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Predictors of Mindfulness Meditation and Exercise Practice, from MEPARI-2, a randomized controlled trial

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Abstract

Objectives: Health-supporting behaviors can be challenging to initiate and maintain. Data from the MEPARI-2 randomized trial were used to assess predictors of sustained exercise and meditation practice.

Methods: Adults aged 30 to 69 years not exercising regularly and without prior meditation training were randomized to 8-week trainings in mindfulness meditation, moderate intensity exercise, or observational control, and monitored for 8 months. Exercise participants reported day-to-day minutes of moderate and vigorous activity; mindfulness meditation participants reported minutes of informal and formal practice. Demographic characteristics and psychosocial factors were assessed as predictors of practice. Growth mixture modeling was used to identify higher and lower practice subgroups.

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Authors' contributions

BB designed the study, acquired funding, directed data acquisition, analysis & interpretation, and wrote this paper, with input from all authors. ET and JM contributed to the implementation of the research, to the analyses of the results, and to the writing of the manuscript. JB and RB performed the analyses, aided in interpreting the results, and worked on the manuscript. All authors provided critical feedback on various stages of writing and have provided final approval of this manuscript for publication.

Competing Interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

This study was approved and monitored by the University of Wisconsin - Madison's Institutional Review Board (HSC#2012-0207). Informed consent was obtained from all individual participants included in the study. 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 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data will be made publicly available upon publication of pending submitted manuscripts. The data will be stored <https://clinicaltrials.gov/show/NCT01654289>.

Results: 413 participants (75.8% female; mean (SD) age 49.7 (11.6) years) were randomized to exercise (137), mindfulness meditation (138), or control (138), with 390 (95%) completing the study. Seventy-nine percent of exercisers and 62% of meditators reported 150 minutes/week practice for at least half of the 37 weeks monitored. Self-reported minutes of mindfulness meditation and/or exercise practice were significantly ($p < 0.01$) predicted by baseline levels of: general mental health, self-efficacy, perceived stress, depressive symptoms, openness, neuroticism, physical activity, smoking status, and number of social contacts. Growth mixture modeling identified subsets of people with moderate (100–200 min/week) and high (300–450 min/week) levels of self-reported practice for both mindfulness meditation (62% moderate; 38% high) and exercise (71% moderate; 29% high).

Conclusions: In this sample, participants randomized to behavioral trainings reported high levels of practice sustained over 37 weeks. Baseline psychosocial measures predicted practice levels in expected directions.

Keywords

behavior change; exercise; health behavior; meditative practices; mindfulness meditation; physical activity

Regularly engaging in positive health-enhancing behavioral practices is essential to achieving and maintaining health. Regular practice of mindfulness-based and other types of meditation appear to help reduce symptoms of anxiety, depression, stress, pain, and psychological distress (Galante et al., 2014; Goldberg et al., 2018; Goldstein et al., 2018; Goyal et al., 2014; Kuyken et al., 2016; Goyal et al., 2014), and may be protective in terms of reducing inflammation (Black & Slavich, 2016; Bower & Irwin, 2016; Buric et al., 2017; Hoge et al., 2017; Ironson et al., 2018), and cardiovascular risk (Aquino-Russell et al., 2014; Redmond et al., 2013; Younge et al., 2015). Mindfulness-based stress reduction programs are among the most rigorously studied and widely implemented of the many types and styles of meditation practiced (Cherkin et al., 2016; Kabat-Zinn, 2003; Ludwig & Kabat-Zinn, 2008). Despite the rapidly accumulating evidence of health benefits, there are no generally accepted guidelines regarding frequency, duration, or practice style of meditation, and very little information regarding the uptake and maintenance of meditative practice. Two recent systematic reviews suggest that adherence to meditative practice as assigned in various training programs is highly variable, and that there are few dose-response studies relating degree of meditative practice with health-related outcomes (Lloyd et al., 2018; Parsons et al., 2017). Best current evidence suggests that less than one in ten Americans regularly engages in a meditation regularly, and that many people who attempt to begin meditative practice do not build a long term practice (Cramer et al., 2016; Purohit et al., 2013; Ribeiro et al., 2018).

Meditation practice may be one aspect a healthy lifestyle. Other ingredients include a high quality diet, and frequent exercise or other forms of physical activity. It is well known that people who engage in regular exercise live longer and healthier lives than those who do not (Rueggsegger & Booth, 2018). For example, lower rates of cardiovascular disease, diabetes and cancer are observed among people who engage in more frequent and strenuous physical activity (Kyu et al., 2016). Regular exercise also supports mental health, helping to prevent or ameliorate both anxiety and depression (Rebar et al., 2015). Physical activity guidelines

recommend at least 150 minutes of sustained moderate intensity exercise per week (Physical Activity Guidelines Advisory Committee, 2008). Exercise practice levels are suboptimal, with less than half of Americans meeting these recommendations (Katzmarzyk et al., 2017; Troiano et al., 2008; Tucker et al., 2011).

