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A pilot study of mindful walking training on physical activity and health outcomes among adults with inadequate activity

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ABSTRACT

Introduction: Mindful walking is a meditation practice that combines physical activity and mindfulness practice. Some mindful walking interventions expect four weeks of attendance (as compared with the traditional 8-week models of mindfulness-based interventions, or MBIs), a practice that could make MBIs more accessible to working-age adults. This study examined whether a 4-week mindful walking intervention increased physical activity and improved mental health outcomes.

Methods: We conducted a randomized experiment among adults with inadequate physical activity (N = 38), whereby the intervention group received a four-week, one-hour-per-week mindful walking intervention and the control group received instructions to increase physical activity. Everyone in both groups received a wrist-worn step count device as participation incentive. Physical activity (as measured by the Rapid Assessment of Physical Activity questionnaire, RAPA) and other health outcomes were assessed with online surveys at baseline (T1), post-intervention (T2), and one month after the intervention (T3). Those mental health outcomes included perceived stress (Perceived Stress Scale), depression (Brief Edinburgh Depression Scale), and Mental Health Inventory (MHI). The primary outcome of device-measured step count was recorded at T1 and T2. Independent two-sample t-tests were used to compare the primary outcomes at T1. Generalized linear mixed models (GLMM) with a random intercept for each subject were used to compare the two groups on the primary outcomes at all time points. The independent variables in the model included a binary variable for group assignment (intervention vs. control), a 3-level categorical variable for time, and their interaction. Age, gender and race/ethnicity are used as covariates in the model. Estimated changes (either differences or ratios between outcomes at time points T1 and T2/T3) are reported to assess change within groups.

Results: Both groups exhibited significant improvements in the RAPA measures of physical activity and depression. However, between-group differences were not statistically significant. There was no within-group or between-group difference on device-measured step count, though both groups yielded an average daily step count close to the recommended level of 8,000 steps per day for older adults. The intervention group exhibited a significant reduction in perceived stress, and this reduction was significantly greater than that of the control group at T2 ($p = .025$) although the difference was insignificant at T3. No significant difference in MHI was found.

Discussion: While these adults with inadequate physical activity increased their physical activity, no significant between-group differences in physical activity were identified. Potential reasons for the lack of significant findings could be due to the ceiling effect (the step count device for everyone in both groups might have encouraged more activity in both groups), limited sample size and low-dose 4-week intervention used in this study. On the other hand, it is encouraging to see that this low-dose, short-duration 4-week intervention (as compared with those popular 8-week MBIs) achieved significantly greater stress reduction among the intervention group than among the control group, even though the between-group difference at one-month follow-up was statistically insignificant. Further studies with larger sample sizes and longer follow-up are needed to assess the possible benefits of these short-duration mindful walking interventions.

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1. Introduction

Mindfulness meditation therapies are a type of therapy that actively cultivate conscious attention and awareness [1,2] while also becoming increasingly popular as a form of treatment for various health conditions. [1,3–6] Mindfulness meditation has been applied for the prevention and treatment of psychological and physiological health disorders, as well as the promotion of healthy lifestyle choices. [7–10]

One concern about meditation therapy is that it is often a sedentary behavior. Considering the importance of physical activity in living a healthy lifestyle, one may want to consider a more physically active alternative to sedentary meditation, an alternative that retains the stress reduction function of standardized mindfulness intervention yet does not increase sedentary hours in a day. Mindful walking (sometimes called "walking meditation") is a combination of light physical activity and mindfulness practice. [11–13] Research has shown it to be efficacious in reducing stress and depressive symptoms, [14–17] decreased HbA1c levels, and reductions in both systolic and diastolic blood pressure among diabetes patients. [18]

It remains unclear, however, whether individuals who have participated in mindful walking interventions actually increased their physical activity or other healthy behaviors or showed improvement in related lifestyle factors. [19–21] It is also unclear whether the previously reported benefits of mindful walking are a result of the meditation component of the intervention or whether there may have been an interaction effect between physical activity and meditation, since mindfulness meditation may improve engagement and performance in physical activity. [22–24] While previous research has shown significant reductions in depression scores, low-density lipoprotein cholesterol, cortisol and interleukin-6 concentrations among the depressed elderly with a 2-week, three-session- per-week intervention, [25] it is questionable whether an intervention with this level of program duration and meeting frequency can be easily applied to working-age adults in community settings. Therefore, it is worthwhile to study whether a shorter-duration intervention with a lower frequency of training sessions can accomplish similar results in outcomes.

