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Use of a Wearable Technology and Motivational Interviews to Improve Sleep in Older Persons with Osteoarthritis and Sleep Disturbance: Pilot Study

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Abstract

We evaluated the feasibility and preliminary efficacy of a mobile health (mHealth) self-management intervention aimed at improving sleep among older adults with osteoarthritis and disturbed sleep. This was a one group pre-posttest pilot study. Feasibility was measured by the number of participants eligible, enrolled, and retained. Primary efficacy outcomes were the Insomnia Severity Index (ISI) and two sleep actigraphy variables - total sleep time (TST) and sleep efficiency (SE). Overall step count, Self-Efficacy (SEff) and Acceptance of Sleep Difficulties (ASD) were mechanisms of action variables. Assessments were at baseline, week 14 (post-intervention), and week 19 (follow-up). Mixed effect models were used to measure change over time. Twenty-four participants (mean age 71.0 ± 4.0 years) were enrolled and twenty-two completed the study. Improvements of 1.2 (95% CI 2.43, 0.05; $p=0.04$) and 2.5 (95% CI 0.9, 4.9; $p=0.02$) points in the ISI and ASD scores, respectively were found over the 19-week period.

Targets: Older adults with osteoarthritis and insomnia symptoms.

Intervention Description: Activity trackers synced to a dashboard that triggered personalized weekly step goals and motivational messages augmented by telephone motivational interviews.

Mechanism of Action: physical activity, SEff and ASD.

Outcomes: sleep measures.

More than 50% of adults aged 65 years and older with osteoarthritis experience bothersome sleep symptoms such as disrupted sleep and insomnia (Foley, Ancoli-Israel, Britz & Walsh, 2004; Kirwan et al., 2005). Arthritis pain has been implicated in sleep problems (Power, Perruccio, & Badley, 2005) and exercise interventions have been shown to improve arthritis pain and sleep quality (Regnaud et al., 2015). Unfortunately, older adults with osteoarthritis are mainly sedentary, and few achieve the recommended US national guidelines of at least 150 minutes of moderate aerobic activity every week (Lee et al., 2015). Besides physical activity, acceptance and self-management practices are additional behavioral approaches that can improve sleep (Taibi & Vitiello, 2011; Vitiello, Rybarczyk, Von Korff & Stepanski, 2009), but are underutilized in this population.

Commercially available activity tracking devices coupled with mHealth technologies are ubiquitous, functionally sophisticated, and have the capacity to provide timely feedback, personalization, and interactivity, all of which are important to support sustainable behavioral change. Digital reinforcers offered by mHealth technologies are especially pertinent for older populations because they target behaviors, bypass memory problems, and alleviate apprehension caused by in-person contacts. Previous studies have shown that wearable activity trackers are feasible and acceptable for use for behavioral activation in general older adult population (Nguyen, Gill, Wolpin, Steele, & Benditt, 2009; Vidoni et al., 2016). However little is known about the feasibility of this technology to elicit behavioral changes, promote self-management, and improve sleep in older adults with osteoarthritis and sleep disturbance. Comorbidities and functional limitations might interfere with older adults' willingness to adopt wearable (Parker, Jessel, Richardson, & Reid, 2013) and thus, affect their self-management behaviors. Another common methodological limitation in prior studies is that changes in behavioral measures were examined only at the end of treatment. Although conceptually sound, this approach focuses on short-term efficacy and might imperfectly predict longer-term behavioral maintenance.

To address these gaps, we conducted a pilot study that evaluated the feasibility and preliminary efficacy of a mHealth self-management intervention aimed at improving sleep among older adults with osteoarthritis and disturbed sleep. Feasibility was determined from number of participants eligible, enrolled, and retained. Primary efficacy outcomes were the Insomnia Severity Index (ISI) score and sleep actigraphy (TST, SE) measures. Overall step count, Self-Efficacy (SEff), and Acceptance of Sleep Difficulties (ASD) were theoretical mechanistic variables of physical and psychological factors involved in self-management (see Figure 1).

METHODS

Study Design

This was a prospective one group pre-posttest study to test the feasibility and efficacy of a multidimensional intervention, the components of which were wearable activity tracking devices, personalized texts, and motivational interviews. Participants received a Fitbit Charge 2 device [Fitbit, San Francisco, CA]) and were given access to the Fitbit mobile app to facilitate their self-monitoring. The study occurred over 19-weeks. In the first 14-weeks, study staff maintained routine contact with participants, including for personalized reminders to sync their activity device with the app. During the 5-post-intervention follow up phase, participants used their activity device and mobile app without support from study staff. University of Washington Institutional Review Board approval of the study protocol was obtained.