Perceived stress is a not only a predictor of the negative psychological consequences of common cold and flu-like syndromes, but also a determinant of viral uptake and replication, and of inflammatory cytokine expression (Cohen et al., 1999; Cohen et al., 1991). Despite increasingly convincing research showing that stress increases susceptibility to acute respiratory infection (ARI) illness, there was no experimental evidence to show that stress reduction could reduce ARI incidence, severity, and impact until the two MEPARI trials (Meditation or Exercise for Preventing Acute Respiratory Infection), each of which randomized participants to 8 weeks of mindfulness meditation training, 8 weeks of matched exercise training, or non-interventional wait-list control, and then followed participants through a cold and flu season, from September to May (Barrett et al., 2018; Barrett et al., 2012).

The first MEPARI trial (n=154) found substantive reductions in ARI illness among those randomized to 8-weeks of training in mindfulness meditation, compared to non-interventional control, with slightly smaller benefits attributable to exercise training (Barrett et al., 2012; Hayney et al., 2013; Obasi et al., 2012; Rakel et al., 2013; Zgierska et al., 2013). MEPARI-2 (n=413) was designed to replicate and extend those findings, and found a consistent pattern of ARI-reduction benefits in both intervention groups, compared to control, albeit with somewhat reduced effect size compared to the first trial (Barrett, Hayney, et al., 2018). In addition to confirming ARI-reduction effects of mindfulness meditation and exercise training, the MEPARI-2 trial found evidence that mindfulness meditation training may increase accelerometry-measured physical activity (Meyer et al., 2018), and that both mindfulness and exercise reduced stress and improved mental health, and that improved self-efficacy might serve as mediator of these benefits (Goldstein et al., 2018). While the first MEPARI trial did not carefully monitor mindfulness meditation and exercise practice patterns, MEPARI-2 corrected this deficit with intensive daily monitoring of mindfulness meditation and exercise practice from the beginning of the 8-week training classes in September until the participants exited the study in May. The present study explores those data regarding the adoption of and sustained adherence to exercise and mindfulness practice, with the goals of: 1) portraying patterns and trajectories of mindfulness meditation and exercise practice, 2) determining whether and to what extent baseline measures predict those patterns, and 3) identifying sub-groups of individuals who exhibit higher or lower levels of practice uptake and adherence.

Method

Participants

This study was conducted in Madison, Wisconsin, and was approved and monitored by the University of Wisconsin - Madison's Institutional Review Board (HSC#2012-0207). Four yearly cohorts of approximately 100 people each were needed to reach the target sample size of 390 participants (130 in each of the comparison groups). Participants aged 30 to 69

were recruited from the community using a variety of advertising techniques, with telephone screening followed by in-person baseline assessment, informed consent, a 2-week run-in period, and then enrollment in the main study. Randomized, equal allocation was accomplished using sealed opaque envelopes, with randomization codes generated using variable block size methods by an independent statistician. Participants were not blinded to interventions, but investigators and data analysts remained masked to study group until the last participant exited the study. Eligibility required answering “Yes” to either “Have you had at least 2 colds in the last 12 months?” or “On average do you get at least 1 cold per year?” Prospective participants were excluded if they scored 14 or higher on the Patient Health Questionnaire-9 (PHQ-9) depression screen (Kroenke et al., 2001), had current practice or prior training in meditation, or if they reported exercising vigorously 1 time per week or moderately 2 times per week, using Centers for Disease Control Behavioral Risk Factor Surveillance System criteria (Centers for Disease Control and Prevention, 2009). Current or anticipated use of antibiotics, antivirals, immunological medications, malignancy, and autoimmune disease were also exclusionary.

Procedures

MEPARI-2 participants were randomly assigned to: 1) 8 weeks of training in mindfulness meditation, 2) a matched 8-week progressive moderate intensity exercise training program, or 3) observational waiting list control. Both interventions included weekly group classes, with 20 to 45 minutes of daily at home practice recommended. Mindfulness training followed the standard Mindfulness Based Stress Reduction format (Kabat-Zinn, 2003; Center for Mindfulness, 2019), and was led by experienced MBSR instructors, all of whom were associated with the University of Wisconsin mindfulness program, and all of whom had previously taught several MBSR classes. Classes of 14 to 16 participants met once weekly for 2.5 hours for 8 weeks, with a 5-hour weekend retreat held around the 6th week. Contact hours, class size, location, and expected practice time were the same for both mindfulness and exercise groups. Experienced exercise instructors led the exercise classes. The goal for exercise participants was to reach and sustain a Borg’s Rating of Perceived Exertion (Borg & Linderholm 1970) level of 12 to 16 points. Exercise practice focused on brisk walking or jogging, with individualized programs developed for those who had access to specific equipment, such as stationary or outdoor bicycle, or elliptical or rowing machine.

Practice time was recorded by participants every day on paper logs, and then entered once weekly into the study database using home computers or other internet-enabled devices. Daily monitoring and weekly self-report began the first week of classes in September, and continued until exit in May. Exercise participants logged daily practice minutes of moderate and vigorous physical activity, and mindfulness participants reported daily practice minutes of informal and formal meditative practice. Mindfulness practice was defined as: “*Formal practice* is when you schedule specific time to just do that particular activity. For example, scheduling 15 minutes to sit and focus on your breath is formal meditation practice. Taking a moment to notice your breath during your work day is *informal practice*. Scheduling time to take a walk for the purpose of practicing meditation is formal practice. Walking mindfully from your kitchen to the living room is *informal practice*.” Following standard conventions in exercise research, exercise practice was defined as: “A *moderate* level of physical activity

noticeably increases your heart rate and breathing rate. You may sweat, but you are still able to carry on a conversation. With *vigorous* activity, you are breathing rapidly and are only able to speak in short phrases. Your heart rate is substantially increased, and you are likely to be sweating.” Participants were asked to prospectively record practice minutes each day on paper, and then to enter data once weekly.