In this study, we aimed to recruit adults with low physical activity levels for a four-week, one-hour- per-week mindful walking intervention. Specifically, we used a randomized controlled trial (RCT) to address the following research questions about the primary outcomes related to physical activity:

1 Does a four-week mindful walking intervention increase physical activity among adults with inadequate physical activity, in comparison to education alone?
2 Does a four-week mindful walking intervention decrease screen time among adults with inadequate physical activity, in comparison to education alone?

The secondary outcomes we examined in this mindful walking intervention included sleep quality, perceived stress, depression symptoms, and trait mindfulness.

This mindful walking intervention is characterized by a relatively short time commitment given its four-week duration and one-hour-per-week class schedule, as compared with those standardized mindfulness intervention protocols that utilized eight-week mindfulness-based stress reduction (MBSR) [26] and eight-week mindfulness-based cognitive therapy (MBCT). [27] Our intervention is also substantially shorter than the 12-week walking meditation interventions used among the depressed elderly, who could have more time available for attending the intervention than working- age adults and adolescents. [25] Our study can be viewed as an attempt to examine whether a low-

dose mindfulness intervention [28] can accomplish similar health benefits as seen in MBSR, MBCT and longer versions of mindful walking interventions.

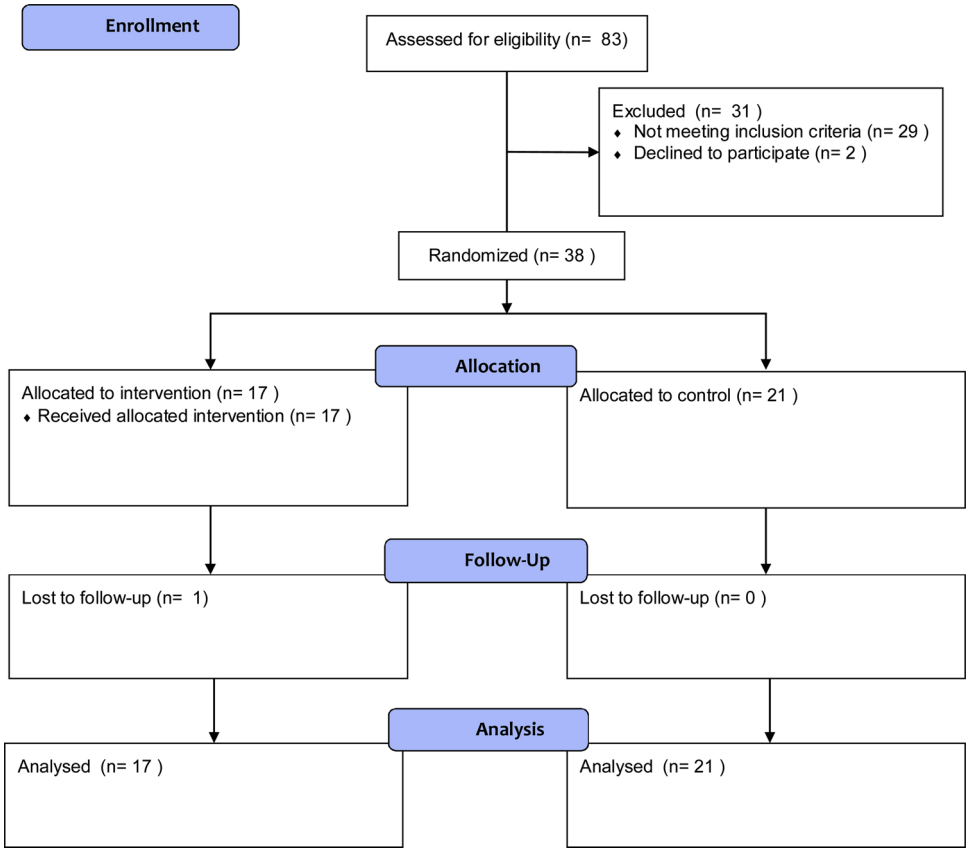

Fig. 1. CONSORT Flow Diagram.

2. Methods

This study was approved by the Clemson University Institutional Review Board. The protocol was registered on ClinicalTrials.gov (Identifier: NCT03856385).

2.1. Study design and population

We recruited a community sample of 40 inadequately active adults through university employee mailing lists and local community group contact lists. The sample was limited to 40 participants due to budget restrictions for this initial feasibility trial. Participants were solicited with electronic and paper recruitment messages that outlined study criteria and participation incentives of a consumer- level mobile physical activity tracking device (Fitbit-HR)—an instrument validated for measurement of over ground activity [29]and the possibility of getting free mindful-walking training sessions. The inclusion criteria and exclusion criteria were as follows:

2.2. Inclusion criteria

(1)
   (1) Willing to wear a Fitbit-HR physical activity monitoring device and attend weekly mindful walking sessions for the duration of the study
   (2) Able to understand and read English
   (3) Have internet access for survey completion and Fitbit-HR device data collection
   (4) Age above 18 years

2.3. Exclusion criteria

(1) Meeting or exceeding the following Centers for Disease Control and Prevention (CDC) physical activity guidelines [30]: Adults who do at least 150 min (2 h and 30 min) a week of moderate-intensity, or 75 min (1 h and 15 min) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity
(2) Student athletes, due to their mandated sport related activity levels
(3) Having a current diagnosis of cognitive impairments that would interfere with the use of technology
(4) Having a condition that would limit their ability to perform normal walking (slow walking for at least 20 min)

2.4. Screening, initial instructions, and randomization

A member of the research team conducted an initial screening of participants, and invited the first 40 eligible participants to a recruitment meeting. A total of 38 participants attended the recruitment meeting, during which they were provided with an overview of the study, a copy of the informed consent form to review and an opportunity to ask any questions (Fig. 1). After providing written consent and completing the baseline survey, participants were given a Fitbit-HR, familiarized with its physical activity measurement features, instructed to wear the device on a daily basis and synchronize their data with the Fitbit-HR website weekly. One week of baseline physical activity data was collected prior to the start of the intervention for use in stratified randomization procedures and to confirm daily Fitbit-HR data was being recorded. Following the baseline phase of the study, all participants were encouraged to set up physical activity goals (e.g., meet CDC-recommended levels of moderate or vigorous physical activity, increase daily steps, or decrease sedentary time) and they received short e-mail messages every other week to encourage them to meet their goals and complete any potential online surveys that were scheduled.

Randomization was conducted by the principal investigator without restriction, using the random number generation function in Microsoft Excel. Participants were also instructed that they would be randomized into two groups and they would need to attend four additional sessions if they were assigned to the mindful-walking group. The participants were initially assigned an ID number based on the order by which they were enrolled, while the principal investigator and the study personnel in charge of participant ID entry had access to this list of participant IDs. Each ID in the list of participant IDs was then randomized by the Excel random number generation (the RAND() function generating random number from 0 to 1) to the intervention group if the random number reached or exceeded the value of 0.5 or to the control group if the number fell below 0.5. Based on the randomization results, we assigned 21 participants into the control group and 17 into the intervention group. One participant randomized into the intervention group left the study after the baseline assessment and therefore this study had a final sample of 37 participants with 21 in the control group and 16 in the intervention group. Participants, study personnel, therapist, and outcome assessors were not blinded to study condition.