Participants

Study participants were recruited between May 2017 and March 2018 through direct mailings, presentations, and flyers in retirement communities and other places frequented by older adults in Seattle, WA. Eligibility criteria included: a) being age 65 years and older, b) having a diagnosis of osteoarthritis, c) having a smartphone, d) having physical activity levels below the U.S. Department of Health and Human Services recommended guidelines evaluated using the Rapid Assessment of Physical Activity scale (Topolski et al., 2006), and e) having Insomnia Severity Index score ≥ 12 (Bastien, Vallières, & Morin, 2001). Exclusion criteria included: a) having an acute injury associated with hip or knee pain, b) inability to stand up without assistance, c) having a Memory Impairment Screen for Telephone (MIST) (Lipton et al., 2003)) score of <4 , d) having severe hearing or visual impairment, and e) an acute episode or change in the treatment of psychiatric problems within the past 3 months. Eligible participants were compensated up for a total of \$150.

Intervention Components

Wearable Activity Tracking Devices—The Fitbit Charge 2 is a heart rate and fitness wristband used to deliver the intervention and measure daily step counts. This device was selected because 1) it can accurately sense step count in older adults (Burton et al., 2018); 2) it has an optical heart rate sensor that monitors and documents heart rate over time, thus allowing for collection of objective wear time; and 3) its technology permitted the retrieval of near real time information exchange between the Fitbit app and the iCardia research platform (described later), thus creating an optimal medium for a personalized intervention.

Personalized Texts—The adaptive personalized intervention was informed by Control Theory framework (Carver & Scheier, 1982), which postulates that to initiate and maintain a desired behavior, such as increased physical activity, behavioral change techniques (e.g., specific goal setting, feedback on performance, self-monitoring of behavior and review of behavioral goals) should be provided. Following a formative process that included an expert panel, end users, and literature review, we developed targeted behavioral change text messages that provided information and motivational reinforcement with regard to participant's past and concurrent physical activity progress. Participants received weekly

targeted and personalized text messages that provided motivational feedback according to their adaptive step count attainment. The step count attainment was determined at 3 time points and calculated as follows. Over the first week, average step count was calculated and constituted participants' baseline. Over the next month, departure from that baseline was calculated each week and categorized according to the extent of percentage difference between baseline and that week average step count. Categories included "decline of more than 5% from baseline", "maintenance within 5%," and "increase of more than 5% from baseline". Weekly categories (i.e., 'decline', 'maintenance', 'increase') informed content of the weekly messages and provided reinforcement for those who increased or maintained, and encouragement for those in a 'decline' category (see supplemental Table 1). After one month, a new baseline count was calculated according to the average step count over the first month. Accordingly, subsequent weekly text messages over the second month reacted to the percentage differences between weekly step counts and a recalibrated one-month baseline. Over the third month, this procedure was repeated again. Upon completion of the intervention, a total of 12 motivational text messages were sent to the participants.

Motivational interviews—In addition to text messages, three phone calls at weeks 1, 5, and 9 that were informed by motivational interviewing principles (Georgopoulou, Prothero, Lempp, Galloway, & Sturt, 2016) were scheduled with participants to discuss their goals and debrief strategies for facilitating behavioral change. These conversations focused on specific goal setting and action planning behavioral change techniques derived from the control theory framework. All phone calls were scripted, recorded and randomly sampled as to ensure the intervention fidelity.

Remote and self-monitoring—The iCardia research platform was used to retrieve data from the Fitbit cloud server, present these data on a user-friendly dashboard, and send personalized text messages to the end user smartphones (Kitsiou et al., 2017). In addition to motivational messages, reminders to sync the Fitbit and charge its battery were sent when participants failed to sync for more than 3 days and/or tracker battery was low. On average, 5 reminders were sent to participants over the first 14 weeks of the study. Participants were also encouraged to maintain sleep diaries (described later) over weeks 1, 5 and 9 as to target acceptance-based behaviors.

Training and Troubleshooting

Participants received a basic orientation when enrolled into the study, assistance with troubleshooting for the next 14 weeks, and limited assistance after that. Approximately half of enrolled individuals called research staff with questions and challenges solvable by phone. On three occasions an in-person visit was needed to address technical issues mainly related failure to sync. In one instance, a tracker had to be replaced by the manufacturer due to technical failure. An interventionist, who delivered phone calls, received training in Motivational Interviewing.