Measures

Physical activity was assessed for participants in all 3 groups using the Global Physical Activity Questionnaire (GPAQ) (Bull et al., 2009), at baseline, and 4 times during the monitoring period (November, January, March, and May). During the final year of the study, an objective assessment of physical activity was conducted using accelerometers (Actigraph GT3X). That sub-sample of participants was asked to wear accelerometers, while awake, for 7 days in August, prior to randomization, and then again after interventions were completed, in November.

The MEPARI-2 trial included validated self-report questionnaire instruments aimed at assessing several psychosocial health domains. These included: general mental and physical health (Short Form Health Survey, SF12)(Ware et al., 2008); perceived stress (Perceived Stress Scale, PSS-10)(Cohen & Janicki-Deverts, 2012) depressive symptoms (Patient Health Questionnaire, PHQ-9)(Kroenke et al., 2001); exercise self-efficacy (Exercise Self-Efficacy Scale, ESES)(Kroll et al., 2007), mindful self-efficacy (Mindfulness Self Efficacy Scale, MSSES)(Cayoun & Freestun, 2004), positive and negative emotion (Positive and Negative Affect Schedule, PANAS)(Watson et al., 1988); mindful attention (Mindful Attention Awareness Scale, MAAS)(Brown & Ryan, 2003); and the sense of feeling loved (Feeling Loved, FL)(Barrett, et al., 2018). Participants self-assessed both perceived social support (Social Provisions Scale, SPS)(Cutrona & Russell, 1987) and number of social contacts (Social Network Index, SNI)(Brissette et al., 2000). Personality traits of openness, conscientiousness, extraversion, agreeableness, and neuroticism were assessed by the Big Five Inventory (BFI)(John et al., 1991). Self-report questionnaires were completed at baseline in August, and then either 3 or 4 times from November to May. Socioeconomic indicators (age, sex, income, education, smoking status) were self-reported, as were major co-morbidities (Seattle Index of Comorbidity)(DeSalvo et al., 2005). Participants were weighed, and height was measured, with body mass index (BMI) calculated.

Data Analyses

Data were entered into a customized internet-accessible REDCap study database (Harris et al., 2009). Weekly practice logs were entered directly by participants using their own computers, tablets, and smart phones. Self-report questionnaires were filled out on paper and then scanned into the study database, with frequent manual cross-checking to ensure accuracy. When missing-completely-at-random (MCAR) criteria were satisfied (Little, 1988), data were imputed using STATA multiple imputation by chained equations (MICE) methods (Azur et al., 2011; Schafer & Graham, 2002). Data cleaning, missing-at-random evaluation, and potential imputation were conducted prior to unblinding and analysis.

Descriptive statistics were summarized as means with standard deviations or 95% confidence intervals for normally distributed variables. For skewed measures, medians and interquartile ranges were used. To determine which demographic and psychosocial characteristics predicted subsequent practice, we assessed the relationship of 28 baseline variables to mean total minutes of mindfulness and exercise practice using general linear regression procedures. SAS version 9.4 was used for these analyses. Growth mixture modelling (GMM) (Ram & Grimm, 2009) techniques using MPlus version 8 were used to identify and assess subgroups of mindfulness meditation and exercise practice patterns (Muthen & Muthen, 2017). GMM methods assess longitudinal over-time trajectories, such as mindfulness and exercise practice patterns. At least 3 contiguous weeks of self-report practice data were required to facilitate GMM analysis, hence 3 cases from exercise and 5 cases from mindfulness were dropped. Predictors of mindfulness and exercise subgroups identified by GMM were sought using best subsets multivariate logistic regression procedures describe by Hosmer, Jovanovic, and Lemeshow (1989), following methodology originally proposed by Lawless and Singhal (1978). Analyses were considered significant at $\alpha < 0.01$ for evidence-of-effect, and at < 0.05 for hypothesis-generation or cautious support of effect.

Results

MEPARI-2 was carried out in 4 successive yearly cohorts of 3 groups each, from the fall of 2012 to the spring of 2016. Participants were screened and enrolled in August, with behavioral trainings carried out in September and October. Weekly monitoring continued throughout the winter until May of the next year. Of 1,197 persons screened, 413 were randomized (313 women, 100 men, mean age 49.7 $\pm$ SD 11.6 years) to mindfulness meditation ($n=138$), exercise ($n=137$), or control ($n=138$). Of the $n=413$ enrolled, 390 (94%) were followed until study exit. Figure 1 displays participant flow. In the exercise group, 129 completed follow-up; 8 of these did not attend any exercise classes. For mindfulness meditation, 128 completed follow-up, with 9 not attending any classes. We prospectively defined “per protocol” intervention adherence to be attending at least 5 of the 9 possible in-person trainings (8 weekly classes, 1 weekend retreat). In the exercise group, 109 met this per protocol adherence criteria; for mindfulness, 115 people attended at least 5 of 9 sessions. Overall, there was less than 2% missing data, all of which met missing-at-random criteria, with MICE imputation carried out (Azur et al., 2011; Little, 1988; Schafer & Graham, 2002). The GMM analysis was based on intention to treat, but required 3 consecutive weekly reporting periods, which kept analyzable sample size to $n=128$ for exercise and $n=126$ for mindfulness meditation. Both mindfulness and exercise practice data approximated normal distributions, but there were 8 outliers, which were winsorized (Lien & Balakrishnan, 2005) to the 97th percentile (480 minutes/week) to reduce potentially biasing effects on analyses. Table 1 displays baseline characteristics for the analyzable sample.

