Prevention Science (2019) 20:863–872
https://doi.org/10.1007/s11121-019-01006-4

Mobile App-Based Small-Group Physical Activity Intervention for Young African American Women: a Pilot Randomized Controlled Trial

Jingwen Zhang[1] · John B. Jemmott III[2]

Published online: 20 February 2019
© Society for Prevention Research 2019

Abstract
A lack of adequate physical activity among young African American women remains a serious public health challenge. Few evidence-based interventions are available to increase physical activity in this population, and none has leveraged mobile technologies, even though African Americans are among the most avid users of mobile applications (apps). We conducted a pilot randomized controlled trial to test the efficacy of a mobile app-based small-group intervention in increasing physical activity among African American women aged 18 to 35 years ($N = 91$) in Philadelphia, PA. Cohorts of eight participants were randomized in a 1:1 ratio to a 4-women small-group intervention or an individual control condition. Control participants used the app to track their own activities. Small-group participants could track their own activities and those of the other three women in their group and could message the other women using a chatting tool. The primary outcome was meeting the goal of engaging in at least 90 min/day of light physical activity during the 3-month study period objectively assessed by a Fitbit device. Data were collected in 2016 and analyzed in 2017. Group participants had higher odds of meeting the goal (OR = 1.48, $p = .048$) than did control participants, an effect that did not wane during the 3-month study period. Irrespective of condition, participants had lower body-mass index ($p = .01$) and performed more push-ups ($p < .0001$) at the 1-month and 3-month assessments compared with the baseline measures. Mobile apps facilitating small online groups can contribute to efforts to increase physical activity among young African American women.

This study is registered at www.clinicaltrials.gov NCT02736903.

Keywords Mobile applications · Women · Exercise · Social support · Wearable electronic devices · African Americans

Some of the largest health disparities in the USA concern African American women, who have disproportionately high morbidity and mortality rates from chronic diseases, including heart disease, stroke, hypertension, type-2 diabetes, and cancer (American Cancer Society 2013; Murphy et al. 2013). Physical activity (PA) is associated with reduced morbidity and mortality from cardiovascular diseases (Nocon et al. 2008; Sattelmair et al. 2011), type-2 diabetes (Katzmarzyk et al. 2007), and colon (Boyle et al. 2013), and breast cancer (Wu et al. 2013), as well as reduced all-cause mortality (Samitz et al. 2011; Wen et al. 2011). Although physical inactivity is common among Americans regardless of sex or race, the prevalence is much higher in African American women than in white women, white men, or African American men. For instance, in 2017, only 13% of African American women met the national guidelines for both aerobic and muscle-strengthening PA, compared with 22% of white women (Lucas and Benson 2018). Paralleling this high rate of physical inactivity is the high rate of obesity in African American women: 57% of African American women compared with 35% of white women were obese in 2016 (*Health, United States,* 2017).

Young adulthood is a period of risk for excessive weight gain and the development of obesity (Dietz 2017). A recent longitudinal cohort study reported a dose–response relationship between weight gain from early to middle adulthood and increased risk of chronic-disease morbidity and mortality (Zheng et al. 2017). In addition, both physical inactivity and

✉ Jingwen Zhang
jwzzhang@ucdavis.edu

[1] Department of Communication, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA

[2] Perelman School of Medicine and Annenberg School for Communication, University of Pennsylvania, 3901 Walnut Street, Suite 500, Philadelphia, PA 19104, USA

chronic diseases were more common among those who gained greater weight during young adulthood (Zheng et al. 2017). Ethnic disparities in the prevalence of obesity begin in adolescence and increase further in young adulthood. For instance, the 25-year Coronary Artery Risk Development in Young Adults (CARDIA) longitudinal study found that aging-related weight gain was greatest in the 20s (Dutton et al. 2016) and that black women experienced the largest mean weight gain (20.8 kg), followed by black men (18.8 kg), white men (14.0 kg), and white women (13.8 kg). Among women 20 to 39 years of age, the obesity prevalence was 57% in non-Hispanic blacks, 43% in Hispanics, and 33% in non-Hispanic whites (Flegal et al. 2016).

The fact that substantial declines in physical activity occur throughout adolescence to young adulthood (Kimm et al. 2002) and that most weight gain in African American women occurs during young adulthood (Rosenberg et al. 2013) underscores the urgent need for interventions to increase PA among young African American women. However, despite the racial disparities, few randomized controlled trials (RCTs) have tested interventions to increase PA in African American women (Lemacks et al. 2013). Although some studies have found improvement in PA, most have focused on individuals and have not considered the social contexts in which the participants' behaviors occurred. A review of qualitative studies of PA correlates in African Americans found that women said group participation would increase their motivation to exercise and having a physically active partner or friend would facilitate their initiation and maintenance of a PA program (Siddiqi et al. 2011; Young et al. 2002). These findings are consistent with other studies that have suggested that social support increases African American women's engagement in PA (Harley et al. 2009; Komar-Samardzija et al. 2012). For instance, a RCT found that employing group meetings was an effective way to increase moderate-to-vigorous PA among African American women (Wilbur et al. 2016).

Mobile applications (i.e., apps) are playing an increasingly influential role in public health. A 2015 national survey revealed that 58% of mobile-phone users had downloaded a health-related app, with fitness apps among the most commonly downloaded (Krebs and Duncan 2015). Mobile apps designed with behavior-change techniques can function as a powerful persuasive technology to increase PA (Zhang et al. 2018). The most commonly used behavior-change techniques in apps were instructions on how to perform the behavior, modeling the behavior, and performance feedback, included in 50% or more of the apps. Less common were social support and self-monitoring of behavior, included in 37% and 10% of apps, respectively (Conroy et al. 2014). Two systematic reviews on mobile-app-based interventions have suggested that apps can be efficacious in promoting PA (Coughlin et al. 2016; Schoeppe et al. 2016). A meta-analysis concluded that mobile apps are as effective as more traditional intervention approaches (Mateo et al. 2015). None of the app-based interventions reviewed focused on African Americans, despite the fact that young African Americans rely on smartphones for online access at elevated levels and are avid users of mobile apps (Krebs and Duncan 2015). Mobile apps, then, are an underutilized but potentially efficacious tool to empower African American women to increase their PA.