Data Collection Procedures

A study coordinator (SC) collected data during one-on-one interviews and remotely using standardized procedures at three-time points. At the baseline in-person assessment, the SC

administered clinical and demographic questionnaires and provided actigraphs (described later). The second and third assessments at weeks 14 and 19 occurred either in-person or remotely by using Research Electronic Data Capture (REDCap) online survey feature. During the second and third data collection points, participants were also provided with actigraphs, which they were instructed to wear for one week and mail back to the research office.

Measures

Questionnaires—Baseline questionnaires included the following demographic variables: self-reported age, sex, educational attainment, race, and ethnicity. Pain was measured using the *Graded Chronic Pain Scale* (GCPS), a 7-item scale that assesses two dimensions of overall chronic pain severity: pain intensity and pain-related disability. Higher GCPS scores indicate worse symptoms. The scale has high internal consistency (IC) from 0.81–0.89 for subscales and global scores in patients with chronic musculoskeletal pain (Salaffi, Stancati, & Grassi, 2006). *Self-efficacy* (SEff) to manage chronic conditions was measured by a 6-item scale (Lorig, Sobel, Ritter, Laurent, & Hobbs, 2001). The items cover several domains that are common across many chronic problems, including symptom control, role function, emotional functioning and communicating with clinicians. A higher SEff score indicates better efficacy. The scale has IC of 0.88–0.95 (Lorig et al., 2001). The *Insomnia Severity Index* (ISI), is a 7-item questionnaire that assesses insomnia symptoms over the past week. The ISI is scored from 0 to 28, with higher scores indicating more severe insomnia symptoms. Internal consistency of the ISI is 0.74 (Bastien et al., 2001). *Acceptance of Sleep Difficulties* (ASD) is an 8-item scale that assesses activity engagement and willingness to accept insomnia symptoms. The scale has IC of 0.89–0.73 across the subscales (Bothelius, Jernelöv, Fredrikson, McCracken, & Kaldo, 2015). A higher ASD score indicates better acceptance.

Sleep diary and Actigraphy—Participants were asked to complete sleep diaries and wear actigraphs at weeks 1, 5 and 9. Sleep diaries collected time in bed (TIB), sleep onset latency (SOL), wake after sleep onset (WASO) and overall sleep quality (a 1 to 9 scale with 1=terrible and 9=great), which were used to compute total sleep time (TST), sleep efficiency (SE), and overall sleep quality (SQual) measures. TST was calculated as TIB – SOL – WASO – time between awakening and arising. SE was calculated as $TST/TIB \times 100$, with a higher value indicating better efficiency.

Participants wore an AW64 actigraph (Phillips/Respironics, Inc., Murrysville, PA) on their non-dominant wrist, which was used to collect objective sleep measurements. The actigraphs recorded activity counts in one-minute epochs, and each epoch was scored as being asleep or awake using the medium sensitivity threshold. Data were analyzed using Actiware version 6.0.9 (Respironics, Inc., Murrysville, PA). Bedtime and rise-time were entered in the software based on participant's sleep diary entries. The calculated sleep variables from the Actiware software included TST and SE measures.

Analyses

De-identified data from RedCap and iCardia were exported and analyzed using Stata 15.0 (StataCorp LLC, College Station, TX) in two phases. First, univariate analyses were conducted to summarize participants' baseline characteristics and follow-up measures. Mixed effect models were utilized next because of the time repeated structure of the data. The advantages of the technique are that is capable of handling nested observations (e.g., multiple observations for each individual) and missing values (Rabe-Hesketh & Skrondal, 2008). Average wear time and step counts over baseline (week 1), intervention (Week 2–14) and postintervention (Week 15–19), and ISI, ST, SE, GCPS, SEff, ASD and SQual scores at weeks 1, 14, and 19 were entered as dependent variables in separate models adjusted for age and gender. Data collection occasions (1, 2, or 3) were also entered in the models to account for change over time. The adjusted main effects for time for each of the variables were tested for significance and reported as estimates and 95% confidence intervals (CI).