Self-reported exercise and mindfulness meditation practice was high. For those randomized to exercise or mindfulness (intention to treat), the median amount of self-reported practice was 236 and 220 minutes/week, respectively, over the 37 weeks of observation. See Figure 2. The proportion of people who attended 5, 7, and all 9 of available sessions was 80%,

61%, and 14% for those randomized to exercise, and 83%, 71%, and 20% for those randomized to mindfulness, respectively. For those who completed 5 of 9 sessions, median minutes of reported practice were 251 for exercise and 226 for mindfulness. Fourteen participants did not complete any of the weekly self-practice reports; 12 of these also did not attend any training classes.

Generally accepted recommendations for physical activity aim for 150 minute of moderate intensity sustained physical exertion each week (Physical Activity Guidelines Advisory Committee, 2008). For comparative purposes, we assessed mindfulness practice in a similar fashion, setting the recommended level at 150 min/week of mindfulness meditation practice (formal plus informal). Following these definitions, 79% of those randomized to exercise training and 62% randomized to mindfulness meditation met the 150 min/week level on more than half of the 37 weeks monitored. For those attending at least 5 of 9 sessions, corresponding rates were 84% in the exercise group and 63% in the mindfulness group.

Using a $p < 0.01$ cutoff for significance, 4 of 28 baseline variables (14%) predicted average total minutes of mindfulness practice, and 6 of 28 (22%) of variables predicted of exercise practice (Table 2). Mindfulness meditation practice minutes were positively predicted at the $p < 0.01$ level by general mental health, openness, and smoking status, and negatively predicted by depressive symptoms. Minutes of exercise practice were positively predicted by exercise and mindful self-efficacy, number of potential social contacts, and GPAQ score at baseline. Exercise practice minutes were negatively predicted by perceived stress and neuroticism. Using a less restrictive $p < 0.05$ significance level, mindfulness practice was also positively predicted by age, conscientiousness, positive emotion, exercise self-efficacy and the feeling of being loved, and negatively predicted by perceived stress and neuroticism. Using the less restrictive $p < 0.05$ cutoff, exercise practice was also positively predicted by: age, agreeableness, conscientiousness, general mental health, network diversity, positive emotion, and mindful attention, and negatively predicted by depressive symptoms.

Self-reported exercise as assessed by GPAQ increased markedly in the exercise group, from 560 MET/week at baseline to 1560 in Nov/Dec, 1380 in January, 1210 in Feb/Mar and 1440 in April (all significant increases using $p < 0.01$ cutoff). In comparison, GPAQ scores did not increase significantly in the mindfulness or control groups. Of the 66 people agreeing to wear accelerometers, there was sufficient data for analysis (3 weekdays and 1 weekend day, > 10 hours/day) at both baseline and follow-up for 49 participants (18 mindfulness; 14 exercise; 17 control). Consistent with seasonal effects of Wisconsin weather on activity, there was a physical activity decline in all 3 groups (mindfulness meditation -5.7 ± 7.5 min/day; exercise -7.4 ± 14.3 min/day; control -17.9 ± 25.7 min/day; NS group by time ANOVA). Moderate or vigorous physical activity in bouts lasting 10 minutes or more (i.e., exercise) decreased by 77.3 ± 106.6 min/week in control, and by 15.5 ± 37.0 min/week in mindfulness; in the exercise group, exercise bouts of 10 minutes increased by 5.7 ± 64.1 min/week, significantly different from control ($p = 0.029$) but not mindfulness meditation ($p = 0.564$; pairwise comparisons of change scores) (Meyer et al., 2018).

Growth mixture modelling (GMM) analysis suggested 2 relatively homogeneous sub-groups (moderate practice; high practice) for both exercise and mindfulness meditation groups

(Table 3 & 4; Figure 3). Selection of the 2 subgroup solution was based on Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), entropy, and likelihood ratio test (LRT) criteria, aiming for parsimony as well as explanatory power (Table 3) (Fraley & Raftery, 1998; Nylund et al., 2007; Rissanen, 1978; Sclove, 1987). Participants in the moderate exercise sub-group (91 of 128; 71% of exercise group) reported mean practice levels between 200 to 250 min/week during the 8 week trainings, decreasing to around 175 min/week during the winter months, and then increasing to around 200 min/week in the spring (Figure 3). For the 37 of 128 (29%) people in the high exercise practice subgroup, practice levels were generally >350 min/week during the fall trainings, between 300 and 350 min/week in the winter months, rising to 350 to 450 min/week in the spring. Participants in the moderate mindfulness meditation sub-group (78 of 126; 62%) reported mean practice levels of >200 min/week during trainings, which decreased mindfulness practice to around 100–150 min/week thereafter. In the high mindfulness meditation subgroup (48 of 126; 38%), mean weekly levels of reported practice were > 300 min/week throughout the study, with a possible very slight decrease over time. See Figure 3.