2.5. The control group

After randomization, the control group was not required to meet again until the end of the study, at which time they were provided with the opportunity to attend a mindful-walking training session. The only contact with control group participants during the intervention was through the e-mail messages encouraging them to meet their weekly physical activity goals.

2.6. The intervention group

In addition to receiving e-mail encouragement to meet their weekly physical activity goals, intervention group participants were required to attend weekly 60 min mindful-walking sessions for a period of 4 weeks. The frequency and duration of our sessions were modeled after one of the lower-frequency, shorter-duration protocols used in mindful walking research, [10] since the primary outcomes of this study are physical activity instead of fitness measures and biomarkers. Each session included the following components taught by a licensed mental health counselor:

(1) Arrival at a predetermined location and greetings
(2) Light warm-up and stretching in a quiet indoor space (10 min)
(3) Group mindful walking instruction (10 min)
(4) Individual mindful-walking practice (30 min): Participants were instructed to mindfully observe their body sensations during light slow walking while focusing on breaths, steps and their moment-to-moment experiences without being lost in thoughts triggered by the experience
(5) Share and discuss mindful-walking experiences (10 min)
(6) Wrap-up and light encouragement to work towards individual physical activity goals

The mindful-walking instruction and discussion content covered during the course of the four-week intervention involved increasing levels of depth on bringing mindfulness practice into one's daily life.

2.7. Data collection and measurement

Physical activity and other health outcomes such as perceived stress, health related quality of life, sleep quality, depression, and mindfulness were measured using three online surveys and step count data collected through the Fitbit-HR data collection website for the period beginning one week prior to the intervention through to the end of the intervention. Survey 1 (T1) was administered at baseline (the week prior to the intervention), Survey 2 (T2) after the four-week intervention and Survey 3 (T3) four weeks after the completion of the intervention. Fitbit-HR device data (daily step counts) was collected throughout the

duration of the study. The study took place in May through August 2017. The trial ended after completion of the data collection phase (i.e., T3 data were collected).

Participation in the mindful walking training sessions was the main exposure variable. The primary outcomes of interest was level of physical activity and screen time. Self-reported weekly physical activity was assessed using the Rapid Assessment of Physical Activity (RAPA) Scale [31] along with questions on daily screen time. Objectively measured weekly physical activity was assessed as average daily step counts, based on data provided by the Fitbit-HR device.

The other primary outcome measured in this study is the self-reported screen time, [32] as it is a health behavior measure negatively related with physical activity. [33] We operationalize the measurement of screen time with four questionnaire items: weekday television time, weekday recreational non-TV screen time, weekend television time, weekend recreational non-TV screen time. [34,35]

Secondary outcomes of interest included self-reported health outcomes which were assessed with validated scales in our online surveys. These outcomes were:

(1) Perceived stress, as measured using the Perceived Stress Scale [36];
(2) Health-related quality of life, as measured using the Mental Health Inventory (MHI-5) [37];
(3) Depression, as measured using the six-item Brief Edinburgh Depression Scale [38];
(4) Mindfulness, as measured using the Freiburg Mindfulness Inventory [39];
(5) Sleep Quality, as measured using the Pittsburgh Sleep Quality Index (PSQI). [40]

All outcome variables were quantified based on coding instructions associated with the surveys and all variables were included in each of the 3 surveys administered during this.

2.8. Incentives

The wrist-wearable device (FitBit-HR), which measures step counts and heart rate, was given to all the participants in both groups as an incentive for participation.