RESULTS

Of the 46 potential candidates screened, 24 were eligible, consented to the study, and provided baseline data. Of the 22 that were ineligible, 50% were due to being 'very active' (Figure 1). One participant could not finish the intervention due to development of a major depressive episode, and one participant did not contribute week 19 sleep data due to a scheduled surgical procedure, which left a total of 22 participants who completed the full protocol and a 96% retention rate. Table 1 summarizes the baseline data. Mean age was 71.0 ± 4.0 years; the majority of participants were white (96%) and 70% were female. Over the first week of the study, participants wore the Fitbit on average 20.4 ± 2.2 hours a day and took 5016 ± 2524 steps. The ISI scores were an average of 14.6 ± 5.7 , which was consistent with moderate insomnia (Bastien et al., 2001). However, actigraphy measured an average TST of 7.13 ± 1.21 hours and $84.1\% \pm 8.1\%$ mean SE.

Table 2 summarizes changes in self-reported and objective measures over time using descriptive statistics and mixed effect models. Overall, there was a significant longitudinal effect for time for one primary outcome, one mechanistic measure, and one secondary outcome. Specifically, ISI scores improved by an average of 1.2 (95% CI 2.43, 0.05; $p=0.04$) points, such that at week 19 the ISI measure was, on average, 11.8 ± 6.3 , which was consistent with subthreshold insomnia (Bastien et al., 2001). Similarly, ASD improved by an average of 2.5 (95% CI 0.9, 4.9; $p=0.02$) points over 19 weeks. Self-reported sleep quality collected from sleep diaries also improved by an average of 0.3 (95% CI 0.02, 0.58; $p=0.04$) points over 19 weeks. Insignificant longitudinal changes were observed for the actigraphy measures, step count, SEff, pain, and other sleep diary variables. Fitbit wear time remained consistently high and did not decline even after cessation of structured memory cues (Table 2).

DISCUSSION

Overall this study showed that the mHealth intervention, designed to improve sleep in older adults with osteoarthritis, augmented through wearable devices and motivational interviews, was feasible and produced promising, albeit small, preliminary efficacy findings in terms of

improved sleep. Enrollment and retention were successful, with the study experiencing only one drop-out during the intervention phase due to reasons unrelated to the study protocol. Our study showed retention rates similar or even better than other studies of mHealth behavioral interventions in adults. A recent review of 23 clinical trials that examined effectiveness of mHealth solutions to achieve behavioral change in adults showed an average 65% retention rate in intervention groups (Zhao, Freeman, & Li, 2016), compared to our 96% retention rate. We hypothesize that the participants valued receiving personalized communication from the research team in the form of weekly text messages and monthly phone calls and that this contributed to the high retention rates.

Fitbit wear time, which was used as a proxy for adherence to wearing and syncing the Fitbit device with the mobile app, was high; participants wore the activity trackers most of the time without memory cues. Encouraging signals with respect to improvement in sleep measures and potential mechanisms that stimulated the change support further research on the mHealth intervention for sleep disturbance in older adults with osteoarthritis.

We are aware of only two prior studies that used wearable technology and personalized texts to promote physical activity in community dwelling people age 65 years and older. One study gained about 2,220 increment in steps/day after an 8-week intervention that utilized daily actigraphy self-monitoring, goal setting, and biweekly counseling (Vidoni et al., 2016). Another study had a paradoxical decrease in about 1,000 steps/day after a 6-month intervention in patients with COPD that utilized daily self-monitoring and weekly tailored reinforcement texts (Nguyen et al., 2009). Our modest, albeit insignificant, increase in step count falls between these two reports. One possible explanation is that our preprogrammed weekly text messages were insufficient to increase physical activity in this relatively sedentary population with bothersome pain symptoms because higher message intensity, personalization and contextualization is needed. This conclusion is supported by our exit interviews in which participants reflected on the intervention. Overall, participants felt texts should be “less canned”, more person-specific and should be contextualized, in terms of frequency and content, in light of potential reasons for their setbacks in weekly progress.

Small, but statistically significant improvements in ISI, SQual, and ASD scores echo growing research interest in acceptance-based processes for treating insomnia symptoms. In behavioral medicine there is growing evidence that acceptance of symptoms while pursuing valued activities may be a more effective approach to chronic disease management than resistance or avoidance (McCracken, 2011). Change in ASD, observed in the study, indicated that parts of our intervention, such as sleep self-monitoring might have had positive effects on psychological factors that, in turn, improved insomnia symptoms and SQual. Indeed, in chronic pain research, evidence showed that low acceptance is correlated with psychological distress and worse functioning (Vowles, McCracken, & O’Brien, 2011). As such, one cautious interpretation is that improvement in acceptance might also improve sleep through reduced psychological distress, in sync with the recent report (Lau, Leung, Wing, & Lee, 2018). The study has some limitations. The effects of the intervention, although promising, must be interpreted with caution as the study did not include a control group. Eligible participants needed to have a smartphone. Although nowadays almost four-in-ten older adults are smartphone owners, those who do not, may respond differently to the

intervention. Additionally, this study was subject to the common limitations of research involving self-report. Although back-filling of sleep diaries was reduced by collecting these forms right after measurement occasions, there was still the potential for delayed completion of the forms.