The present study evaluated the efficacy of a mobile app-based (PennFit) small-group intervention in increasing light-intensity PA among African American women aged 18 to 35 years. Accumulating evidence has indicated that light-intensity PA confers health benefits, which suggests that insufficiently active people should be encouraged to engage in light-intensity PA (Fuzeki et al. 2017; Khoja et al. 2016; LaMonte et al. 2017). We designed the app based on the social cognitive theory (Bandura 1986), integrated with formative research with the target population. Consistent with research highlighting the importance of social support to African American women's PA (Harley et al. 2009; Joseph et al. 2017; Komar-Samardzija et al. 2012; Lee et al. 2012), social support for PA was the primary social cognitive variable the app targeted. We randomized women to an online group intervention designed to increase social support for PA through opportunities to connect with a small group of other women interested in PA or an individual control condition. We hypothesized that the online group intervention would increase the probability of meeting a daily light PA goal during the 3-month study period compared with the individual control condition.

Method

Participants

African American women, aged 18 to 35 years, using an android smartphone, and residing in Philadelphia, were eligible to participate. Individuals were excluded if they were unable to perform physical activities, had underlying diseases that were likely to affect their safety (Canadian Society for Exercise Physiology, CSEP, 2002), had participated in another physical-activity study in the past 12 months, and were unable or unwilling to carry an android smartphone, or were pregnant.

Participants were recruited in the Philadelphia area through advertising on social media, including targeted ads on Facebook and Instagram, through flyers posted on streets near supermarkets, parks, shopping malls, and bars expecting a high African American women turnout, and through the referrals of participants (i.e., snowballing) from December 2015 to January 2016.

A priori, we assumed a 1-tailed test based on a firm directional hypothesis. Because there was no prior published app-based PA intervention trial for young African American women, we assumed a medium effect size of Cohen's $d = 0.50$ for our primary outcome based on results from two online group-based PA intervention studies conducted among a young adult population (Zhang et al. 2016; Zhang et al. 2015). With $\alpha = 0.05$, 15% attrition, effect size of $d = 0.50$ (equaling odd ratio of 2.48), intraclass correlation coefficient = 0.02 for dependency among participants in small groups (Simons et al. 2018; Yates et al. 2012), and a mean correlation of $r = .24$ among within-person reports of PA, a total of 80 women would yield statistical power of 80%.

The final sample included 91 African American women, with 44 randomized to the group intervention and 47 to the individual control condition. All participants completed the 1-month assessment, and all except one in the intervention condition completed the 3-month assessment. Figure 1 shows the flow of participants through the trial.

Table 1 reports baseline sociodemographic characteristics. The mean age was 26.8 years (SD = 5.1). About 14% were married; 30% had children, and 33% had monthly income less than $850. The mean BMI at baseline was 31.6 (SD = 0.8). About over half (53%) of the participants were obese, and 24% were overweight.

Interventions

Formative Research We developed the PennFit app based on the social cognitive theory (Bandura 1986), particularly social support, integrated with formative research: namely, one-on-one interviews with 30 African American women aged 18 to 35 years recruited in Philadelphia (Zhang et al. 2018). A total of 20 were overweight or obese, and only 7 had tried using free health and fitness apps. When asked what would make it easier for them to engage in PA regularly, 19 (63%) of the 30 mentioned having some form of social support or new exercise buddies and 23 (77%) mentioned having daily reminders.

Individual Control Condition Participants in the individual control condition could use the PennFit app to monitor their behaviors by tracking daily steps and light-intensity PA objectively collected from Fitbit's application program interface. To increase awareness of exercise effort, we encouraged participants to manually enter their exercise minutes for specific workouts involving moderate (e.g., walking briskly) or vigorous (e.g., jogging) aerobic PA or muscle-strengthening PA (e.g., push-ups). They received system-generated notifications that reminded them to wear their Fitbit at 8 am and to log their PA minutes at 9 pm. They could see only their own profile and PA data and could not see other participants' profiles or PA data or connect with them.

The PennFit App-Based Small-Group Intervention The PennFit app-based small-group intervention was designed to facilitate not only self-monitoring of behavior, but also social support (Uchino 2004) and observational learning (Bandura 1991; Carels et al. 2005). Participants could use all of the features of the PennFit app available to those in the individual control condition. Research has shown that people in small

