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Understanding Engagement in and Affective Experiences During Physical Activity: The Role of Meditation Interventions

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Abstract

Objective: Meditation interventions promote an array of well-being outcomes. Yet, the way in which these interventions promote beneficial outcomes is less clear. Here, we expanded on prior work by examining the influence of mindfulness and loving-kindness meditation on a key health behavior: physical activity.

Methods: To test our hypotheses, we drew upon two randomized intervention studies. In Study 1, 171 adults (73.0% female) received 6 weeks of training in either mindfulness meditation, loving-kindness meditation, or were assigned to a control condition. In Study 2, 124 adults (60.0% female) were assigned to a 6-week mindfulness or loving-kindness meditation group.

Results: Study 1 demonstrated that individuals who received mindfulness training reported sustained levels of physical activity across the intervention period (Pre: $M = 4.09$, $SD = 2.07$; Post $M = 3.68$, $SD = 2.00$; $p = .054$), while those in the control (Pre: $M = 3.98$, $SD = 2.25$; Post $M = 3.01$, $SD = 2.07$; $p < .001$) and loving-kindness (Pre: $M = 4.11$, $SD = 2.26$; Post $M = 3.45$, $SD = 1.96$; $p < .001$) conditions reported lower levels. Study 2 demonstrated those who received mindfulness training experienced increases in positive emotions during physical activity from pre to post-intervention (Pre: $M = 6.06$, $SD = 2.51$; Post: $M = 6.54$, $SD = 2.43$, $p = .001$), whereas those trained in loving-kindness meditation experienced decreases in positive emotions during physical activity (Pre: $M = 6.45$, $SD = 2.35$; Post: $M = 6.09$, $SD = 2.46$, $p = .040$).

Conclusions: These results suggest mindfulness training (but not loving-kindness training) promotes sustained physical activity, and one plausible reason why this occurs is enhanced positive emotion during physical activity.

Keywords

meditation; physical activity; mindfulness; loving-kindness; emotion

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An extensive body of research demonstrates that meditation interventions – including both mindfulness and loving-kindness interventions – are associated with beneficial mental and physical well-being outcomes across a wide range of populations, including healthy adults, people with chronic pain, and people at risk for depression (1–3). Although the link between meditation interventions and beneficial outcomes is well-documented, the mechanisms by which these interventions have a beneficial influence are less clear (1). In particular, a noticeable absence from the literature is an examination of how meditation interventions may influence health behaviors (1). This absence is notable because prior research demonstrates that a) affective experiences (i.e., the experience and regulation of positive and negative emotions) play an important role in the extent to which people initiate, sustain, and repeat health behaviors (4, 5), and b) one of the hallmark benefits of meditation interventions is that they can transform affective experiences (3, 6–8). Because of this, an examination of whether meditation interventions influence health behaviors is warranted.

One key positive health behavior is physical activity, as it can (among other benefits) decrease the risk of major health challenges (9) and improve mental health (10). Because of its benefits, a number of interventions have been designed to increase engagement in physical activity, yet many have been criticized for having high dropout rates, requiring laborious time commitments, or failing to promote behavior change (11, 12). As such, recent reviews of the literature suggest a need for physical activity interventions which are feasible, scalable, and cost-effective (11, 12).

In light of the need for effective interventions, what factors might enhance the extent to which an intervention may promote physical activity? In this work, we focus on the role of *affect*. Prior research and theory suggest people's affective experiences related to physical activity, especially affective experiences *during physical activity itself*, are a robust and consistent predictor of future physical activity (4, 5). As such, prior research suggests that any intervention that can transform affective experiences (i.e., increase positive affect and reduce negative affect) *during* physical activity is likely to have a robust influence in promoting physical activity (4, 5). Because of its influence on affective experiences, we believe meditation training represents just such an intervention. Although prior research has linked dispositional mindfulness and self-reports of meditation to physical activity at the correlational level (e.g., 13, 14), no prior research has used a randomized design to examine how actually training people to meditate influences physical activity. As such, below we will review theory and research linking mindfulness meditation to physical activity, and then discuss loving-kindness meditation in relation to physical activity.

Mindfulness Meditation and Physical Activity

According to theory and research in mindfulness, one of the central benefits of mindfulness training is that it enhances *emotional regulation* (e.g., 15–17). According to these ideas, when people are trained in mindfulness it serves to a) reduce the negative emotional impact of potentially threatening stimuli, b) enhance the extent to which positive moments are noticed and savored, and c) render neutral moments a source of value and enjoyment (15–17). As such, theory suggests that mindfulness training influences the experience of both positive and negative emotions (15–17). Extensive empirical research supports the

notion that mindfulness training reduces negative affectivity and enhances positive emotions (e.g., 6, 7, 18). Importantly, research demonstrates mindfulness training promotes affective benefits throughout the daily life of the practitioner, *even when they are engaging in activities other than meditation* (e.g., 6, 18).

Because prior research demonstrates that the emotions people experience during physical activity play a key role in whether they engage in physical activity (4, 5), training in mindfulness meditation may promote physical activity by transforming these affective experiences. During physical activity, many types of experiences are likely to arise, including difficult sensations (e.g., aches and pains or fatigue), positive sensations (e.g., feelings of strength or vigor), and neutral ones (e.g., the sensation of footfalls during a run). We suspect people who are trained in mindfulness will more readily a) observe challenging experiences without a strong negative emotional reaction, b) notice and savor positive experiences, and c) derive enjoyment from previously neutral experiences during physical activity. All of this should mean that mindfulness training promotes positive emotions and reduces negative emotions during physical activity itself, meaning people trained in mindfulness meditation may become be more likely to engage in and persist with (during a given bout) physical activity.

Loving-kindness Meditation and Physical Activity

In addition to mindfulness meditation, we also believed loving-kindness meditation would influence engagement in physical activity. At the heart of loving-kindness meditation is *compassion*: participants are trained to focus warm and compassionate feelings towards themselves and others (19). Additionally, loving-kindness meditation has a transformative influence on the affective experiences of practitioners throughout daily life (3, 6), including on both positive and negative emotions (20).