To assess which baseline variables were most important in predicting classification into the moderate vs. high practice sub-groups, we employed optimal best subset logit model techniques mentioned above (Hosmer et al., 1989; Lawless & Singhal, 1978). Based on the R-squared values and Mallows's Cp (a measure of regression model fit) (Gilmour, 1996; Mallows, 1973), it was discovered that 93% (26 of 28) of the baseline variables should be considered. Loading these 26 potential predictors in a logit algorithm of GMM model subgroups, then using further pruning methods (systematic removal of non-significant predictors), yielded the independent predictive variables shown in Table 4. For predicting classification into the high exercise subgroup (relative to moderate), significant baseline variables were: household income, neuroticism, social network high contact and roles, and exercise self-efficacy. The best model for predicting high mindfulness meditation practice included depressive symptoms, perceived social support, and household income, assessed at baseline.

Discussion and Conclusions

Our findings suggest that a large proportion of people entering a mindfulness meditation or exercise training program can adopt and maintain these behavioral practices over a 9-month period. This supports the optimistic view that initiation and maintenance of health-related behavior change is possible as well as desirable. The relatively high levels of self-reported mindfulness meditation and exercise practice observed in this study may be due to the population sampled, the quality of the instruction, the close follow-up procedures, or other unmeasured factors. We suspect that the weekly practice self-reports may have served to strengthen commitment to practice, by providing participants weekly incentives to practice and report health behaviors. It should be noted, however, that the participants recruited into this study were willing to be randomized to mindfulness meditation or exercise training, or to noninterventional control, and agreed to carry out the many protocol activities, regardless of group assignment. These people were also healthier and perhaps more motivated than many people for whom exercise or meditation practice might be recommended, such as

those with type 2 diabetes, obesity, hypertension, cardiovascular disease, chronic pain, depression, anxiety, or high levels of experienced stress.

We found several factors that predicted which people were most likely to adopt and maintain exercise or mindfulness meditation practices. Looking at baseline indicators for each intervention separately, predictive factors for exercise practice included perceived stress, neuroticism, number of social contacts, exercise self-efficacy, and baseline physical activity. For mindfulness practice, predictive factors were: general mental health, openness, depressive symptoms, and smoking status. While statistically significant and potentially important, these results should be interpreted cautiously, as even the best individual predictors explained only 5–10% of the variance. Nevertheless, these predictors do make sense. For example, people with higher levels of self-efficacy, openness, or mental health, or with lower levels of neuroticism or depressive symptoms, would be expected to be more motivated and able to adopt and sustain health practices. Social support is already known to predict health behaviors and outcomes (Holt-Lunstad et al., 2015; Segrin & Passalacqua, 2010), hence the association of social contact scores with practice levels is not unexpected. We are not sure how to interpret the unexpected finding that current smokers reported more mindfulness practice but would note that the number of smokers was small, and that chance or selection bias may be involved. It is interesting that while 10 of the 28 baseline factors significantly ($p < 0.01$) predicted total minutes of either exercise or mindfulness practice, none of these were predictive for both mindfulness and exercise. When using the less restrictive $p < 0.05$ criterion, however, practice levels for both mindfulness and exercise were positively predicted by age, general mental health, conscientiousness, positive emotion, and exercise self-efficacy, and were negatively predicted by neuroticism, perceived stress and depressive symptoms. These findings did fit with our expectations.

Growth mixture modelling (GMM) suggested 2 subgroups of practice trajectories for both mindfulness meditation and exercise: those able to adopt and maintain moderate levels of practice (100 to 200 min/week), and those able to achieve high levels of practice (300 to 450 min/week). For both exercise subgroups, practice was relatively strong during the 8-week trainings, waned in the winter months of November to February, and then increased in the spring months from March to May. Practice patterns in the mindfulness subgroups were similar to exercise, with initially high levels of practice during the trainings (and especially the week of the retreat), followed by lower practice levels throughout the winter. While springtime increases were not seen among those randomized to mindfulness training, practice levels were sustained, with mean levels 100 min/week in the moderate mindfulness meditation subgroup, and around 350 min/week in the high mindfulness meditation subgroup. Using best-subset logit methods to seek predictors of GMM subgroups, we found that a combination of household income, neuroticism, social contacts and exercise self-efficacy best predicted exercise subgroup classification, and that income, depressive symptoms, and perceived social support together best predicted mindfulness meditation practice trajectories. Looking for consistencies between the unadjusted baseline prediction of practice minutes approach with the GMM analysis and best-subset logit methods, only depressive symptoms, exercise self-efficacy and neuroticism appeared significant in both approaches. While these predictors of higher or lower uptake and maintenance of mindfulness meditation and exercise practice patterns are not particularly

surprising, they are potentially important. Medical and psychological practitioners should be aware of factors that influence their patients' abilities to initiate and maintain health behaviors such as meditation and exercise, so that they can individually tailor advice and referral to health behavior training programs.