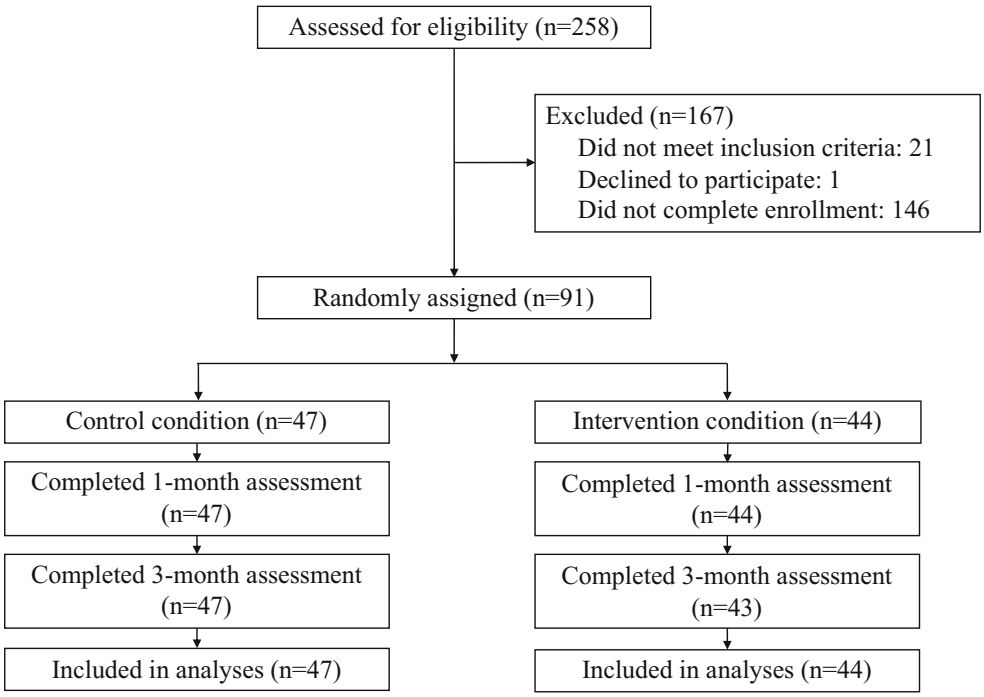

Fig. 1 Flow diagram of participants through the trial, Philadelphia, PA, 2016

Table 1 Baseline sociodemographic characteristics of participating African American women by intervention condition, Philadelphia, PA, 2016

Characteristic	Total ($n = 91$)	Control ($n = 47$)	Small group ($n = 44$)
Mean age (SD), *y*	26.8 (5.1)	26.4 (5.4)	27.2 (4.7)
Married, *n* (%)	13 (14.3)	5 (10.6)	8 (18.2)
Children, *n* (%)	27 (29.7)	15 (31.9)	12 (27.3)
Education, *n* (%)			
High school diploma	8 (8.8)	6 (12.8)	2 (4.6)
2-year college	34 (37.4)	20 (42.6)	14 (31.8)
4-year college	29 (31.9)	12 (25.5)	17 (38.6)
Post-graduate	20 (22.0)	9 (19.2)	11 (25.0)
Employed, *n* (%)	79 (86.8)	39 (83.0)	40 (90.9)
Monthly income, *n* (%)			
Less than $850	30 (33.0)	23 (48.9)	7 (15.9)
$851 to $2500	35 (38.5)	14 (29.8)	21 (47.7)
$2501 or more	26 (28.6)	10 (21.3)	16 (36.4)
Mean overall quality of life (SD)[a]	3.3 (0.8)	3.4 (0.7)	3.3 (0.9)
Mean BMI (SD), kg/m^2	31.6 (8.2)	30.4 (6.8)	33.0 (9.4)
Overweight, *n* (%)	22 (24.2)	14 (29.8)	8 (18.2)
Obese, *n* (%)	48 (52.8)	22 (46.8)	26 (59.1)

[a] Overall quality of life was rated on a 5-point scale: 1 (poor), 2 (fair), 3 (good), 4 (very good), 5 (excellent)

online groups who can see their peers engaging in PA-related behaviors are likely to increase their own engagement in such behaviors (Zhang et al. 2016; Zhang et al. 2015) and that online relationships can improve PA through supportive interactions (Cavallo et al. 2014). Accordingly, participants in the small-group intervention could use the PennFit app to see both their own profile and PA data and those of the three other women in their group. The homepage of the app displayed all four women's PA data in form of colored bars that indicated the amount of Fitbit-recorded light PA and steps and the self-reported PA updated in real time. The homepage resets the activity bars every day at midnight. Therefore, the app made it easy for participants to continuously monitor their own PA in comparison to other women's PA each day. An important feature designed to increase social support was the ability to send messages to their small group through an instant chatting tool. Thus, the intervention allowed participants to continuously observe their own PA and the PA of three other African American women interested in increasing their PA. Figure 2 illustrates the different app designs for the two conditions.

Procedure

Eligible African American women were invited to complete a baseline assessment at a research office. During the baseline visit, they provided written informed consent, completed an online questionnaire on sociodemographic characteristics, and had their height, weight, and 1-min push-up test performance assessed by a research assistant.

After the baseline assessments, the women participated in a 2-h training session on the health benefits of PA and the national guidelines for both aerobic and muscle-strengthening PA (Department of Health and Human Services 2008) led by a certified PA trainer. Participants learned both aerobic and muscle-strengthening exercise movements under the trainer's supervision for 30 min. The trainer also addressed self-efficacy and skills to fit 90 min of light PA into their daily routines (e.g., casual walking during lunch break, stretching at work, and doing household chores). Light-intensity PA was targeted because of growing evidence highlighting the benefits of light PA for obesity, cardiovascular risk, and all-cause mortality (Fuzeki et al. 2017; Khoja et al. 2016). All participants then received, to wear daily during the 3-month study period, a Fitbit Zip, a small, wireless activity-tracking device that measures active minutes and steps (Ferguson et al. 2015).

After the training session, participants created their profiles in the PennFit app, including username, picture, age, and favorite exercise. Their body mass index (BMI) was automatically calculated based on height and weight measurements and added to their profile.

We continuously assembled cohorts of eight women as recruitment proceeded. Women in each cohort were electronically randomized in a 1:1 ratio to the online group condition or the individual control condition. The four women randomized to the group condition became connected in an online group through the app. Participants and researchers were blind to the randomization process.

Participants wore the Fitbit and used the PennFit app for 3 months. One month after the start of the intervention, they

completed the 1-month assessment; 2 months later, they completed the 3-month assessment on weight and 1-min push-up test performance at the research office.

As compensation, participants received $15 at the baseline assessment, $35 at the 1-month assessment, $50 at the 3-month final assessment, and the Fitbit. All data were collected in 2016 in Philadelphia, PA.

All study procedures were approved by an institutional review board at the University of Pennsylvania.

Measures

Our primary outcome was a binary variable indicating whether the women engaged in at least 90 min/day of light PA during the 3-month study period. The minutes for light activity were objectively collected through the participants' Fitbit device, with light activity defined as 1.1 to 2.9 METs (metabolic equivalents). The national guidelines (Department of Health and Human Services 2008) state that the health benefits of PA depend mainly on total weekly energy expenditure and recommend a range from 500 to 1000 MET-minutes per week to reap health benefits. Because light activity is 1.1 to 2.9 METs, 90 min/day of light PA translates to 693 to 1827 MET-minutes per week, which falls in or exceeds the recommended 500 to 1000 range.