This research suggests that loving-kindness meditation could also have benefits in the context of physical activity. People who are trained in loving-kindness meditation may be less self-critical, more self-compassionate, and hold their own experience with kindness and care. When it comes to physical activity, this suggests that people trained in loving-kindness may approach challenges that arise during physical activity with compassion and care, which likely boosts their experience of positive emotions, and reduces their experience of negative emotions during the activity, thus enhancing the frequency and duration of physical activity.

The Current Study

In two studies, we examined the possibility that meditation interventions promote physical activity. In Study 1, we draw on data from a three-arm (mindfulness, loving-kindness, and control), randomized controlled trial of 171 individuals across a six-week meditation intervention. Participants provided self-reports during the week prior to the intervention (baseline), then during each week for the subsequent 6 weeks (Weeks 1–6). Although participants began reporting their physical activity during Week 1 of the intervention, because the timing of the first meditation classes varied across the week, a considerable

subset of participants had not yet begun their daily meditation practice by the time they provided their first report of physical activity, rendering Week 1 data uninterpretable. Thus, because we aimed to assess whether meditation training influenced reports of physical activity (relative to baseline), we focused on Weeks 2–6 of the intervention period. We predicted that people who received mindfulness (**Hypotheses 1**) and loving-kindness (**Hypothesis 2**) training would report significantly greater change from baseline in physical activity frequency and duration during Weeks 2–6 of the intervention period as compared to those in the control condition. We did not predict differences between the mindfulness and loving-kindness conditions.

In Study 2 we examined the possibility that meditation training may influence affective experiences during physical activity among a sample of 121 people who engaged in a separate, six-week meditation intervention. Specifically, prior to the intervention, participants came to a laboratory where they walked on a treadmill for 20 minutes, and reported their positive and negative emotions at 5-minute intervals. After this baseline assessment, participants were randomly assigned to receive 6-weeks of training in either mindfulness or loving-kindness meditation, after which, they returned to the laboratory to re-complete the treadmill task. We predicted mindfulness meditation would enhance positive emotions (**Hypothesis 3A**) and reduce negative emotions (**Hypothesis 3B**) during the treadmill task from baseline to the second assessment. Additionally, we predicted loving-kindness meditation would enhance positive emotions (**Hypothesis 4A)** and reduce negative emotions (**Hypothesis 4B**) during physical activity from baseline to the second assessment. We also examined whether the mindfulness and loving-kindness conditions differentially predicted change from pre to post-intervention, although we did not have specific predictions of between-groups differences.

STUDY 1

Method

Study Overview and Participants—Data from this study (NIH-supported R01NR012899) have been reported on in other distinct publications (6, Study 1; 21) and will continue to support other investigations in the future. Participants for Study 1 were midlife adults, ranging from 35–64 years old. Participants were eligible for the study if they had access to the internet at their home, had little or no meditation experience, and had no chronic illnesses or disabilities. Participants were randomly assigned to one of three conditions: mindfulness meditation (n=61), loving-kindness meditation (n=62), or wait-list control (n=48). A consort table, reproduced from Isgett et al. (21), is provided in the OSF page for this study (https://osf.io/gb9w4/?view_only=ded71533eb5c4dd687fca751acd4e146). On average, participants in the final sample were 48.39 years old (*SD* = 8.82). 73% of participants were female, and 79% of the participants identified as White, with 13% identifying as African-American, 7% identifying as Asian, and 2% identifying as another race.

Procedures and Materials—All procedures for this study were approved by the IRB of the University of North Carolina at Chapel Hill, and participants provided informed consent

prior to completing the study. Participants reported their health behaviors in an online survey on a weekly basis both prior to and during the meditation intervention. Here, we draw upon reports of physical activity a) frequency and b) duration. These reports were provided at 7 time points, at weekly intervals: at baseline (during the week prior to the intervention), and during each week of the 6-week intervention (Weeks 1–6). Because data collection for the full sample occurred with two groups of participants, the weekly reports occurred at different times during the week for half of the participants in our study; for half of the participants, the weekly reports occurred during the 3rd day of the week (Tuesdays), and for half of them, the weekly report occurred on the 7th day of the week (Saturdays).

After random assignment, those who were assigned to the mindfulness or loving-kindness conditions were booked to attend 6-weeks of evening meditation workshops (one class per week), which were capped at 16 people. The meditation classes were designed in consultation with experts, and lasted for 60 minutes each week. The mindfulness and loving-kindness classes were designed to be parallel in structure with the exception of the content of the meditation itself. During the first class, both groups received an overview of the course of the 6-week meditation training, guidelines for their in-home practice, and recordings for guided meditations. Participants were encouraged to cultivate a daily meditation practice, with a realistic guideline set at 3–5 times per week and 20 minutes per day.

In the mindfulness intervention, participants were taught to cultivate an open and accepting attention to their present-moment experiences. To do so, the participants were progressively instructed to direct their attention to a series of different objects in the present-moment, including the breath, the body, their emotions, and their thoughts. By cultivating an accepting, open attention towards various stimuli in the present-moment, the overarching goal of the intervention was to foster an ability to "re-perceive" and less fully identify with the stream of present-moment experiences.

In the loving-kindness intervention, participants were instructed to self-generate open and warm-hearted feelings. To do so, they were instructed to mentally direct messages of compassion, love, and kindness to various individuals, including themselves, those whom they already care about, strangers, those who they struggle with, and all beings. The overarching goal of this intervention was to foster an ability to self-generate warm and positive feelings, and therefore create a shift towards kindness and connectedness.

Physical activity frequency and duration were assessed using two items adapted from Oaten and Cheng (22): "*In the past week, on how many days did you intentionally engage in moderate or strenuous physical activity for a period of 20 minutes or longer*?" and participants reported on a scale from 0 days – 7 days. For physical activity duration, participants were asked the following question: "*What was the average duration of each period of physical activity?*" and participants reported the average duration in minutes.

