anxiety 4a, Sleep Disturbance 4a and Positive Affect and Wellbeing.<sup>14</sup> Average pain intensity over the past 7 days was rated from zero (no pain) to 10 (worst pain imaginable). Additional measures included the four-item Perceived Stress Scale (PSS-4),<sup>15</sup> the 14-item Freiburg Mindfulness Inventory (FMI-14),<sup>16</sup> the 13-item Pain Catastrophizing Scale (PCS),<sup>17</sup> and the twenty-item revised Chronic Pain Acceptance Questionnaire (CPAQ).<sup>18</sup> For all measures, higher scores indicate higher levels of the construct measured.

### Intervention

The mindfulness intervention was adapted and abbreviated from the MBSR<sup>1</sup> and Mindfulness-based Pain Management<sup>19</sup> programs and consisted of four, weekly group mindfulness classes each lasting 90 min. While standard mindfulness curricula typically assign around 45 min of daily mindfulness practice, in this abbreviated program, participants were encouraged to engage in 10 to 20 min of guided home mindfulness practice per day, and the lengths of the guided practice audio-recordings provided aligned with this recommendation. For this study, formal practice assignments included body scan and sitting meditation with mindfulness of breathing. Informal practice assignments included breathing space and instructions to be mindful while undertaking self-selected activities of daily life (e.g., eating, brushing teeth,

washing dishes). The breathing space, sometimes called the "three-minute breathing space,"<sup>2</sup> is a short practice involving three defined steps and has been described as both a formal and informal practice. We chose to define it as an informal practice for this study, even though a 3-minute guided audio recording was provided, as participants were also instructed to practice it spontaneously in daily life for any desired length of time as painful or stressful experiences occurred. Formal practices were introduced in session 1, whereas informal practices were introduced in session 2; thus, there were 3 weeks and 2 weeks of data collected on formal and informal home practice quantity, respectively. Additional information about the intervention is described in a previous report.<sup>12</sup>

### Procedure

Participants were recruited through referral from UNC Pain Management Center providers; flyers placed in UNC outpatient clinics, including the Pain Management Center, Family Medicine, and Physical Medicine and Rehabilitation; a listserv-serve email sent to university/hospital employees and students at UNC; and by word-of-mouth. Eligibility was determined with a telephone screen and written informed consent was provided via an electronic REDCap form. Participants were emailed links to REDCap surveys within one week of session 1 (pre-treatment) and one week after session 4 (post-treatment). A link to the mindfulness practice survey was emailed daily for 20 days during the intervention period. Each daily practice survey was available to complete on the day of practice through the following day. Group mindfulness classes with 6 to 9 participants enrolled per group were held at an outpatient clinic. Participants were given a \$15 Amazon gift card for completing the pre-treatment and post-treatment surveys (\$30 for both).

### Statistical Analyses

Daily practice was separated into formal practice (body scan, sitting meditation with awareness of breath) and informal practice (breathing space, mindfulness of daily activities). For each individual participant, we calculated the mean number of days per week and the mean number of minutes per day of formal and informal practice. All measures were examined for missing data, distribution, and outliers. To handle one extreme outlying value for minutes per day of informal practice, the extreme value was replaced with the next highest value. The mean number of days per week engaged in each of the four mindfulness skills was also calculated. To characterize the sample, descriptive statistics (medians, interquartile range (IQR), and minimum and maximum values) were then calculated for each practice variable. We chose the median as the measure of central tendency because the distributions of practice variables were skewed or had outlying values. Incomplete daily practice surveys were considered days on which practice did not occur when calculating days and

minutes practiced. The median number of missing daily surveys out of 20 was 3 (interquartile range = 0 - 5).

Bivariate correlations (Spearman's rho) were examined for patterns of association between each of four practice variables (days and minutes of formal and informal practice) and the pre- to post-treatment change score for each outcome measure. The nonparametric correlation was chosen due to practice variables having non-normal distributions and some outlying values. Correlation coefficients were interpreted as weak ( $< .30$ ), moderate ( $.30 - .49$ ), and strong ( $\geq .50$ ). Change scores were calculated such that negative values indicate a decrease and positive values indicate an increase in the score from pre- to post-intervention and are presented in a previous report.<sup>12</sup> Based on the observed pattern of bivariate correlations showing that only informal practice quantities were significantly and more than weakly correlated with outcomes, we subsequently conducted separate multivariable linear regression models, with each model regressing the change in one outcome on one practice variable (either average days or minutes of informal practice), controlling for age, sex, and income; while practice variables exhibited non-normal distributions, the distributions of the change scores were reasonably symmetric. We did not conduct regression models with amounts of formal practice due to the lack of bivariate associations with outcomes. We did not adjust the type 1 error rate for multiple comparisons as these post-hoc analyses were exploratory and intended to help generate hypotheses for testing in future trials. IBM SPSS version 28 was used to conduct analyses.