Secondary outcomes included daily logins recorded by the app, and daily steps, minutes of light activity, and minutes of moderate-to-vigorous PA recorded by the Fitbit. In addition, we collected participants' BMI and 1-min push-up test performance at baseline, 1-month assessment, and 3-month assessment.

Data Analysis

For each participant on each day of the study, we obtained the number of active minutes of light, moderate, and vigorous PA, steps, and PennFit app logins. Physical activity behavior data could be missing for any day if a participant did not wear the Fitbit. We first used a generalized estimating equations (GEE) model to analyze the binary outcome of missing wearing the Fitbit on a given day, adjusting for longitudinal repeated measurements and participants clustered within small groups (Fitzmaurice et al. 2004). The model included intervention condition and time (90 categories representing 1 to 90 days).

We tested the small-group intervention's efficacy compared with the control condition using GEE models, adjusting for repeated measurements and participants clustered within small groups. The models included intervention condition and time (90 categories representing 1 to 90 days). For the primary outcome, we also tested effects at three time periods (days 1 to 30, days 31 to 60, and days 61 to 90) to examine specific effects over the 3 months.

For outcomes of the BMI and 1-min push-up test, we used GEE models adjusting for repeated measurements at the 1-

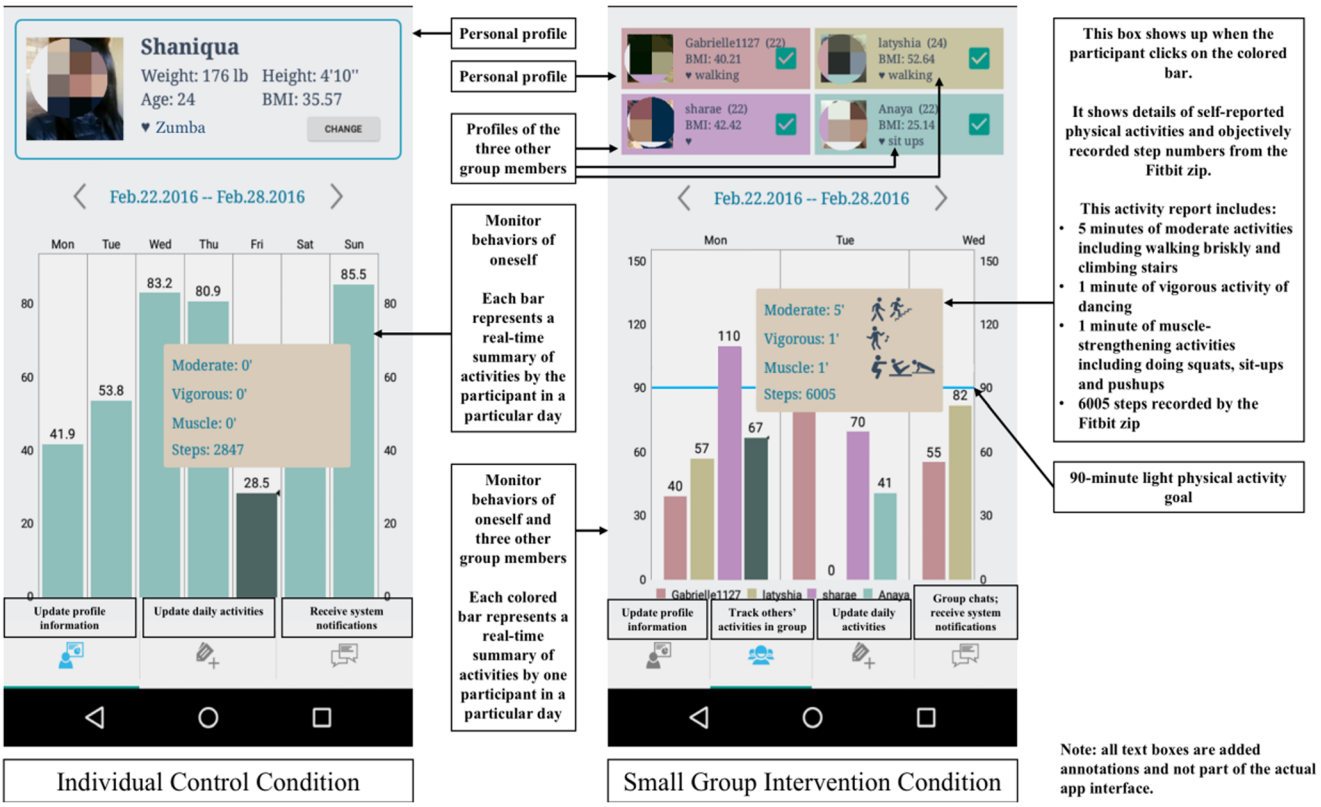

Fig. 2 Interface designs of the PennFit app for the small-group intervention condition and the individual control condition, Philadelphia, PA, 2016

month and 3-month assessments and participants clustered within small groups and controlling for baseline measure of the criterion. The models included intervention condition and the two assessment times.

We fit the models and specified contrast statements to obtain estimated odd ratios for the primary binary outcome and mean differences for the continuous outcomes and their corresponding 95% confidence intervals. Robust standard errors were used, and an independent working correlation matrix was specified. We report 95% confidence intervals and significance levels based on 2-tailed tests.

We performed the analyses using an intention-to-treat mode with participants analyzed based on their intervention assignment, regardless of the number of days of wearing the Fitbit or using the app. We used GEE models to handle missing data, models that use all available data for each participant. Analyses were completed using SAS V9 in 2017.