Results

Descriptive statistics are presented in Table S1 (Supplemental Digital Content). To test study hypotheses, we conducted linear mixed modeling analyses in SPSS (23). For each

outcome variable, (assuming no missing data) each individual provided one data point pre-intervention, and 5 data points (from Weeks 2 through 6) post-intervention. Linear mixed models account for the nested nature of the within-person data, allowing for the examination of within-person effects, between-condition effects, and the interaction of the two (23). We examined three primary coefficients in these analyses: a) the main effect of condition, b) the main effect of time, and c) most importantly, whether there was an interaction between time and condition, or whether being in a particular intervention group was associated with greater changes in self-reported physical activity from pre- to post-intervention. In all analyses, the control condition was set as the reference group. Each of the models was specified with random intercepts and fixed slopes, and with a scaled identity covariance matrix. Additionally, because mixed models allow individuals in the analysis to have missing data points (23), individuals were included in the analyses even if they were missing a data point post-intervention. All data analytic syntax for this research can be found in the OSF page for this study.

Results in Table 1 examine the influence of the mindfulness and loving-kindness interventions (as compared to the control condition) on physical activity *frequency* at baseline vs. during Weeks 2–6 of the intervention. With respect to our primary hypotheses, a significant interaction between the mindfulness condition and time emerged ($B = -0.61$, $p = .031$), whereas no statically significant interaction between loving-kindness meditation and time emerged ($B = -0.31$, $p = .268$). Estimated marginal means for the intervention conditions before and during the intervention are presented in Figure 1. Least squared difference tests demonstrated that whereas individuals in the loving-kindness condition ($M_{diff} = -.66$, $p < .001$, $D = .30$) and the control condition ($M_{diff} = -0.97$, $p < .001$, $D = .46$) reported decreases in physical activity from baseline to the intervention period, those in the mindfulness condition did not report statistically significant changes in physical activity frequency from baseline to the intervention period ($M_{diff} = -.36$, $p = .054$, $D = .13$). Moreover, although no significant differences between the mindfulness group and the other two conditions were evident before the intervention (all p's > .76), during the intervention, there was a marginally statistically significant difference between those in the mindfulness condition and those in the control condition, such that individuals in the mindfulness condition reported engaging in physical activity more frequently than those in the control condition ($M_{diff} = .67$, $p = .053$, $D = .38$).

Table 2 presents results of the parallel model examining physical activity *duration* before and after the meditation intervention. Once again, the interaction between the mindfulness meditation condition and time was statistically significant ($B = -19.01$, $p = .04$), whereas the interaction between the loving-kindness condition and time was not ($B = -12.04$, $p = .19$). Estimated marginal means by condition and time are presented in Figure 2. Results demonstrated that while people in the mindfulness ($M_{diff} = 5.08$, $p = .407$, $D = .09$) and loving-kindness ($M_{diff} = -1.89$, $p = .754$, $D = .07$) conditions did not report significant changes from before the intervention to during the intervention, individuals in the control condition reported a significantly lower duration of physical activity during the intervention than they did at baseline ($M_{diff} = 13.94$, $p = .046$, $D = .17$). Additionally, while no significant differences emerged between the three conditions in terms of physical activity duration at baseline (the lowest p value for each of the comparison tests was .37), during

the intervention, people in the mindfulness condition reported significantly greater physical activity duration than those in the loving-kindness condition (M_{diff} = 15.91, p = .027, D = .31) and those in the control condition (M_{diff} = 20.98, p = .007, D = .40).

Study 1 Discussion

Results of Study 1 provided partial support for Hypothesis 1, but did not support Hypothesis 2. While individuals in the control and loving-kindness conditions both reported statistically significant, within-group decreases in physical activity *frequency*, and those in the control condition reported significant, within-group decreases in physical activity *duration*, those in the mindfulness condition did not report significant decreases in physical activity frequency or duration during the intervention period as compared to baseline. Moreover, although there were no differences between any of the conditions prior to the intervention in terms of physical activity duration or frequency, during the intervention people in the mindfulness condition reported significantly greater duration of physical activity than those in both the control and loving-kindness conditions.

Although the randomized design with repeated assessments in Study 1 provides robust causal evidence of a link between mindfulness training and sustained physical activity, it does not provide evidence as to why mindfulness meditation influences physical activity. Moreover, one limitation of Study 1 is the use of retrospective, self-report measures (over the past week) in assessing physical activity, which can be biased. As such, in Study 2, we expanded upon Study 1 by examining how mindfulness and loving-kindness meditation influenced affective experiences during a standardized, laboratory-based physical activity task. Before and after receiving training in either mindfulness or loving-kindness meditation, participants reported on their affective experiences *as they occurred* during a physical activity task.

STUDY 2

Method

Study Overview and Participants—Data from this NIH-funded study (R01CA170128) have been used in previous publications to test distinct research questions (6, Study 2; 24), and will continue to be used in future publications. Participants for Study 2 were 231 adults, ranging from ages 35 to 64, and were recruited from the community surrounding University of North Carolina at Chapel Hill. Power analyses were conducted prior to the collection of the data, based on the specific aims of the grant that was submitted in support of the collection of the underlying data. After recruitment, participants were randomized to receive training in loving-kindness (n = 118) or mindfulness (n = 113) meditation. The meditation interventions were identical the those in Study 1. A consort table, adapted from Fredrickson, et al. (Study 2; 6), can be found in the OSF page for this study. Our key analyses focus on a behavioral treadmill task, and because of the rigor of this task, participants were screened using the Physical Activity Readiness Questionnaire (The PAR-Q; 25). The screening processes resulted in 151 participants completing the treadmill task at the pre-intervention laboratory session, and 124 participants with complete data for the post-intervention laboratory session. Because we focus on change in affect during the treadmill

activity from pre- to post-intervention, the final sample for subsequent analyses consists of the 124 people who completed treadmill task in the post-intervention laboratory session. On average, participants were 46.77 years old (*SD* = 8.68), and 60.00% female. With respect to race and ethnicity, 5.6% as Asian, 14.4% as Black or African American, 1.6% as Hispanic or Latino/Latina, and 79.8% as White. We note here that we originally pre-registered a set of hypotheses that were focused on Study 2 only. Although the general nature of our hypotheses in this manuscript were same as in that pre-registration (i.e., we predicted both mindfulness and loving-kindness meditation would enhance physical activity), we ultimately revised aspects of our methodological approach in this manuscript (as compared to the pre-registration) based on feedback we received throughout the editorial process. We have included a link to the original pre-registration here for transparency: https://aspredicted.org/blind.php?x=4hr2zn.