## Results

Demographic and pain characteristics of the analyzed sample ( $N = 21$ ) are described in Table 1 and of the total enrolled sample ( $N = 23$ ) in a previous publication.<sup>12</sup> The mean age was 54.1 years ( $SD = 15.7$ ) and most participants self-identified as female (81.0%), non-Hispanic White (81.0%), and had a college degree or greater (76.2%). The mean duration of chronic pain was 7.4 years ( $SD = 7.3$ ). The most prevalent sources of pain were reported as back pain (81.0%) followed by neck pain (57.1%). Most participants (71.4%) reported having 3 or more areas or sources of chronic pain. Four participants (19.0%) reported not taking any medications for pain, with most participants (61.9%) taking at least two medications to treat pain. Eight participants (38.1%) reported taking at least one opioid pain medication.

Participants reported completing formal practice on a median of 4.3 days per week for a median of 13.5 minutes per day over 3 weeks. Participants reported completing informal practice on a median of 3.5 days per week for a median of 8.6 minutes per day over 2 weeks. When accounting only for the days on which mindfulness practice actually occurred, the median minutes of formal and informal practice was 18.6 and 16.3 min, respectively. The number of days and minutes of formal practice were

**Table 1.** Baseline Sample Characteristics ( $N = 21$ ).

Variable	N (%) or M(SD), range
Age in years	54.1 (15.7), 26-77
Female gender (remaining are male)	17 (81.0%)
Race/Ethnicity	
White, non-Hispanic	17 (81.0%)
Black or African American	3 (14.3%)
Hispanic or Latinx	1 (4.8%)
Education Level	
Less than high school	0 (0%)
High school diploma or equivalent	1 (4.8%)
Some college, no college degree	4 (19.0%)
College degree or greater	15 (71.4%)
Chose not to answer	1 (4.8%)
Annual Income Level	
Less than \$20,000	5 (23.8%)
\$20,000-40,000	1 (4.8%)
\$40,000-60,000	4 (19.0%)
\$60,000-80,000	2 (9.5%)
More than \$80,000	7 (33.3%)
Chose not to answer	2 (9.5%)
Years with Chronic Pain	7.4 (7.3), 1-30
Sources of Pain	
Back	17 (81.0%)
Neck	12 (57.1%)
Arthritis (any type)	11 (52.4%)
Neuropathy	9 (42.9%)
Headache/migraine	6 (28.6%)
Fibromyalgia	4 (19.0%)
Pelvic	4 (19.0%)
Other	8 (38.1%)
Number of Sources of Pain	
1	4 (19.0%)
2	2 (9.5%)
3 or greater	15 (71.4%)
Number of Pain Medications	
0	4 (19.0%)
1	4 (19.0%)
2	7 (33.3%)
3 or greater	6 (28.6%)

strongly correlated with each other (Spearman's rho [ $\rho$ ] = .80), the number of days and minutes of informal practice were strongly correlated with each other ( $\rho = .57$ ), and the number of days and minutes of formal practice were weakly to moderately correlated with the number of days and minutes of informal practice ( $\rho$ 's = .14-.38). Additional descriptive statistics characterizing mindfulness practice quantities are shown in Table 2.

In Spearman's  $\rho$  correlations (Table 3), the number of days and minutes of formal practice were weakly correlated ( $\rho$ 's  $< .30$ ) with nearly all outcomes and all correlations were nonsignificant. In contrast, the number of days and/or minutes of informal practice were moderately to strongly correlated