2.9. Data analyses

Response rates were determined as the percentage of baseline participants who submitted follow-up survey data and complete Fitbit- HR data. To test for balance between the intervention and control group at baseline, we used Kruskal-Wallis tests for continuous variables (age and BMI), Cochran-Armitage trend tests for ordinal variables (age group, BMI group, education, general health), chi-squared tests for binary variables (gender, born in US), and Fisher's exact test for multinomial variables (race). Independent two sample *t*-tests were used to compare the primary outcomes at baseline. The primary outcomes for the survey data were recorded at baseline (T1), immediately after intervention (T2), and 1 month post intervention (T3). The primary outcomes for Fitbit data were recorded at T1 and T2. Independent two sample t-tests were used to compare the primary outcomes at T1. Generalized linear mixed models (GLMM) with a random intercept for each subject were used to compare the two groups on the primary outcomes at all time points. The predictors in the model included a binary variable for group, a 3-level categorical variable for time, and their interaction. Baseline covariates were examined for inclusion in the model, but did not significantly alter the results. A Poisson distribution was assumed for discrete count variables. All other variables were assessed for normality, and some log transformations were applied. Estimated changes (either differences or ratios between outcomes at time points T1 and T2/T3) and corresponding confidence intervals are reported to assess change within groups. Within group differences or ratios are deemed significant at the $\alpha = 0.05$ level if the estimated confidence intervals exclude 0 or 1, respectively. Between group comparisons at T2 and T3 are deemed significant for p-values $< \alpha$. Following an intent-to-treat principle, multiple imputation was performed to replace missing values. Inference is based on the parameter estimates from the GLMM corresponding to 10 imputed data sets. Analyses were conducting using the MI, GLIMMIX, and MIANANALYZE procedures in SAS.

3. Results

3.1. Recruitment, participation, and follow-up

All participants attempted the baseline survey questionnaires, of which 89.47% were complete. The response rate was 94.74% for the immediate post-intervention follow-up survey, of which 83.33% surveys were complete. The response rate was 89.47% for the one-month post-intervention follow- up survey, of which 94.12% surveys were complete. Adherence to instructions to wear Fitbit-HR daily beginning from the baseline period (one week before beginning of intervention) to end of the intervention period (28 days) was 97.37%. We did not specifically ask respondents about adverse events in survey questionnaires, and no adverse events were reported from the qualitative answers about their experience with mindful walking and the use of the wearable device.

3.2. Baseline demographic characteristics

Table 1 shows the demographic characteristics of the study population recorded at baseline. The age range was 23–73 years, with 54.05% of the population falling in the 40–60 age group. Female participants comprised 86.84% of the total sample. The average BMI was 30.07, with about 34.21% of the population falling in the overweight category (BMI $>= 25$ & < 30) and 39.47% of the population falling in the obese category (BMI $>= 30$). The racial composition included Whites (76.32%), Blacks (18.42%), American Indian or Alaska Natives (2.63%) and an Asian (2.63%). A majority of the participants (94.74%) were born in the United States. Fifty percent of the participants were from the Clemson Employee community and 50% from local community groups. Eleven participants (29%) reported a chronic medical condition, with the most frequent being thyroid disorder (n = 5), back pain/degenerative disc disorder (n = 5), and asthma (n = 3). There were no significant differences in the baseline demographic characteristics, physical activity and health outcomes between the intervention and control group. Table 2 compares the primary outcomes at baseline, indicating there were no significant differences between groups.

3.3. Comparing behavioral and health outcomes

The intervention group exhibited a significant reduction in perceived stress, and this reduction was significantly greater than that of the control group at T2 (p = .025) (Table 3). Both groups exhibited significant improvements in the survey measures of physical activity score and depression, however between group differences were not statistically significant. The control group exhibited a significant reduction in weekday non-TV screen time hours while the intervention group did not, however between group differences did not reach statistical significance. The control group had a higher average of non-TV hours on weekdays at baseline (5.02 vs 2.82), and it is plausible that the significant within group reduction in the control group may simply be a case of regression to the mean. The groups did not exhibit significant changes on mindfulness, health-related quality of life, or sleep quality.

There was no within group or between group difference on physical activity as measured by the Fitbit-HR step count, though both groups yielded an average daily step count close to the recommended level of 8000 steps per day for older adults. [41] One week prior to the intervention, six out of 21 participants (29%) in the control group averaged

Table 1
Baseline Descriptive Statistics.