Procedures

All procedures for this study were again approved by the IRB of the University of North Carolina at Chapel Hill, and all participants provided informed consent prior to the start of the study. Prior to the interventions, participants first came to a laboratory where they completed a series of assessments, including the initial treadmill task. Three weeks later, participants began meditation classes, which lasted for 6 weeks. Three weeks after the end of the meditation classes (12 weeks after the initial lab-visit), they returned to the lab to complete the treadmill task again.

Treadmill task—Participants completed a physical activity task in accordance with the procedures of Williams et al. (26). Specifically, participants walked on a TR3000i treadmill while connected to a heart-rate monitor, and the incline of the treadmill was adjusted to keep exertion constant at 85% of the individual's age predicted maximum heart rate. Based on CDC guidelines, the following formula was used to calculate 85% of the person's age predicted maximum heartrate: (220-age) x 0.85 = 85% of the individual's age predicted maximum heart rate in beats per minute. At 5-minute intervals during the task (5, 10, and 15 minutes into the task), participants reported their positive and negative emotions on a scale of 0 = *experiencing no emotion at* all to 10 = *experiencing extreme emotions*. Ten positive (*amusement, awe, gratitude, hope, inspiration, interest, joy, love, pride*, and *serenity*) and ten negative (*anger, shame, contempt, disgust, embarrassment, guilt, hate, sadness, fear*, and *stress*) emotion words from the modified Differential Emotion Scale (27) were posted on the wall of the room directly in front of the treadmill to give them a reference of what to include in their reports of positive and negative emotions.

Results

Descriptive statistics are presented in Table S2 (Supplemental Digital Content). Generally speaking, participants reported low levels of negative emotions during the treadmill task and moderate levels of positive emotions during the treadmill task at both Time 1 and Time 2.

Prior to conducting substantive analyses, we wanted to examine whether there were changes in affect *prior to* engaging in the treadmill task from pre- to post-intervention, depending on meditation training. As such, we conducted two repeated-measures ANOVAs in examining

whether there were changes in positive and negative emotions immediately prior to the treadmill task, and whether these changes depended on meditation condition. For both positive ($F = .10$, $p = .79$) and negative ($F = .72$, $p = .40$) emotions, there was no main effect of time, and condition did not interact with time (positive emotions: 3.13, $p = .08$; negative emotions: $F = 1.67$, $p = .20$). Thus, participants in both conditions did not report statistically significant changes in positive or negative emotions from pre- to post-intervention prior to engaging in the treadmill task.

To test Hypotheses 3 and 4, which examine the effect of mindfulness and loving-kindness meditation on positive and negative emotions during physical activity, we conducted two linear mixed model analyses in a similar manner as in Study 1. In particular, the models were specified to examine whether the intervention (coded as a 0 = loving-kindness and 1 = mindfulness) was differentially associated with positive and negative emotions during the treadmill task before versus after participants completed 6-weeks of meditation training. All 3 positive and negative emotion data points during physical activity were used in each model, meaning each participant had 3 emotion data points before and after the intervention (6 total points of data per individual per analysis). The two key tests of our hypotheses were a) the main effect of time (which assesses the possibility that *both* interventions enhance emotions during physical activity), and b) the interaction between treatment condition and time (which assesses the possibility that one of the two interventions outperforms the other in terms of its influence on affective experiences during physical activity).

Results of analyses predicting positive and negative emotions during the treadmill task are presented in Table 3. With respect to positive emotions, there was a significant main effect time ($B = -0.481$, $p = .004$), no significant main effect of condition ($B = -0.45$, $p = .234$), and a significant interaction between time and condition ($B = 0.83$, $p < .001$). The estimated marginal means are presented in Figure 3. In support of Hypothesis 3A results demonstrated individuals trained in mindfulness demonstrated a statistically significant increase in positive emotions during the treadmill task from pre- to post-intervention ($M_{diff} = .48$, $p = .004$; $D = .24$). Contrary to Hypothesis 4A, people in the loving-kindness condition demonstrated a *decrease* in positive emotions from pre- to post-intervention ($M_{diff} = .35$, $p = .040$; $D = .15$). No significant between groups differences between the mindfulness and loving-kindness condition emerged with respect to positive emotions either before ($M_{diff} = -.38$ $p = .324$, $D = .21$) or after ($M_{diff} = .45$, $p = .234$, $D = .18$) the intervention.

Turning to negative emotions during the treadmill task, there was no significant main effect of time ($B = 0.14$, $p = .329$), and there was a significant main effect of condition ($B = 0.72$, $p = .008$), however these main effects were qualified by a significant interaction between time and condition ($B = -0.47$, $p = .018$). The estimated marginal means for this interaction are presented in Figure 4. Results demonstrated that, contrary to Hypothesis 4B, individuals in the loving-kindness condition experienced an *increase* in negative emotions during the treadmill task from baseline to after the intervention ($M_{diff} = .72$, $p = .008$, $D = .17$), while people in the mindfulness condition did not experience significant changes ($M_{diff} = -.25$, $p = .37$, $D = .11$). Additionally, whereas there was no difference between the two groups prior to the intervention ($M_{diff} = -.25$, $p = .37$, $D = .09$), those who received loving-kindness training were more likely to experience negative emotions during

the treadmill task post-intervention, as compared to those who received mindfulness training (M_{diff} = −.72, p = .008, D = .37).

Study 2 Discussion

Study 2 expands upon the results of Study 1 by identifying a plausible account of how mindfulness meditation may influence physical activity adherence. In particular, in support of Hypothesis 3A, we found that individuals in the mindfulness condition reported increases in extent to which they experienced positive emotions during the laboratory-based physical activity task, whereas those in the loving-kindness condition experienced decreases. Although there was a between-groups difference between the mindfulness and loving-kindness conditions in terms of negative emotions during the treadmill task after the intervention, simple effects analyses suggested that this was primarily a function people in the loving-kindness condition experiencing *increases* in negative emotions during the treadmill task. Thus, the weight of the evidence supported Hypothesis 3A, or the idea that mindfulness meditation enhances positive emotions during physical activity. Contrary to Hypotheses 4A and 4B, we found little evidence that loving-kindness meditation enhanced affective experiences during physical activity. Instead, loving-kindness meditation appeared to render physical activity more affectively challenging in terms of both positive and negative emotions.