**Table 2.** Characterizing Home Mindfulness Practice During a 4-Week Mindfulness Program for Chronic Pain Management.

Practice Measure	Median	Interquartile Range 25 <sup>th</sup> percentile; 75 <sup>th</sup> percentile	Minimum; Maximum
Average days practiced per week			
Formal practice (includes Body Scan and Sitting Meditation)	4.3	3.3; 6.5	2.7; 6.7
Informal practice (includes Breathing Space and Mindfulness of Daily Activities)	3.5	2.5; 4.8	.0; 7.0
Average minutes practiced per day			
Formal practice	13.5	6.7; 26.2	3.8; 40.5
Informal practice	8.6	4.6; 14.1	.0; 38.2
Average minutes practiced per day accounting only for the number of days on which practice occurred			
Formal practice	18.6	12.4; 27.4	9.4; 42.6
Informal practice	16.3	10.3; 25.6	.0; 162.5
Individual Skills Practice			
Sitting Meditation average days per week (over 3 weeks)	4.0	3.0; 6.5	2.0; 6.7
Body Scan average days per week (over 2 weeks)	3.0	1.3; 6.0	.5; 7.0
Mindfulness of Daily Activities average days per week (over 2 weeks)	1.5	.5; 2.5	.0; 3.5
Breathing Space days per week (over 1 week)	2.0	1.0; 5.0	.0; 7.0

**Table 3.** Spearman’s Rho ( $\rho$ ) Bivariate Correlations Between Home Mindfulness Practice Quantities and Pre- to Post-mindfulness-based Intervention MBI Change in Outcomes.

	Pain Interference	Physical Function	Depression	Anxiety	Sleep Disturbance	Positive Affect	Pain Intensity	Perceived Stress	Mindfulness	Pain Catastroph.	Pain Acceptance
Days Formal	.11	.10	.11	.32	-.09	.01	.05	.10	-.27	-.07	-.11
Minutes Formal	-.03	.17	.02	.16	-.22	.11	-.04	.17	-.26	-.14	-.04
Days Informal	-.32	.57*	-.19	-.29	-.46*	.38	-.27	-.32	.07	-.53*	.22
Minutes Informal	-.40	.45*	-.23	-.19	-.19	.66*	-.04	.10	.25	-.35	.36

Key: Weak  $\rho < .30$  Moderate  $.30 \leq \rho < .50$  Strong  $\rho \geq .50$

Abbreviation: Catastroph = Catastrophizing.

\*  $P \leq .05$ .

Note. Positive correlations indicate that as practice quantity increases, the change-score of the outcome is positive. Negative correlations indicate that as practice quantity increases, the change-score of the outcome is negative. A positive change is favorable for Physical Function, Positive Affect, Mindfulness and Pain Acceptance. A negative change is favorable for Pain Interference, Depression, Anxiety, Sleep Disturbance, Pain Intensity, Perceived Stress, and Pain Catastrophizing.

( $\rho$ 's  $\geq .30$  or  $\geq .50$ , respectively) with changes in 7 out of the 11 outcomes, and were significantly correlated with changes in 4 outcomes including physical function, sleep disturbance, positive affect, and pain catastrophizing ( $p$ 's  $\leq .05$ ).

In multiple linear regression models adjusting for sex, age, and income (Table 4), the average number of days per week of informal practice was significantly associated with improvements in pain interference, pain catastrophizing, physical function, and sleep disturbance ( $p$ 's  $\leq .05$ ). The average number of minutes per day of informal practice was significantly associated with improvements in pain interference, pain catastrophizing, anxiety, and positive affect ( $p$ 's  $\leq .05$ ). There were no significant associations between either the number of days or minutes of informal practice with pain

intensity, depression, perceived stress, mindfulness, or chronic pain acceptance.

### Discussion

In this post-hoc, exploratory analysis, we characterized the frequency and duration of participant-reported home mindfulness practices during an abbreviated, 4-week mindfulness program for chronic pain management with reduced home practice assigned compared with standard 8-week programs. We then evaluated the associations between participant-reported quantities of formal and informal home mindfulness practice and pre- to post-intervention changes in pain-related and psychosocial outcomes. To our knowledge, this



**Table 4.** Multivariable Linear Regression Models With Days per Week or Minutes per Day of Informal Mindfulness Practice Predicting Change in Outcomes During a 4-Week Mindfulness Program for Chronic Pain Management.