Variable	Total	Group		P-value
		Control Group	Intervention	
Age (years)[1]	49.3 (14.0)	46.5 (12.4)	52.7 (15.3)	0.14
Age Group				0.33
Age < 40[2]	10 (27.0)	6 (30.0)	4 (23.5)	.
Age between 40-60	20 (54.1)	12 (60.0)	8 (47.1)	.
Age > 60	7 (18.9)	2 (10.0)	5 (29.4)	.
Gender (female)[4]	33 (86.8)	19 (90.5)	14 (82.4)	0.46
Race				0.17
White[4]	29 (76.3)	18 (85.7)	11 (64.7)	.
Black	7 (18.4)	2 (9.52)	5 (29.4)	.
American Indian or Alaska Native	1 (2.63)	1 (4.76)	0.0 (0.0)	.
Asian	1 (2.63)	0.0 (0.0)	1 (5.88)	
Body Mass Index[1]	30.1 (7.61)	29.5 (5.37)	30.7 (9.76)	0.76
Body Mass Index Group				0.70
BMI < 18.5[2]	1 (2.70)	1 (5.00)	0.0 (0.0)	.
BMI between 18.5-25	8 (21.6)	2 (10.0)	6 (35.3)	.
BMI between 25-30	13 (35.1)	9 (45.0)	4 (23.5)	.
BMI > 30	15 (40.5)	8 (40.0)	7 (41.2)	.
Born in US[4]	36 (94.7)	20 (95.2)	16 (94.1)	0.88
Education[2]				
Some College, no degree	6 (15.8)	2 (9.52)	4 (23.5)	.
2 year degree	2 (5.26)	2 (9.52)	0.0 (0.0)	.
4 year degree	10 (26.3)	6 (28.6)	4 (23.5)	.
Master's Degree	13 (34.2)	7 (33.3)	6 (35.3)	.
Doctorate Degree	7 (18.4)	4 (19.0)	3 (17.6)	0.71
General Health[2]				
Excellent	2 (5.26)	2 (9.52)	0.0 (0.0)	.
Very Good	11 (28.9)	6 (28.6)	5 (29.4)	.
Good	16 (42.1)	10 (47.6)	6 (35.3)	.
Fair	9 (23.7)	3 (14.3)	6 (35.3)	0.19

[3]Binomial Proportions compared using Chi-Square Test; Reported Values: N(%).
[1] Continuous variables compared using Wilcoxon/Kruskal-Wallis Test; Reported Values: Mean (SD).
[2] Ordinal variables compared using Cochran–Armitage Trend Test; Reported Values: N(%).
[4] Multinomial Proportions compared using Fisher's Exact Test; Reported Values: N(%).

over 8000 steps per day and six out of 16 participants (38%) in the intervention group averaged over 8000 steps per day. During the intervention (30 days), six participants in the control group (29%) and seven participants in the intervention group (44%) averaged over 8000 steps per day. In the last seven days of the intervention, seven participants in the control group (33%) and five participants in the intervention group (31%) averaged over 8000 steps per day.

4. Discussion

Mindful walking, a traditional meditation practice that combines physical activity and meditation, has received far fewer assessments of efficacy as compared with other forms of meditation such as mindfulness-based stress reduction and mindfulness-based cognitive therapy. Our study is among the early attempts to evaluate the feasibility and efficacy of this low-dose community-based intervention that combines light physical activity and meditation. Although the small sample size of our study limits our ability to fully assess the health outcomes of our mindful walking intervention among adults with inadequate physical activity levels, the overwhelming majority of the study participants finished the study and submitted the Fitbit-HR data, which is an encouraging sign of feasibility for future trials with larger sample sizes. The other limit of our study is our simple randomization procedure: although Table 1 shows the differences between our two study groups were statistically insignificant, for a small sample restricted randomization will still be a beneficial approach. [42]