Results

Program Engagement and Evaluation

The total percentage of participant days on which Fitbit-tracked behavior data were missing during the 90-day intervention was 16%. Specifically, of the potential 8190 records of Fitbit-tracked behavior data, 1310 were missing. Intervention condition and time did not affect individuals' rate of missing Fitbit data.

The mean number of logins to the app per day during the 90-day study period was 2.4 (SD = 4.4) in the group intervention and 1.1 (SD = 2.8) in the control condition. Thus, the intervention increased the number of logins by 1.2 (95% CI: 0.6, 1.8) compared with the control condition ($p = .0002$). Time did not affect the frequency of logins, indicating the number of daily logins did not significantly decline over the 90 days, adjusting for intervention condition.

No participant in the group intervention complained about revealing personal information or observing others' information. Participants' evaluations of the PennFit app were high and did not differ between conditions. On a scale from 0 to 10, participants' mean ratings on liking the program and recommending the PennFit app to friends and colleagues were 8.5 (SD = 2.2) and 8.3 (SD = 2.2), respectively.

During the 3-month study period, the 44 participants in the 11 groups in the intervention condition generated 616 messages or 56 messages per group. The most active group generated 119 messages, and the least active generated 30 messages. The average number of group messages did not significantly decrease over the 3-month period. The lead author and a research assistant coded the messages. The lead author generated themes based on several iterations of reading the messages. Each coder then coded the themes from the messages independently. The two coders then met to review their coding and resolve any differences. We did not identify any uncivil or inflammatory messages. Only 6% of the messages concerned problems of forgetting to wear the Fitbit or using the PennFit app, and 3% were general greetings. The majority of messages (92%) concerned emotional and informational support, such as sending encouragement and sharing specific exercise suggestions. For instance, one randomly selected short group conversation illustrates the supportive messages the women shared: "Hey ladies!! Hope everyone is good day. It's nice out, so I'm definitely taking advantage of the good weather after work!!" "Ugh, have about 2,000 steps to hit the goal for today. Guess I'll make a target run lol." and "Get that 2000! If u do a line dance like the wobble or cupid shuffle 2/3 times u will have ur steps with no prob."

Efficacy of the PennFit App-Based Small-Group Intervention

The GEE model showed that the odds of engaging in at least 90 min/day of light activity were greater in the group intervention than in the individual control condition. The odd ratio was 1.48 (95% CI 1.004, 2.18), indicating an overall small effect of the intervention compared with the control condition. About 81% of the group-intervention participants and 74% of the control participants met the daily activity goal of 90 min/day of light PA during the intervention period. Table 2 presents the estimated probabilities for individuals meeting the daily goal in the two conditions and in three time periods. It

Table 2 Model-based estimated probability of achieving 90 min/day or more of light activity, by condition and time period, Philadelphia, PA, 2016

	Time period			
Condition	Days 1–90	Days 1–30	Days 31–60	Days 61–90
Individual control	0.741 (0.739, 0.742)	0.765 (0.762, 0.767)	0.738 (0.736, 0.740)	0.716 (0.713, 0.720)
Group intervention	0.808 (0.806, 0.809)	0.807 (0.805, 0.809)	0.810 (0.808, 0.812)	0.808 (0.805, 0.811)
Odd ratio	1.48 (1.004, 2.18)	1.29 (0.84, 1.99)	1.52 (0.99, 2.33)	1.68 (1.09, 2.60)
p value	0.048	0.242	0.057	0.020

Numbers in parentheses indicate 95% confidence intervals; significance levels were based on 2-tailed tests

reveals that the effect of the group intervention increased over the 90-day period, from the first 30 days, to the second 30 days, to the final 30 days. Examination of the estimated probabilities of getting 90 min/day of light activity indicates a decline in the individual control condition. In contrast, the probabilities were similar during the three time periods in the group intervention, suggesting that the group intervention sustained engagement in light PA during the 90-day period.

Table 3 shows descriptive statistics for all secondary behavior outcomes by condition and time period. There were no significant effects of intervention condition or time on daily steps, minutes of light activity, and minutes of moderate-to-vigorous activity. On average, participants had 7587.0 steps/day (median = 7081, SD = 4550.2), 146.1 light active minutes/day (median = 138, SD = 75.8), and 29.7 moderate-to-vigorous active minutes/day (median = 19, SD = 34.9) during the study period. The distributions of steps and active minutes were highly skewed. Although no participant had zero step for a day, 27% had zero active minutes at least 1 day when wearing the Fitbit device.

There were no differences between conditions on BMI and 1-min push-up test performance. However, contrasts revealed significant time effects on these two outcomes, adjusting for intervention condition. Participants had lower mean BMI at the 1-month and 3-month assessments (mean = 31.4, SD = 8.2) compared with the baseline assessment (mean = 31.6, SD = 8.2), $\chi^2 = 6.56$, $p = .01$. In addition, participants performed more push-ups at the 1-month and 3-month assessments (mean = 30.1, SD = 10.7) than at the baseline assessment (mean = 18.0, SD = 9.0), $\chi^2 = 68.96$, $p < .0001$.

In sum, we found the intervention condition increased the probability of meeting the goal of 90 min/day of light PA and the number of app logins compared to the control condition. The intervention did not affect the other secondary behavior outcomes. Participants irrespective of condition had lower BMI and performed more push-ups at the follow-up assessments compared with the baseline.

Discussion

Despite the promise of mobile app-based health interventions, the effects of social interactions facilitated by apps have remained poorly understood. One app-based gamification intervention involving family members significantly increased steps compared with the control condition (Patel et al. 2017). To our knowledge, the present study is the first to demonstrate the efficacy of a mobile app-based small-group intervention among young African American women.

The results showed that the intervention increased the probability of engaging in at least 90 min of light activity daily during the 3-month study period. Several recent studies have highlighted the health benefits of light-intensity PA (Fuzeki et al. 2017; Khoja et al. 2016; Loprinzi 2017). Arguably, then, for this sample with a mean BMI of 31.6 and 53% being obese, starting with light exercises such as casual walking, stretching, and doing household chores for at least 90 min a day could lead to significant health benefits in the long term.