Outcome Variable (Possible score on measure)	Predictor	Unstandardized Estimate	95% CI		P-value
		B (SE)	Lower	Upper	
Pain Interference (T-score: M = 50, SD = 10)	Days per week	-2.37 (.79)	-4.03	-.70	<.01
	Minutes per day	-.46 (.14)	-.76	-.16	<.01
Physical Function (T-score: M = 50, SD = 10)	Days per week	.80 (.38)	-.01	1.60	.05
	Minutes per day	.11 (.08)	-.05	.27	.17
Depression (T-score: M = 50, SD = 10)	Days per week	-.43 (.62)	-1.74	.88	.50
	Minutes per day	-.17 (.11)	-.40	.06	.15
Anxiety (T-score: M = 50, SD = 10)	Days per week	-1.22 (.71)	-2.73	.29	.11
	Minutes per day	-.30 (.12)	-.56	-.04	.05
Sleep Disturbance (T-score: M = 50, SD = 10)	Days per week	-1.76 (.66)	-3.16	-.36	.02
	Minutes per day	-.14 (.14)	-.44	.17	.36
Positive Affect (T-score: M = 50, SD = 10)	Days per week	1.33 (.66)	-.06	2.72	.06
	Minutes per day	.42 (.09)	.23	.61	<.001
Pain Intensity (0 - 10)	Days per week	-.44 (.24)	-.94	.07	.08
	Minutes per day	-.03 (.05)	-.13	.07	.51
Perceived Stress (0 - 16)	Days per week	-.36 (.32)	-1.04	.31	.27
	Minutes per day	-.01 (.06)	-.14	.12	.88
Mindfulness (14 - 56)	Days per week	.02 (1.23)	-2.58	2.63	.99
	Minutes per day	.12 (.23)	-.36	.60	.14
Pain Catastrophizing (0 - 52)	Days per week	-2.59 (.76)	-4.20	-.97	<.01
	Minutes per day	-.38 (.16)	-.72	-.04	.03
Pain Acceptance (0 - 120)	Days per week	1.27 (1.62)	-2.18	4.72	.44
	Minutes per day	.37 (.29)	-.26	.98	.23

Notes. 1. Each of the 22 rows indicates a separate multivariable linear regression model with the practice variable predicting the change in the outcome variable, adjusting for age (continuous variable), sex (male/female), and income (ordinal). 2. The unstandardized estimate (B) represents the pre- to post-intervention increase (positive values) or decrease (negative values) in the outcome shown per 1-unit increase in days of informal practice per week or in minutes of informal practice per day. For example, the model estimates that for each additional day of informal practice per week, there is a 2.37-point reduction in pain interference from pre- to post-intervention.

may be the only study of an MBI for chronic pain that describe quantities of formal and informal home mindfulness practices separately in addition to evaluating their associations with self-reported outcomes separately. Furthermore, the study focuses on an abbreviated MBI for chronic pain compared with standard 8-week programs, for which there is still limited literature on home practice engagement.

Our results on formal practice engagement are well-aligned with those of a recent systematic review of studies measuring adherence to home meditation practice in participants with chronic pain, in which the authors observed that across many studies, participants with chronic pain report moderately frequent (four days per week) meditation practices of shorter duration on average, compared with many of the programs' recommendation to engage in 45 minutes of formal meditation practice on 6 days of the week.<sup>10</sup>

The average frequency and duration of informal practice was less than that of formal practice. This contrasts with results of several previous studies. In the systematic review described above, 3 of the 31 included studies distinguished between formal and informal practice, and in 2 of those 3 studies, participants with chronic pain reported spending

either more minutes or more days engaging in informal practices than on formal practices, although methods of assessing home practice engagement differed across studies.<sup>10</sup> In a study of patients with chronic low back pain participating in an MBI, engagement in the brief, 3-min breathing space accounted for more minutes practicing outside of sessions than engagement in the longer, formal meditation practices.<sup>20</sup> Studies in non-pain populations find that participants report sustaining greater engagement in brief and informal practices than in lengthier, guided meditations in the months following the MBI.<sup>21</sup> These prior results may reflect the increased accessibility of brief, informal mindfulness practices compared with lengthier formal practices with regards to the time and effort required,<sup>22</sup> warranting a better understanding of the distinct and/or shared benefits achieved with both practice types when engaged in separately or in combination. It is possible that the abbreviated nature of our intervention in which informal practice was not introduced until the 2<sup>nd</sup> week out of 4 did not provide enough time for some participants to develop a consistent informal practice. We did not measure mindfulness practice engagement after the MBI, so it is unknown whether participants sustained their mindfulness practice and with which skills.