GENERAL DISCUSSION

The current research was the first to examine how two different meditation interventions influence a key health behavior: physical activity. In Study 1, we found that individuals who were randomly assigned to receive training in mindfulness meditation were more likely to maintain physical activity, both in terms of frequency and duration, while those randomly assigned to loving-kindness meditation or a control condition did not show the same pattern. In Study 2, we identified a plausible reason why mindfulness meditation may encourage the maintenance of physical activity: enhanced positive emotions during physical activity. Together, results of these studies suggest mindfulness meditation may contribute to the frequency and duration of physical activity, potentially due to enhanced positive emotions during physical activity.

Meditation and Physical Activity Frequency and Duration

Based on past theory and research, we hypothesized that individuals who were randomly assigned to receive mindfulness and loving-kindness training would experience increases in the extent to which they engaged in physical activity. Rather than promoting *greater* physical activity and frequency, we found individuals who received training in mindfulness meditation retained the levels of physical activity frequency and duration which they reported at baseline, while those in the loving-kindness and control conditions reported reductions during the intervention period. A number of interpretations are possible for this finding, and we mention two here. First, the most obvious interpretation is that mindfulness meditation helps people sustain engagement in physical activity (both in terms of frequency and duration). This would explain why people in the mindfulness condition continued to report their baseline levels of physical activity frequency and duration across the study,

while those in the loving-kindness and control condition reported decreases from baseline to the intervention period. This is notable considering individuals in both meditation conditions were also in the process of adding another new wellness behavior to their daily routine (i.e., daily meditation practice).

Another interpretation is that the baseline reports of physical activity were positively biased, in which case mindfulness meditation may have actually promoted greater physical activity. For instance, it is possible that the baseline reports of physical activity and duration were biased in the positive direction for all three groups (e.g., 28). If this were the case, what appeared to be sustained levels of physical activity frequency and duration as compared to baseline may have actually been enhanced levels of physical activity for those in the mindfulness condition. Regardless, our results suggest that people who are trained in mindfulness were more active than those trained in loving-kindness meditation and wait-list controls, however future research using objective assessments of physical activity behavior is needed to determine whether this is a result of sustained physical activity or increased physical activity.

Given that we predicted both mindfulness and loving-kindness training would enhance engagement in and affective experiences during physical activity, we were surprised at how consistently those trained in mindfulness meditation outperformed those trained in loving-kindness meditation in terms of the outcomes we examined. In Study 2, we were particularly surprised that, after the intervention, those trained in loving-kindness meditation, on average, were worse off post-intervention in terms of their affective experiences during physical activity. We suspect these differences between mindfulness and loving-kindness training can be explained by the fact that mindfulness training has an overt emphasis on *acceptance* of present-moment experiences, whereas loving-kindness does not. This acceptance of challenging experiences may be critical during physical activity, where challenging experiences often arise. While research suggests the self-cultivation of compassion involved in loving-kindness meditation has many benefits, including affective benefits *outside of physical activity* (6, 8), our results suggest these benefits do not extend to affect during physical activity.

We hasten to mention a few important methodological considerations about both studies. First, in Study 1, although there was a wait-list control condition in which participants did not engage in meditation, the gold-standard for control groups in physical activity intervention studies is to provide participants with health education regarding the importance of physical activity (e.g., 29). Because Study 1 did not include health education, we interpret these results with caution. Second, Study 2 did not include a control group. Because of this, we were limited to a) examining pre- and post-intervention change, and b) comparing the mindfulness and loving-kindness conditions to each other. Despite these two important limitations, we note that, when compared to the mindfulness condition, the loving-kindness condition serves as a useful proxy for an active control condition. Individuals in the loving-kindness condition engaged in many of the same behaviors and activities as those in mindfulness condition, such as attending classes, following guided meditations for multiple days per week, and engaging in meditation for similar periods of time. Loving-kindness meditation does not, however, include the key facets of mindfulness meditation

that theoretically promote emotional regulation (i.e., becoming aware and accepting of present-moment experiences). Thus, the differences in the patterns of findings between the mindfulness and loving-kindness conditions provide evidence to suggest that mindfulness meditation has particular relevance to physical activity outcomes. Even so, future research is needed to replicate these findings while comparing mindfulness to an active physical activity control condition (rather than a comparative efficacy condition, like loving-kindness meditation).

Understanding the Benefits of Meditation Interventions: The Role of Physical Activity

It is important to note the practical significance of the difference between the intervention conditions in terms of physical activity. For instance, the Center for Disease Control (CDC) recommends Americans engage in at least 150 minutes of moderate intensity physical activity per week. Based on the estimated marginal means, in Study 1 the average person in the control condition engaged in physical activity for approximately 3.01 days per week for 31.91 minutes during the intervention period (96.05 minutes total per week, on average) – well under the recommended 150 minutes of physical activity per week. Individuals in the mindfulness condition, on the other hand, on average engaged in physical activity 3.68 days per week, for over 52.97 minutes during each period they physical activity (194.93 minutes total per week, on average) – well over the CDC's recommendations. In light of these results, should future studies replicate our findings with behavioral assessments of physical activity, mindfulness meditation may be used as an intervention not just to enhance things like coping with stress and emotional regulation, but also for maintaining adherence to physical activity.

Limitations

This research is not without limitations. First, physical activity was assessed in Study 1 self-report measures. As such, it is possible that these reports are biased, and as mentioned previously, this seems plausible based on the results of Study 1. Second, our samples included only midlife adults, and because patterns of physical activity differ among different age groups, these results require replication in samples of a different demographic profile. Third, although the treadmill task in Study 2 provides real-time, behavioral evidence as to participants' affective experiences during physical activity, participants' physical activity routines in the real-world may be different. As such, while we gain interpretational precision from this standardized paradigm, we also necessarily lose generalizability. Fourth, we note that although part of the rationale for this research was a need for a cost-effective and time-efficient physical activity interventions, the way we implemented meditation training did require substantial time and effort on behalf of participants (e.g., coming to in-person, weekly classes). Notably, however, recent research has demonstrated that mindfulness meditation training, when delivered via smartphone, can similarly influence key outcomes via this less invasive and relatively brief smartphone format (e.g., 19). As such, we suspect that our results would generalize to a less invasive meditation training format, and future research should test this possibility. Finally, we note that while we were able to identify one plausible reason why mindfulness meditation influences physical activity adherence (by enhancing positive emotions during physical activity), we only examined one potential

mechanism, and there are likely other means by which mindfulness meditation influences physical activity adherence.