Table 3 Descriptive statistics for all secondary behavior outcomes, by intervention condition and time period, Philadelphia, PA, 2016

Secondary behavior outcome, mean (SD)	Time period		
	Days 1–30	Days 31–60	Days 61–90
Steps/day			
Individual control	7475.74 (4208.40)	7744.52 (4551.43)	7668.09 (4604.88)
Group intervention	7283.84 (4462.74)	7478.12 (4698.90)	7947.72 (4802.13)
Minutes of light PA/day			
Individual control	147.85 (76.95)	142.81 (80.40)	143.11 (84.33)
Group intervention	147.54 (70.87)	145.25 (68.41)	149.18 (74.55)
Minutes of moderate-to-vigorous PA/day			
Individual control	28.87 (31.35)	32.40 (34.73)	32.22 (38.15)
Group intervention	25.69 (33.04)	27.85 (34.40)	32.17 (37.85)
	Baseline	1-month assessment	3-month assessment
BMI			
Individual control	30.40 (6.78)	30.20 (6.81)	30.25 (6.81)
Group intervention	32.95 (9.35)	32.81 (9.35)	32.88 (9.32)
1-min push-up test performance			
Individual control	15.92 (8.75)	25.57 (8.47)	31.77 (9.76)
Group intervention	20.11 (8.93)	28.71 (10.84)	34.70 (11.54)

One potential explanation for the increases in light activity caused by the online small group is that they resulted from the intervention's effect in increasing social support, a component of social cognitive theory found to mediate many PA interventions (Marquez et al. 2016; McAuley et al. 2003; Sallis et al. 1999). Consistent with this view, the women in the small-group intervention messaged emotional and informational support for PA to one another and never sent messages discouraging PA. This possibility should be confirmed in a larger trial.

Although evidence suggests that participants' engagement in social-media health promotion interventions is low or declines over time (Valle and Tate 2017; Williams et al. 2014), we found the engagement with the PennFit app did not decline over time. Moreover, the small-group intervention's effect on light PA did not wane over time. The small-group intervention significantly increased participants' use of the PennFit app, suggesting that organizing people in small online groups can increase their fitness app usage. Like PennFit, some fitness apps include self-monitoring, a well-established behavior-change technique (Conroy et al. 2014). However, self-monitoring is only effective when people use the app consistently. Our research contributes to research on app engagement (Asimakopoulos et al. 2017) by showing that building small groups for supportive interactions with strangers significantly increased fitness app usage. The messages exchanged among group members raise the possibility that mobile apps are a communication channel for facilitating social support.

Importantly, we observed that participants decreased their BMI and increased the number of push-ups they could perform. This result suggests mobile apps are a potentially promising intervention platform to address the problems of obesity and a lack of muscle-strengthening activity in this population. However, the small sample size limited our statistical power to detect a difference between conditions.

This study has several important strengths. It employed a RCT design. We developed the app using formative research with the target population. Participants were blind to intervention condition before enrollment, thus avoiding differential self-selection bias. We gave all participants a 2-h training session to ensure the correct installation of the app on their phones and to provide them with essential knowledge on PA and practical advice on initiating and sustaining daily PA in their familiar environments. Participants in both conditions gave equally high ratings for the program, suggesting the app can be disseminated to other young African American women.

Limitations

A limitation of this pilot study is the small sample, which reduced our power to detect differences on our outcomes. Given limited resources, we developed the app using only the Android platform; accordingly, we could not include interested women who used iPhones. The results may not generalize to all African American women. We did not collect baseline PA data; accordingly, we could not evaluate changes from baseline or adjust for baseline PA to increase statistical power. In addition, we did not exclude women who were already physically active, which may have caused us to underestimate the efficacy of the intervention. Future research should test the intervention's efficacy in populations with inadequate baseline PA. Lastly, the study had a short intervention period. Although we found use of the Fitbit device did not decline over the 3 months, we do not know whether this level of usage would be sustained in the long term. Future research should examine the longer-term sustainability of the effects we observed in this pilot RCT.

Conclusion

A lack of adequate PA among young African American women remains a serious public health challenge. Our study demonstrated the feasibility and efficacy of a mobile app-based small-group intervention in increasing PA in this population. Future research should test whether social support and other social cognitive variables mediate the intervention's efficacy. Young African American women are avid users of mobile phones, and if current growing trends in smartphone ownership continue, our research suggests a promising approach: creating supportive online groups for young African American women to reduce physical inactivity and its associated health risks.

Acknowledgements The authors appreciate the contributions of Janet Hsu, BA, Mikia Croom, MSEd, Peter Danzig, MA, Rafael Perez, MA, and Brittney Raglin to the implementation of this research. The contributions of Han Sun, MS, and Ze Li, PhD, to the design and implementation of the mobile application system are gratefully acknowledged.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval The study was reviewed and approved by University of Pennsylvania's IRB. 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 the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

American Cancer Society. (2013). *Cancer facts & figures 2013.* Atlanta, GA: American Cancer Society.

Asimakopoulos, S., Asimakopoulos, G., & Spillers, F. (2017). Motivation and user engagement in fitness tracking: Heuristics for mobile healthcare wearables. Informatics, 4, 5, 1–16.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood cliffs: Prentice-Hall.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*, 248–287.

Boyle, T., Fritschi, L., Platell, C., & Heyworth, J. (2013). Lifestyle factors associated with survival after colorectal cancer diagnosis. *British Journal of Cancer, 109*, 814–822.

Canadian Society for Exercise Physiology (CSEP). (2002). Physical activity readiness questionnaire: PAR-Q. Available at: http://www.csep.ca/en/publications/get-active-questionnaire. Accessed 17 Feb 2019.

Carels, R. A., Darby, L. A., Rydin, S., Douglass, O. M., Cacciapaglia, H. M., & O'Brien, W. H. (2005). The relationship between self-monitoring, outcome expectancies, difficulties with eating and exercise, and physical activity and weight loss treatment outcomes. *Annals of Behavioral Medicine, 30*, 182–190.