CONCLUSION

It is feasible to use a technology-enhanced behavioral intervention for older adults with osteoarthritis to improve their sleep experience. This adds to a growing literature that suggests older adults might reap benefits from mHealth interventions. Results from this quasi-experimental study highlight a need for further research through a randomized control trial.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1:
Mobile Motivational Activity Targeted Intervention (MobMPATI) Study diagram

Table 1.

Baseline characteristics of 24 participants in the mobile motivational physical activity targeted intervention (MobMPATI) study

Variable	N (%) or mean (SD)
Demographics	
Age, yr (SD)	71.0 (4.0)
Female, n (%)	17 (70)
White, n (%)	23 (96)
Post college education, n (%)	7 (30)
Fitbit	
Fitbit wear time, hr/day (SD)	20.4 (2.2)
Step count, steps/day (SD)	5016 (2524)
Questionnaires	
Insomnia Severity Index ¹ , score (SD)	14.6 (5.7)
Graded Chronic Pain Scale ² , score (SD)	4.7 (2.0)
Self-Efficacy ³ , score (SD)	6.7 (1.7)
Acceptance of Sleep Difficulties ⁴ , score (SD)	24.0 (8.3)
Actigraphy	
Total Sleep Time, hr (SD)	7.1 (1.2)
Sleep Efficiency, % (SD)	84.2 (8.1)
Sleep Diary	
Total Sleep Time, hr (SD)	6.8 (1.3)
Sleep Efficiency, % (SD)	78.3 (9.9)
Sleep Quality ⁵ , score (SD)	5.4 (1.2)

Scale theoretical range: (0–28)¹; (1–10)²; (1–10)³; (0–48)⁴; (1–9)⁵

Table 2.

Descriptive and mixed effects model inferential estimates of longitudinal changes in behavioral and health outcomes in 24 participants in the mobile motivational physical activity targeted intervention (MobMPATI) study

Measure	Baseline (n=24)	Week 14 (n=23)	Week 19 (n=22)	Estimate (95% CI)	P value
Fitbit					
Wear Time, hr/day	20.4 (2.2)	20.9 (2.3)	20.9 (2.4)	0.4 (-0.4; 1.1)	0.3
Step Count, step/days	5016 (2524)	5286 (2381)	5262 (2470)	44 (-321; 410)	0.8
Actigraphy					
Total Sleep Time, min	422.7 (72.8)	418.0 (76.1)	414.2 (65.8)	-4.5 (-13.4; 4.4)	0.32
Sleep Efficiency, %	84.2 (8.1)	83.7 (7.8)	83.5 (7.4)	-0.3 (-1.0; 0.4)	0.4
Questionnaires					
Insomnia Severity Index	14.6 (5.7)	12.2 (6.7)	11.8 (6.3)	-1.24 (-2.43; -0.05)	0.04
Graded Chronic Pain Scale	4.7 (2.0)	4.4 (2.0)	4.1 (1.8)	-0.13 (-0.47; 0.20)	0.4
Self-Efficacy	6.7 (1.7)	7.1 (1.2)	7.3 (1.6)	0.28 (-0.07; 0.63)	0.1
Acceptance of Sleep Difficulties	24.0 (8.3)	30.4 (7.7)	28.9 (6.8)	2.49 (0.91; 4.09)	0.002
Sleep Diary					
Total Sleep Time, min	410.1 (75.8)	426.5 (51.7)	425.9 (52.0)	8.9 (-2.9; 20.8)	0.14
Sleep Efficiency, %	78.3 (9.9)	81.6 (8.6)	81.0 (9.8)	1.7 (-0.06; 3.38)	0.06
Sleep Quality	5.4 (1.2)	5.5 (1.3)	6 (1.2)	0.3 (0.02; 0.58)	0.04

[/] Mixed effect models are adjusted for age and gender