It is possible and perhaps likely that the mindfulness meditation and exercise practice patterns reported by our participants were positively biased or exaggerated, through "social desirability bias" or other similar mechanisms (Brenner & DeLamater, 2014; Edwards, 1957). Studies that have used both accelerometers and validated self-report questionnaires have consistently shown positive bias for self-reports, compared to accelerometry (Dyrstad et al., 2014; Taber et al., 2009; Troiano et al., 2008). Accelerometry assessment in a sub-sample suggested that, compared to control, exercise training attenuated the expected August-to-November decline in physical activity, and that mindfulness meditation training may have had similar but slightly smaller effects supporting physical activity. While the combination of self-reported exercise practice and rapidly rising GPAQ scores in the exercise group strengthens confidence in the data shown here, some caution is called for, considering the marked asymmetry between GPAQ scores and the accelerometry results.

Limitations

There are several limitations to this study. As noted in Barrett et al. 2018, the MEPARI-2 trial was likely under powered. Daily practice of mindfulness meditation and exercise were recorded only in the assigned groups, so between-group analysis cannot be accomplished. We did not have well-defined *a priori* hypotheses regarding practice predictors, hence these results should be considered exploratory, descriptive, and hypothesis-generating rather than conclusive. The data portrayed here come from a trial in which participants were willing to be randomized to training in exercise or meditation, or to observational control, and to be monitored closely for 9 months. As such, this sample is likely not representative, and the results may not be generalizable. Although we did use validated and widely respected questionnaire instruments, the validity of resulting data depends on accurate and unbiased reporting. Many well-designed studies have shown that human beings tend to be biased in their self-reporting of behaviors and tend to enhance or inflate reporting of "positive" attributes or activities, such as exercise (Brenner & DeLamater, 2014; Dyrstad et al., 2014; Edwards, 1957; Taber et al., 2009). Multiple testing considerations should also be acknowledged. We assessed more than 2 dozen potential predictors of mindfulness meditation and exercise practice. By chance alone, we might expect that at least one of these would show statistically significant predictive relationships to mindfulness or exercise practice.

In conclusion, we will note that this analysis probably brings more light to the study of mindfulness meditation than to that for exercise, for which practice levels have been well characterized for decades. In our opinion, the health benefits of mindfulness practice have only recently become incontrovertible, as a critical mass of randomized trial reports have become available. Next steps will include research aimed at determining a dose-response curve relating degree of practice adherence to magnitude of health benefit. To do this,

investigators will need to develop better methods for assessing practice, and will need large cohorts and robust health assessments.

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Figure 1.
Participant Flow (CONSORT) Diagram

Figure 2. Average Weekly Practice Minutes

MM = Mindfulness Meditation; EX = Exercise

Bars indicate mean number of minutes per week of reported practice, averaged over each month

Figure 3. Moderate and High Practice Subgroups

Mean weekly minutes of MM and EX practice for people categorized into Moderate (1) and High (2) practice subgroups derived using Growth Mixture Model methods

Of $n = 126$ in MM = meditation group, $n = 48$ (38%) are in high practice and $n = 78$ (62%) in moderate practice subgroups

Of $n = 128$ in EX = exercise group, $n = 37$ (29%) are in high practice and 91 (71%) in moderate practice subgroups

Increased levels of MM practice in the 5th week corresponds to the weekend retreat which is standard for MBSR training

Table 1.

Demographic and Psychosocial Characteristics of Study Population

Characteristic	Exercise	Meditation	Control
Sample, N	128	126	138
Age (years) , mean $\pm$ SD	49.2 $\pm$ 11.3	49.0 $\pm$ 11.3	50.7 $\pm$ 12.1
Female, n (%)	98 (77)	95 (75)	101 (73)
Current Smoker, n (%)	7 (5.5)	5 (4.0)	11 (8.0)
Race, n (%)			
White/Caucasian	100 (78)	111 (89)	123 (89)
Black/African American	12 (9)	4 (3)	6 (4)
Asian	8 (6)	5 (4)	3 (2)
Other/More Than One Race	8 (6)	5 (4)	6 (4)
Hispanic Ethnicity, n (%)	5 (4.0)	10 (8.1)	8 (6.0)
BMI (kg/m ²) , mean $\pm$ SD	29.2 $\pm$ 7.0	29.7 $\pm$ 7.8	29.0 $\pm$ 6.6
SIC Comorbidity Score *, mean $\pm$ SD	1.7 $\pm$ 1.6	1.6 $\pm$ 1.4	1.7 $\pm$ 1.8
College Graduate or Higher, n (%)	102 (80)	100 (79)	102 (74)
Income > \$50,000, n (%)	76 (60)	78 (63)	85 (63)
Systolic BP (mmHg), mean $\pm$ SD	122 $\pm$ 15	121 $\pm$ 17	124 $\pm$ 17
Diastolic BP (mmHg), mean $\pm$ SD	75 $\pm$ 9	75 $\pm$ 9	76 $\pm$ 9
Instruments, mean $\pm$ SD			
BFI: Agreeableness	37.3 $\pm$ 5.5	37.6 $\pm$ 4.9	37.7 $\pm$ 5.4
BFI: Conscientiousness	36.1 $\pm$ 5.5	36.3 $\pm$ 5.4	35.6 $\pm$ 5.8
BFI: Openness	40.3 $\pm$ 5.3	40.1 $\pm$ 5.3	39.2 $\pm$ 6.3
BFI: Extraversion	26.9 $\pm$ 6.9	27.5 $\pm$ 6.2	26.8 $\pm$ 5.9
BFI: Neuroticism	20.8 $\pm$ 6.1	20.4 $\pm$ 5.9	20.8 $\pm$ 5.7
SF12: Physical Health	51.9 $\pm$ 8.0	51.5 $\pm$ 7.8	51.4 $\pm$ 8.3
SF12: Mental Health	47.8 $\pm$ 10.6	47.8 $\pm$ 10.3	47.6 $\pm$ 9.9
SPS Social Support	83.5 $\pm$ 9.8	83.4 $\pm$ 10.2	83.3 $\pm$ 9.3
SNI: Network Diversity	6.3 $\pm$ 2.1	6.4 $\pm$ 1.8	6.3 $\pm$ 1.8
SNI: Potential Contacts	24.2 $\pm$ 9.9	23.7 $\pm$ 8.9	23.6 $\pm$ 8.1
SNI: Number of Roles	7.3 $\pm$ 1.9	7.5 $\pm$ 1.8	7.2 $\pm$ 1.8
PANAS Positive Emotion	35.3 $\pm$ 6.6	35.1 $\pm$ 7.1	33.9 $\pm$ 7.5
PANAS Negative Emotion	18.6 $\pm$ 6.8	17.9 $\pm$ 5.8	18.6 $\pm$ 6.7
PSS10 Perceived Stress	13.2 $\pm$ 6.7	13.3 $\pm$ 6.5	12.4 $\pm$ 5.9
PHQ9 Depression Symptoms	2.8 $\pm$ 2.9	2.3 $\pm$ 2.4	2.9 $\pm$ 3.1
PSQI Sleep Quality	6.0 $\pm$ 3.5	5.7 $\pm$ 3.2	5.7 $\pm$ 3.3
MAAS Mindful Attention	4.2 $\pm$ 0.8	4.1 $\pm$ 0.8	4.3 $\pm$ 0.7
MSES Mindful Self-Efficacy	97.4 $\pm$ 14.1	98.2 $\pm$ 15.8	96.8 $\pm$ 14.6
ESES Exercise Self-Efficacy	114 $\pm$ 38	114 $\pm$ 37	116 $\pm$ 39