Cavallo, D. N., Brown, J. D., Tate, D. F., DeVellis, R. F., Zimmer, C., & Ammerman, A. S. (2014). The role of companionship, esteem, and informational support in explaining physical activity among young women in an online social network intervention. *Journal of Behavioral Medicine, 37*, 955–966.

Conroy, D. E., Yang, C. H., & Maher, J. P. (2014). Behavior change techniques in top-ranked mobile apps for physical activity. *American Journal of Preventive Medicine, 46*(6), 649–652.

Coughlin, S. S., Whitehead, M., Sheats, J. Q., Mastromonico, J., & Smith, S. (2016). A review of smartphone applications for promoting physical activity. *Jacobs Journal of Community Medicine, 2*, 021.

Department of Health and Human Services. (2008). 2008 physical activity guidelines for Americans. Available at: http://www.health.gov/PAGuidelines/pdf/paguide.pdf. Accessed 17 Feb 2019.

Dietz, W. H. (2017). Obesity and excessive weight gain in young adults: New targets for prevention. *Journal of the American Medical Association, 318*, 241–242.

Dutton, G. R., Kim, Y., Jacobs, D. R., Jr., Li, X., Loria, C. M., Reis, J. P., et al. (2016). 25-year weight gain in a racially balanced sample of U.S. adults: The CARDIA study. *Obesity, 24*, 1962–1968.

Ferguson, T., Rowlands, A. V., Olds, T., & Maher, C. (2015). The validity of consumer-level, activity monitors in healthy adults worn in free-living conditions: A cross-sectional study. *International Journal of Behavioral Nutrition and Physical Activity, 12*, 42.

Fitzmaurice, G. M., Laird, N. M., & Ware, J. H. (2004). *Applied longitudinal analysis*. New York: John Wiley & Sons.

Flegal, K. M., Kruszon-Moran, D., Carroll, M. D., Fryar, C. D., & Ogden, C. L. (2016). Trends in obesity among adults in the United States, 2005 to 2014. *Journal of the American Medical Association, 315*, 2284–2291.

Fuzeki, E., Engeroff, T., & Banzer, W. (2017). Health benefits of light-intensity physical activity: A systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES). *Sports Medicine, 47*, 1769–1793.

Harley, A. E., Katz, M. L., Heaney, C. A., Duncan, D. T., Buckworth, J., Odoms-Young, A., & Willis, S. K. (2009). Social support and companionship among active African American women. *American Journal of Health Behavior, 33*, 673–685.

Health, United States, 2016: With Chartbook on Long-term Trends in Health. (2017). Available at: https://www.cdc.gov/nchs/data/hus/hus16.pdf. Accessed 17 Feb 2019.

Joseph, R. P., Ainsworth, B. E., Mathis, L., Hooker, S. P., & Keller, C. (2017). Utility of social cognitive theory in intervention design for promoting physical activity among African-American women: A qualitative study. *American Journal of Health Behavior, 41*, 518–533.

Katzmarzyk, P. T., Craig, C. L., & Gauvin, L. (2007). Adiposity, physical fitness and incident diabetes: The physical activity longitudinal study. *Diabetologia, 50*, 538–544.

Khoja, S. S., Almeida, G. J., Wasko, M. C., Terhorst, L., & Piva, S. R. (2016). Association of light-intensity physical activity with lower cardiovascular disease risk burden in rheumatoid arthritis. *Arthritis Care & Research, 68*, 424–431.

Kimm, S. Y. S., Glynn, N. W., Kriska, A. M., Barton, B. A., Kronsberg, S. S., Daniels, S. R., . . . Liu, K. (2002). Decline in physical activity in black girls and white girls during adolescence. New England Journal of Medicine, 347, 709–715.

Komar-Samardzija, M., Braun, L. T., Keithley, J. K., & Quinn, L. T. (2012). Factors associated with physical activity levels in African-American women with type 2 diabetes. *Journal of the American Academy of Nurse Practitioners, 24*, 209–217.

Krebs, P., & Duncan, D. T. (2015). Health app use among US mobile phone owners: A national survey. *Journal of Medical Internet Research Mhealth and Uhealth, 3*, 107–119.

LaMonte, M. J., Lewis, C. E., Buchner, D. M., Evenson, K. R., Rillamas-Sun, E., Di, C. Z., et al. (2017). Both light intensity and moderate-to-vigorous physical activity measured by accelerometry are favorably associated with cardiometabolic risk factors in older women: The objective physical activity and cardiovascular health (OPACH) study. *Journal of the American Heart Association, 6*, e007064.

Lee, R. E., O'Connor, D. P., Smith-Ray, R., Mama, S. K., Medina, A. V., Reese-Smith, J. Y., et al. (2012). Mediating effects of group cohesion on physical activity and diet in women of color: Health is power. *American Journal of Health Promotion, 26*, E116–E125.

Lemacks, J., Wells, B. A., Ilich, J. Z., & Ralston, P. A. (2013). Interventions for improving nutrition and physical activity behaviors in adult African American populations: A systematic review, January 2000 through December 2011. *Preventing Chronic Disease, 10*, E99.

Loprinzi, P. D. (2017). Light-intensity physical activity and all-cause mortality. *American Journal of Health Promotion, 31*, 340–342.

Lucas, J. W., & Benson, V. (2018). Tables of summary health statistics for the U.S. Population: 2016 National Health Interview Survey. Available at: https://www.cdc.gov/nchs/nhis/SHS/tables.htm. Accessed 17 Feb 2019.

Marquez, B., Dunsiger, S. I., Pekmezi, D., Larsen, B. A., & Marcus, B. H. (2016). Social support and physical activity change in Latinas: Results from the Seamos Saludables trial. *Health Psychology, 35*, 1392–1401.