Conclusion

In two randomized interventions studies, this research demonstrated that mindfulness meditation predicts sustained frequency and duration of physical activity, and increases positive emotions during physical activity. Future research should continue to explore how training in the present-focused and accepting attention characteristic of mindfulness promotes well-being via a diverse range of pathways.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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List of abbreviations:

OSF	open science framework.

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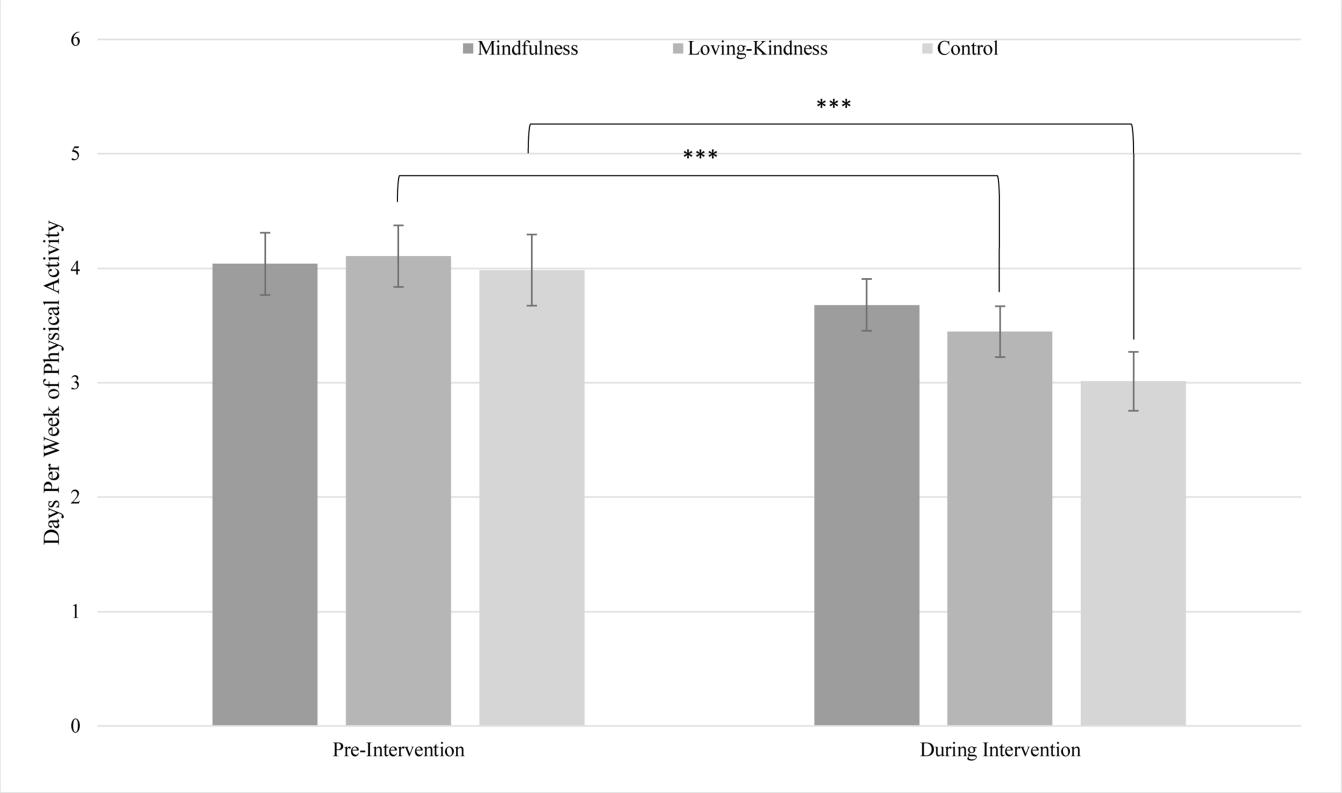

Figure 1.

Estimated marginal means for self-reported physical activity frequency by condition pre- and post-intervention in Study 1

Note. *** $p < .001$** $p < .01$* $p < .05$. The error bars display the standard error of the estimated marginal mean.