Characteristic	Exercise	Meditation	Control
Instruments, median (IQR)			
GPAQ MET-hrs/wk	560 (190 – 1260)	780 (240 – 2160)	1020 (320–2400)
Feeling Loved Score	369 (330 – 387)	370 (333 – 389)	370 (340–389)

Abbreviations: SD = standard deviation, IQR = interquartile range, BP = blood pressure, BFI = big five inventory, SF12 = medical outcomes study short form, SPS= social provisions scale, SNI = social network index, PANAS = positive and negative affect schedule, PSS = perceived stress scale, PSQI = Pittsburg sleep quality index, MAAS = mindfulness attention awareness scale, MSES = mindfulness self-efficacy scale, ESES = exercise self-efficacy scale, GPAQ = global physical activity questionnaire, SIC = Seattle index of comorbidity.

* Seattle Index of Comorbidity – was modified to exclude age and current smoking status, as these were tested separately

Table 2:

Baseline Characteristics Predicting Mean Weekly Minutes of Practice

Baseline Characteristic	Meditation							Exercise						
	N	R ²	Beta	SE	LCL	UCL	Pvalue	N	R ²	Beta	SE	LCL	UCL	Pvalue
Age (years)	126	0.04	2.06	0.93	0.24	3.88	0.028 [*]	128	0.04	1.68	0.78	0.15	3.22	0.033 [*]
Gender (Female)	126	0.00	−15.7	24.65	−64.0	32.60	0.53	128	0.02	−29.9	21.16	−71.3	11.61	0.16
Education ¹	126	0.01	−16.2	12.54	−40.8	8.40	0.20	128	0.00	1.26	10.13	−18.6	21.11	0.90
Household Income ¹	126	0.03	−11.7	6.37	−24.2	0.77	0.07	127	0.00	4.29	5.71	−6.90	15.48	0.45
BMI (kg/m ²)	126	0.00	−0.31	1.37	−2.99	2.37	0.82	128	0.00	0.62	1.29	−1.91	3.14	0.63
Current Smoker	126	0.05	142.0	52.97	38.21	245.9	0.008 ^{**}	128	0.02	−62.9	39.34	−140	14.20	0.11
Seattle Index of Comorbidity ²	126	0.01	9.43	7.72	−5.69	24.56	0.22	128	0.01	−4.69	5.80	−16.1	6.68	0.42
BFI: Agreeableness	126	0.02	3.59	2.16	−0.65	7.83	0.10	128	0.03	3.29	1.63	0.09	6.48	0.046 [*]
BFI: Conscientiousness	126	0.05	4.76	1.95	0.94	8.57	0.016 [*]	128	0.03	3.47	1.63	0.28	6.66	0.035 [*]
BFI: Openness	126	0.07	6.04	1.93	2.26	9.83	0.002 ^{**}	128	0.01	1.63	1.71	−1.72	4.98	0.34
BFI: Extraversion	126	0.02	2.90	1.70	−0.43	6.24	0.09	128	0.01	1.70	1.30	−0.85	4.25	0.19
BFI: Neuroticism	126	0.04	−3.88	1.76	−7.33	−0.42	0.030 [*]	128	0.07	−4.51	1.42	−7.30	−1.72	0.002 ^{**}
SF12: Physical Health	126	0.01	−1.30	1.36	−3.97	1.36	0.34	128	0.01	1.05	1.13	−1.16	3.26	0.35
SF12: Mental Health	126	0.06	2.75	1.01	0.77	4.72	0.007 ^{**}	128	0.04	2.01	0.83	0.38	3.64	0.017 [*]
SPS Social Support	126	0.01	1.36	1.04	−0.67	3.39	0.19	128	0.03	1.80	0.91	0.00	3.59	0.05
SNI: High Contact Score (Network Diversity)	124	0.00	1.00	5.92	−10.6	12.60	0.87	128	0.04	9.44	4.32	0.97	17.92	0.031 [*]
SNI: Potential Contacts	124	0.00	0.38	1.22	−2.00	2.76	0.76	128	0.08	2.90	0.87	1.19	4.62	0.001 ^{**}
SNI: # of Roles	124	0.01	−5.71	6.11	−17.7	6.27	0.35	128	0.02	6.50	4.68	−2.68	15.67	0.17
PANAS Positive	126	0.03	3.07	1.48	0.16	5.98	0.041 [*]	128	0.04	3.25	1.34	0.62	5.88	0.017 [*]
PANAS Negative	126	0.02	−2.90	1.84	−6.51	0.70	0.12	128	0.02	−1.89	1.32	−4.47	0.69	0.15
PSS10 Perceived Stress	126	0.03	−3.36	1.61	−6.53	−0.20	0.039 [*]	128	0.10	−4.83	1.29	−7.36	−2.31	<.001 ^{**}
PHQ9 Depressive Symptoms	126	0.09	−14.9	4.33	−23.4	−6.40	<.001 ^{**}	128	0.04	−7.15	3.10	−13.2	−1.08	0.022 [*]
PSQI Sleep Quality	124	0.01	−3.70	3.39	−10.3	2.94	0.28	125	0.01	−3.45	2.56	−8.47	1.57	0.18
MAAS Mindful Attention	126	0.01	14.65	12.60	−10.0	39.35	0.25	128	0.05	26.07	10.58	5.33	46.82	0.015 [*]