In our four-week mindful walking intervention with the training frequency of one hour per week, those in the intervention group improved on perceived stress, physical activity, and depression. In addition, the intervention group exhibited greater improvements than the control group on perceived stress. We expected to see greater differences between groups on mindfulness and depression, based on prior literature documenting the effects of mindful walking interventions on these outcomes. [14–17] Mindfulness-based interventions are considered to exert these effects via their impact on self-regulation and re-perceiving. [25] (shifts in perspective). [43] In addition, participants with depression can benefit from the social connection and social skills training afforded by group treatment modalities. [44] Aside from the limited sample size, it is plausible to infer that the lack of significant between-group difference in our study is a function of our intervention's shorter duration and lower frequency as compared with the 12-week intervention of thrice-a-week walking meditation sessions. [25] It is possible that the training frequency of twice a week for four weeks [10] or once a week for six weeks [28] might be the minimum dosage needed for significant health outcomes to be at an observable level. In addition, we utilized broad inclusion criteria for this study. This may have made it difficult to detect differences between groups, due to large standard

Table 2
Baseline Scores on Outcome Measures.

Outcomes	Total MeanSD		Control MeanSD		Intervention MeanSD		P-value[3]
Physical activity (RAPA Score)[2]		4.71	1.80	4.86	2.01	4.53	1.55
Step count (device-measured, thousands)[2]	7.83	3.01	7.66	3.12	8.01	2.96	0.73
Perceived stress[1]		9.18	2.71	9.05	2.33	9.35	3.18
Health-related quality of life[1]		11.95	3.88	12.24	3.75	11.59	4.12
Depression[2]		19.05	2.83	18.95	2.78	19.18	2.96
Mindfulness[2]		37.42	8.09	37.90	9.53	36.82	6.09
Sleep Quality[1]		12.14	2.66	12.55	2.84	11.65	2.42
TV hours on weekdays[1]		2.55	2.78	2.61	2.48	2.49	3.20
TV hours on weekends[1]		3.56	3.23	4.13	3.97	2.85	1.85
Non-TV Screen time on Weekdays[1]		4.07	3.42	5.02	3.81	2.82	2.39
Non-TV Screen time on Weekend[1]		2.74	2.12	2.81	2.10	2.65	2.19

Notes:
N = 38.
4The Fitbit-HR data from 7 days prior to the intervention was used to calculate average step count per day during baseline.
[1] lower score implies better outcome.
[2] higher score implies better outcome.
[3] p-values at T1 based on independent two sample *t*-test comparing groups on outcomes at T1.

Table 3
Results of Generalized Linear Mixed Models Estimating Change in Outcomes.

Variable	T2			T3		
	Control Estimate (CI)	Intervention Estimate (CI)	P-Value Estimate	Control Estimate (CI)	Intervention Estimate (CI)	P-Value Estimate
Physical Activity (RAPA Score)[1a]	1.17 (0.36, 1.98)	1.74 (0.80, 2.68)	0.37	1.77 (0.93, 2.62)	1.39 (0.45, 2.33)	0.55
Step count[a]	418.8 (-580, 1417)	80.1 (-999, 1159)	0.65			
Perceived stress[1b]	0.62 (-0.43, 1.67)	−1.21 (-2.41, -0.01)	0.02	−0.76 (-1.92, 0.40)	−1.01 (-2.21, 0.20)	0.77
Health-related quality of life[1b]	−0.19 (-1.75, 1.37)	−1.09 (-2.92, 0.74)	0.46	−1.64 (-3.28, 0.00)	−0.58 (-2.42, 1.25)	0.40
Depression[2]	1.14 (0.11, 2.17)	1.06 (-0.14, 2.27)	0.92	1.86 (0.75, 2.97)	1.66 (0.50, 2.81)	0.80
Mindfulness[1a]	−0.56 (-2.91, 1.78)	1.20 (-1.58, 3.98)	0.34	−0.58 (-3.09, 1.93)	1.08 (-1.59, 3.75)	0.37
Sleep Quality[1b]	0.46 (-0.39, 1.31)	−0.42 (-1.56, 0.71)	0.22	−0.12 (-1.22, 0.98)	−0.97 (-2.05, 0.11)	0.30
TV hours on weekdays[2]	0.79 (0.48, 1.11)	0.77 (0.41, 1.13)	0.92	1.01 (0.62, 1.40)	0.70 (0.34, 1.06)	0.25
TV hours on weekends[2]	0.90 (0.63, 1.18)	0.85 (0.44, 1.25)	0.81	0.89 (0.61, 1.17)	0.76 (0.39, 1.13)	0.60
Non-TV hours on weekdays[2]	0.61 (0.42, 0.80)	0.97 (0.56, 1.38)	0.08	0.67 (0.46, 0.87)	1.10 (0.65, 1.56)	0.05
Non-TV hours on weekends[2]	1.19 (0.78, 1.60)	1.27 (0.74, 1.80)	0.82	1.28 (0.83, 1.73)	1.12 (0.65, 1.58)	0.62