Mateo, G. F., Granado-Font, E., Ferre-Grau, C., & Montana-Carreras, X. (2015). Mobile phone apps to promote weight loss and increase physical activity: A systematic review and meta-analysis. *Journal of Medical Internet Research, 17*.

McAuley, E., Jerome, G. J., Elavsky, S., Marquez, D. X., & Ramsey, S. N. (2003). Predicting long-term maintenance of physical activity in older adults. *Preventive Medicine, 37*, 110–118.

Murphy, S. L., Xu, J., & Kochanek, K. D. (2013). Deaths: Final data for 2010. *National Vital Statistics Reports, 61*(4). Available at: https://www.cdc.gov/nchs/data/nvsr/nvsr61/nvsr61_04.pdf. Accessed 17 Feb 2019.

Nocon, M., Hiemann, T., Muller-Riemenschneider, F., Thalau, F., Roll, S., & Willich, S. N. (2008). Association of physical activity with all-cause and cardiovascular mortality: A systematic review and meta-analysis. *European Journal of Cardiovascular Prevention & Rehabilitation, 15*, 239–246.

Patel, M. S., Benjamin, E. J., Volpp, K. G., Fox, C. S., Small, D. S., Massaro, J. M., et al. (2017). Effect of a game-based intervention

designed to enhance social incentives to increase physical activity among families: The BE FIT randomized clinical trial. *JAMA Internal Medicine, 177*, 1586–1593.

Rosenberg, L., Kipping-Ruane, K. L., Boggs, D. A., & Palmer, J. R. (2013). Physical activity and the incidence of obesity in young African-American women. *American Journal of Preventive Medicine, 45*, 262–268.

Sallis, J. F., Calfas, K. J., Alcaraz, J. E., Gehrman, C., & Johnson, M. F. (1999). Potential mediators of change in a physical activity promotion course for university students: Project GRAD. *Annals of Behavioral Medicine, 21*, 149–158.

Samitz, G., Egger, M., & Zwahlen, M. (2011). Domains of physical activity and all-cause mortality: Systematic review and dose-response meta-analysis of cohort studies. *International Journal of Epidemiology, 40*, 1382–1400.

Sattelmair, J., Pertman, J., Ding, E. L., Kohl, H. W., 3rd, Haskell, W., & Lee, I. M. (2011). Dose response between physical activity and risk of coronary heart disease: A meta-analysis. *Circulation, 124*, 789–795.

Schoeppe, S., Alley, S., Van Lippevelde, W., Bray, N. A., Williams, S. L., Duncan, M. J., & Vandelanotte, C. (2016). Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 13*, 127.

Siddiqi, Z., Tiro, J. A., & Shuval, K. (2011). Understanding impediments and enablers to physical activity among African American adults: A systematic review of qualitative studies. *Health Education Research, 26*, 1010–1024.

Simons, D., De Bourdeaudhuij, I., Clarys, P., De Cocker, K., Vandelanotte, C., & Deforche, B. (2018). Effect and process evaluation of a smartphone app to promote an active lifestyle in lower educated working young adults: Cluster randomized controlled trial. *JMIR Mhealth Uhealth, 6*, e10003.

Uchino, B. N. (2004). *Social support and physical health: Understanding the health consequences of relationships*. New Haven: Yale University Press.

Valle, C. G., & Tate, D. F. (2017). Engagement of young adult cancer survivors within a Facebook-based physical activity intervention. *Translational Behavioral Medicine, 7*, 667–679.

Wen, C. P., Wai, J. P. M., Tsai, M. K., Yang, Y. C., Cheng, T. Y. D., Lee, M. C., et al. (2011). Minimum amount of physical activity for reduced mortality and extended life expectancy: A prospective cohort study. *Lancet, 378*, 1244–1253.

Wilbur, J., Miller, A. M., Fogg, L., McDevitt, J., Castro, C. M., Schoeny, M. E., et al. (2016). Randomized clinical trial of the women's lifestyle physical activity program for African-American women: 24- and 48-week outcomes. *American Journal of Health Promotion, 30*, 335–345.

Williams, G., Hamm, M. P., Shulhan, J., Vandermeer, B., & Hartling, L. (2014). Social media interventions for diet and exercise behaviours: A systematic review and meta-analysis of randomised controlled trials. *BMJ Open, 4*.

Wu, Y., Zhang, D., & Kang, S. (2013). Physical activity and risk of breast cancer: A meta-analysis of prospective studies. *Breast Cancer Research and Treatment, 137*, 869–882.

Yates, T., Davies, M. J., Henson, J., Troughton, J., Edwardson, C., Gray, L. J., & Khunti, K. (2012). Walking away from type 2 diabetes: Trial protocol of a cluster randomised controlled trial evaluating a structured education programme in those at high risk of developing type 2 diabetes. *BMC Family Practice, 13*, 46.

Young, D. R., He, X. X., Harris, J., & Mabry, I. (2002). Environmental, policy, and cultural factors related to physical activity in well-educated urban African American women. *Women & Health, 36*, 29–41.

Zhang, J., Brackbill, D., Yang, S., & Centola, D. (2015). Efficacy and causal mechanism of an online social media intervention to increase physical activity: Results of a randomized controlled trial. *Preventive Medicine Report, 2*, 651–657.

Zhang, J., Brackbill, D., Yang, S., Becker, J., Herbert, N., & Centola, D. (2016). Support or competition? How online social networks increase physical activity: A randomized controlled trial. *Preventive Medicine Report, 4*, 453–458.

Zhang, J., Calabrese, C., Ding, J., Liu, M., & Zhang, B. (2018). Advantages and challenges in using mobile apps for field experiments: A systematic review and a case study. *Mobile Media & Communication, 6*(2), 179–196.

Zheng, Y., Manson, J. E., Yuan, C. Z., Liang, M. H., Grodstein, F., Stampfer, M. J., et al. (2017). Associations of weight gain from early to middle adulthood with major health outcomes later in life. *Journal of the American Medical Association, 318*, 255–269.