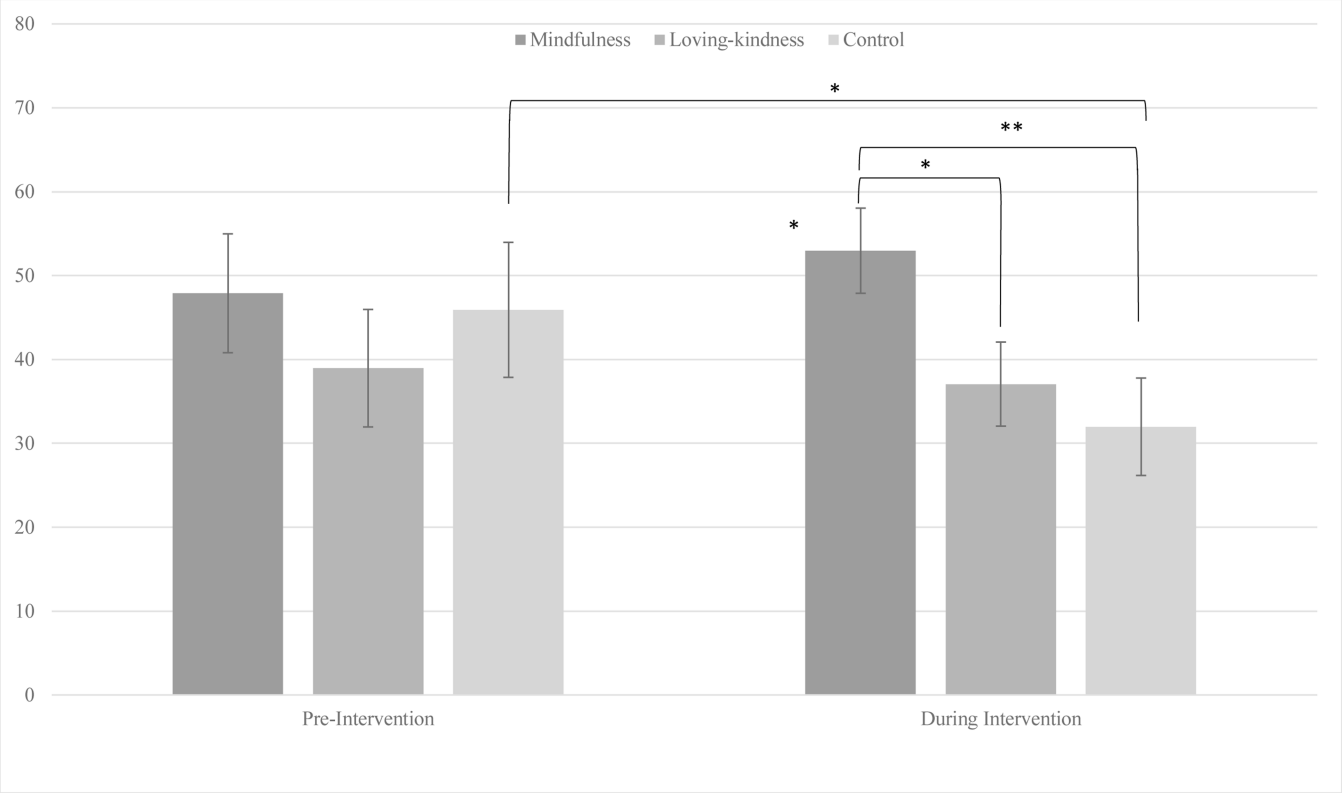

Figure 2.

Estimated marginal means for self-reported physical activity duration by condition pre- and post-intervention in Study 1

Note. *** $p < .001$** $p < .01$ * $p < .05$. The error bars display the standard error of the estimated marginal mean.

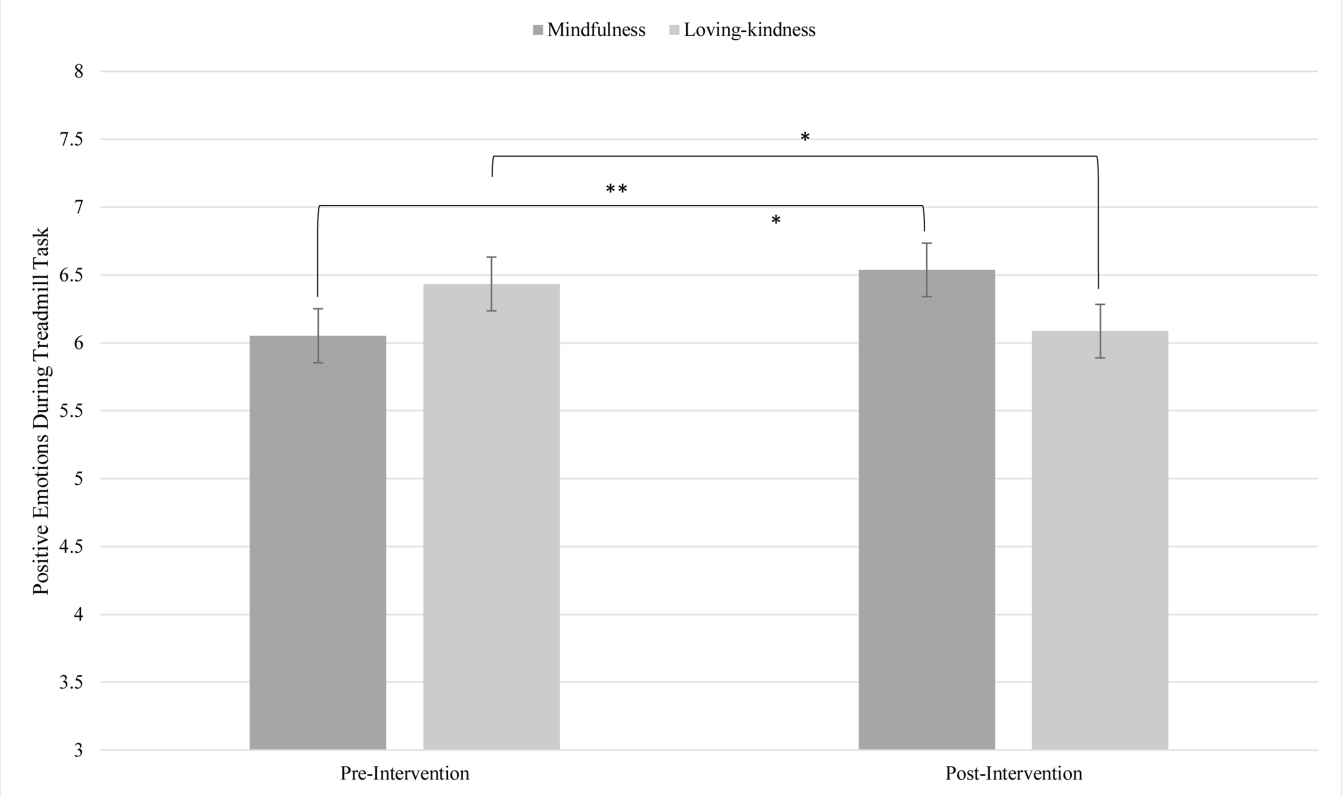

Figure 3.

Estimated marginal means for positive emotions during the treadmill task pre and post-intervention in Study 2

Note. The error bars display the standard error of the estimated marginal mean. ** $p < .01$.