Note. N = 38.
[1]Estimate represents difference in pre-post score.
[a]Positive change score implies improvement in outcome.
[b]Negative change score implies improvement in outcome.
[2]Estimate represents ratio of pre-post score, where ratio < 1 implies improvement in outcome.

deviations on outcome measures. It is also possible that if we limited our sample to participants with more significant impairments in mental and physical health, we would have observed greater changes in response to the intervention.

It is encouraging to see that as per the results of the RAPA measure, both groups in our study, which had relatively low physical activity levels prior to the study, significantly increased their physical activity over baseline and were able to sustain a higher level of physical activity one month after our low-dose four-week intervention. While it is possible that our small sample limits our capability of detecting a significant difference, it is also likely that our use of Fitbit-HR as a participation incentive for both groups motivated both groups to be substantially more active to a degree where both groups reached a temporary ceiling of physical activity improvement. The fact that both groups had an average daily step count around 8000 steps during the intervention further hints that they could be at a temporary ceiling of physical activity: the upper bound of step count range among older adults is observed to be 9000 steps. [41] The within group difference seen in the RAPA scores was not supported by the Fitbit-HR data. A possible reason for this discrepancy could be that the participants received the Fitbit-HR device after they had completed the baseline survey. Therefore, the Fitbit-HR device did not really capture the true baseline physical activity level.

The findings from this study do not provide adequate evidence to establish the efficacy of mindful walking on, mindfulness, sleep quality, and health-related quality of life. However, the fact that the intervention group improved on physical activity and depression, and exhibited greater improvements than the control group on perceived stress, after a mere total of four hours of training gives promise that mindful walking could be a potential cost-effective intervention, as our total budget for therapist's pay and facility rental was less than $1000. Because mindful walking appeared to exert an impact on perceived stress, this intervention has broader implications for its potential impact on physical health outcomes associated with chronic stress. Future studies might consider adopting a larger sample with a higher dose of mindful walking training (e.g., aerobic walking exercise incorporating the meditation three times per week for twelve weeks [25]) for a more rigorous assessment of its mental and physical health effects.

Using mobile devices to measure health outcomes is a relatively new practice in complementary and alternative medicine. The fact that 78% of our subjects used the Fitbit-HR every day and 100% used the Fitbit-HR at least 6 days per week implies promising potential for using Fitbit-HR in terms of physical activity assessment. The temporal patterns we detected using Fitbit-HR-measured step count were consistent with the patterns we detected using the validated RAPA score, which echoes previous researchers' finding that certain consumer-level devices could provide moderately valid measures of physical activity. [45] Given consumer-level mobile devices' function for monitoring sleep duration, [45] future studies could consider using mobile devices to provide an additional measure of mindful walking's impact on sleep patterns and other health behaviors.

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