Baseline Characteristic	Meditation							Exercise						
	N	R ²	Beta	SE	LCL	UCL	Pvalue	N	R ²	Beta	SE	LCL	UCL	Pvalue
MSES Mindful Self-Efficacy	126	0.02	0.95	0.67	−0.37	2.26	0.16	127	0.05	1.68	0.63	0.45	2.92	0.008**
ESES Exercise Self-Efficacy	126	0.04	0.64	0.28	0.09	1.19	0.025*	128	0.05	0.62	0.23	0.16	1.08	0.009**
GPAQ Score (MET-minutes/ week)	126	0.00	0.00	0.01	−0.01	0.01	0.53	128	0.05	0.01	0.01	0.00	0.02	0.008**
Feeling Loved Score	126	0.03	0.33	0.17	0.01	0.66	0.046*	128	0.00	0.01	0.14	−0.27	0.29	0.94

* Pvalues: < 0.05,

**
< 0.01

¹ variable modeled as ordinal (ordered categorical)

² Seattle Index of Comorbidity modified to exclude age and current smoker in the computation

LCL= 95% lower confidence limit, UCL= 95% upper confidence limit, SE=standard error

Table 3.

Growth Mixture Models for Identifying the Number of Practice Subgroups

Number of Subgroups	AIC	BIC	aBIC	Entropy	LRT	Subgroup Size
Meditation						
1	54388	54587	54365	-	-	S1=126
2	51581	51882	51547	0.992	P = 0.16	S1=78 S2=48
3	50238	50640	50191	0.988	P = 0.29	S1=49 S2=47 S3=30
Exercise						
1	55805	56004	55783	-	-	S1 =128
2	54348	54651	54314	0.982	P = 0.40	S1=91 S2=37
3	53437	53842	53393	0.982	P = 0.44	S1=61 S2=63 S3=4

AIC = Akaike Information Criteria

BIC = Bayesian Information Criteria

aBIC = Adjusted Bayesian Information Criteria

LRT = Likelihood Ratio Test

Table 4.

Optimal Logistic Regression Models: Factors Predicting Higher vs Lower Practice Subgroups

Independent Variable	Regression Coefficient	Standard Error	Lower 95%CI	Upper 95%CI	Wald p-value	Odds Ratio
Exercise Practice Logit Model						
Intercept	−0.017	1.616	−3.184	3.150	0.991	0.98
Household Income	0.529	0.173	0.190	0.868	0.002	1.70
BFI: Neuroticism	−0.133	0.044	−0.220	−0.046	0.002	0.88
SNI: # of Roles Score	−0.628	0.262	−1.142	−0.115	0.016	0.53
ESES Exercise Self-Efficacy Score	0.017	0.007	0.002	0.031	0.024	1.02
SNI: High Contact Score	0.473	0.241	0.000	0.946	0.049	1.61
Meditation Practice Logit Model						
Intercept	−2.451	1.937	−6.248	1.347	0.205	0.08
PHQ9 Depression Symptoms Score	−0.262	0.107	−0.471	−0.052	0.014	0.76
SPS Social Support Score	0.048	0.023	0.004	0.093	0.033	1.04
Household Income	−0.277	0.125	−0.527	−0.032	0.026	0.75