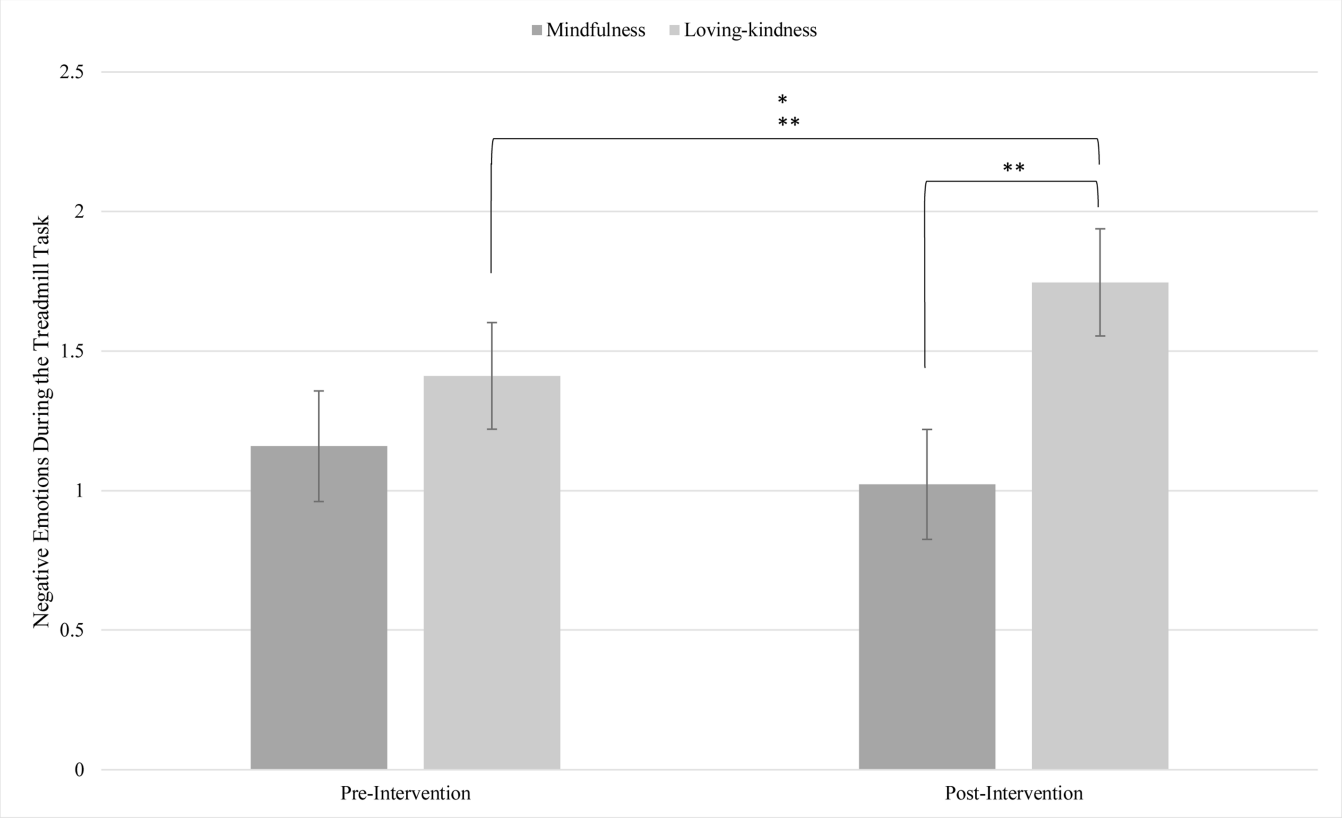

Figure 4.

Estimated marginal means for negative emotions during the treadmill task pre and post-intervention in Study 2

Note. * $p < .05$. The error bars display the standard error of the estimated marginal mean.

Table 1.

Results of linear mixed models predicting physical activity frequency in Study 1.

						95% CI	
Parameter	***Estimate***	***SE***	***df***	***t***	***p***	***Lower***	***Upper***
Intercept	3.01	0.26	178.42	11.70	<.001	2.50	3.52
Mindfulness Condition	0.67	0.34	176.31	1.94	.053	−0.01	1.34
Loving-Kindness Condition	0.43	0.34	174.37	1.27	.204	−0.24	1.11
Time (Pre vs. During Intervention)	0.97**	0.21	698.42	4.54	<.001	0.55	1.39
Mindfulness × Time	−0.61*	0.28	698.18	−2.16	.031	−1.17	−0.06
Loving-Kindness × Time	−0.31	0.28	697.33	−1.10	.268	−0.87	0.24

Note.

* $p < .05$.

** $p < .01$.

Total number of individuals $N = 171$ people, total number of unique data points = 866.

Table 2.

Results of linear mixed models predicting physical activity duration in Study 1.

					95% CI	
Parameter	***Estimate***	***SE***	***df***	***p***	***Lower***	***Upper***
Intercept	31.98	5.81	198.70	<.001	20.52	43.44
Mindfulness Condition	21.00**	7.72	194.88	.007	5.78	36.22
Loving-Kindness Condition	5.09	7.68	193.93	.508	−10.06	20.23
Time (Pre vs. During Intervention)	13.94	6.97	699.75	.046	0.25	27.62
Mindfulness × Time	−19.01*	9.28	699.64	.041	−37.22	−0.80
Loving-Kindness × Time	−12.04	9.23	701.05	.193	−30.17	6.09

Note.

* $p < .05$.

$N = 171$ individuals, total number of unique data points = 850.

Table 3

Results of linear mixed models predicting positive and negative emotions during the treadmill task before and after the intervention in Study 2.

						95% CI	
Outcome	**Predictor**	***Estimate***	***SE***	***df***	***p***	***lower***	***upper***
Treadmill	Intercept	6.54	0.27	143.87	<.001	6.01	7.06
Positive Emotions	Time (Pre vs. Post Intervention)	−0.48 **	0.17	576.73	.004	−0.82	−0.15
	Condition	−0.45	0.38	144.77	.234	−1.20	0.29
	Time × Condition	0.83 **	0.24	576.80	.001	0.36	1.30
Outcome	**Predictor**	***Estimate***	***SE***	***df***	***p***	***lower***	***upper***
Treadmill	Intercept	1.02	0.19	148.68	<.001	0.64	1.40
Negative Emotions	Time (Pre vs. Post Intervention)	0.14	0.14	577.42	.329	−0.14	0.41
	Condition	0.72 **	0.27	149.89	.008	0.19	1.26
	Time × Condition	−0.47 *	0.20	577.51	.018	−0.86	−0.08

Note.

** $p < .01$

* $p < .05$.

N = 124 individuals, 690 observations