There were no significant correlations between formal practice and the change in any self-reported health outcomes. There is mixed evidence for a linear relationship between formal mindfulness practice quantity and health outcomes.<sup>9,10</sup> For example, for patients with chronic pain completing an MBSR class, there was a positive association between average weekly minutes of formal home practice and improvements in overall psychological distress, somatic symptoms and self-rated health, but no association with bodily pain, anxiety, or depressive symptoms.<sup>23</sup> A study of patients with chronic low back pain randomized to either mindfulness meditation alone, cognitive therapy alone, or MBCT found that formal, at-home practice quantity was not significantly associated with change in pain interference or pain intensity.<sup>20</sup> It is possible that there is a minimum threshold of days of practice needed to increase likelihood of improvement in certain outcomes. Studies evaluating MBCT for mood disorders found that those who engaged in formal practice on at least 3 days per week during the intervention experienced significantly improved depressive and anxiety symptoms or risk of depression relapse compared with those who practiced less than 3 days per week.<sup>24,25</sup> Only one participant in our study reported practicing an average of less than 3 days per week. It is also possible that longer amounts of daily formal practices than were assigned in our intervention would have produced stronger correlations with outcomes. It has also been hypothesized that a potentially important mechanism of mindfulness interventions is the improving quality of practice over time and not merely the quantity of practice. Investigators developed a self-reported measure of mindfulness practice quality titled Practice Quality-Mindfulness (PQ-M) and defined practice quality as “a balanced perseverance/resolve in (a) receptive and (b) present-moment attention, during the act of formally practicing mindfulness meditation.”<sup>26</sup> Several studies have found that improved practice quality predicted improved psychological function and/or self-reported mindfulness<sup>26–28</sup> and that practice quality was a more robust predictor than practice quantity of long-term improvement.<sup>28</sup> As far as we are aware, mindfulness practice quality has not been evaluated as a potential mechanism of MBIs for chronic pain management.

In contrast to the lack of associations between formal practice and outcomes, results demonstrated a pattern of significant, moderate to strong associations between reported frequency (average days per week) or duration (average minutes per day) of informal practice and improvement in multiple self-reported health outcomes including pain interference, pain catastrophizing, physical function, anxiety, sleep disturbance, and positive affect and wellbeing. Informal practice quantities were not significantly associated with changes in pain intensity, perceived stress, mindfulness, or chronic pain acceptance in regression models. Previous studies in non-pain populations have evaluated the informal practice and outcome association with some studies demonstrating that informal practice adherence but not formal

practice adherence is a significant predictor of positive outcomes<sup>8</sup> and others concluding the opposite.<sup>24</sup> However, these studies evaluated different MBIs, populations, and treatment outcomes.

Our results indicate the utility of measuring the quantity of both formal and informal practice engagement to better understand the differential and interacting effects of these types of practices for patients with chronic pain participating in MBIs. Quantifying informal mindfulness practice is likely subject to greater recall bias as participants must estimate how much time they spent mindfully attending to daily activities compared with formal practice which involves listening to an audio recording of a set duration. It is important to develop more reliable methods of measuring at-home practice, such as using mobile apps<sup>29</sup> or smart watches to readily indicate when beginning and ending an informal or unguided mindfulness practice and to track completion of formal, guided practices.

There are several limitations of our study to highlight. This was a single-arm feasibility study with a small sample, so these analyses were exploratory and aimed to generate questions and hypotheses for future research. Additional and larger studies are warranted to continue to disentangle the impacts of quantity and types of mindfulness practice and how they may interact with other factors to mediate chronic pain outcomes. While we believe administering a daily practice survey was a strength of the study, there are also limitations of this method due to missing daily surveys which we considered days on which practice did not occur, and uncertainty as to the reliability of measuring informal practice quantity by asking participants how many minutes they engaged in mindfulness during daily activities. Participant interviews including open-ended and self-reflective questions could help clarify how participants measure their informal practice quantity. In addition, the study included only participant-reported measures but could have benefitted from including other indicators of alterations in pain processing and brain states (e.g., psychophysical testing, functional magnetic resonance imaging, electroencephalogram) to determine if the associations we found are consistent across other methods of measurement. Finally, the participant sample is predominantly female, White, Non-Hispanic, and holds at least a college degree, which is comparable to participant samples included in many studies of mindfulness-based interventions.<sup>30</sup> Future research on this topic should employ strategies such as improved outreach and community-based participatory research methods<sup>30</sup> in order to represent the more diverse population affected by chronic pain.

## Conclusion

The quantity of informal home mindfulness practice, but not formal home mindfulness practice, is associated with improvement in several pain-related and psychosocial outcomes

during an abbreviated MBI for chronic pain. These results are exploratory and should be confirmed in larger trials evaluating the distinct roles of formal and informal practice. It is important to better understand the impacts of mindfulness practice quantity on treatment effects so that appropriate recommendations can be made to patients who participate in MBIs for chronic pain.

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