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Author manuscript
Ann Behav Med. Author manuscript; available in PMC 2017 December 01.

Published in final edited form as:
Ann Behav Med. 2016 December ; 50(6): 885–897. doi:10.1007/s12160-016-9814-8.

Engineering Online and In-person Social Networks for Physical Activity: A Randomized Trial

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Conflict of Interest

Liza S. Rovniak, Lan Kong, Melbourne F. Hovell, Ding Ding, Chester A. Ray, Jennifer L. Kraschnewski, Stephen A. Matthews, Elizabeth Kiser, Vernon M. Chinchilli, Daniel R. George, and Christopher N. Sciamanna declare that they have no conflict of interest. James F. Sallis has received grants from Nike Inc, royalties from San Diego State University Foundation, consulting fees from SPARK Programs of Sportime Inc, and is a stockholder in Santech Inc.

Conflict of Interest

Dr. Sallis reports disclosures (please see attached); all other authors declare that they have no conflicts of interest.

Compliance with Ethical Standards

Ethics Approval

All procedures performed in this study were in accordance with the ethical standards of Pennsylvania State University's Institutional Review Board, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

Informed Consent

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

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Abstract

Background—Social networks can influence physical activity, but little is known about how best to engineer online and in-person social networks to increase activity.

Purpose—To conduct a randomized trial based on the Social Networks for Activity Promotion model to assess the incremental contributions of different procedures for building social networks on objectively-measured outcomes.

Methods—Physically inactive adults (n = 308, age, 50.3 (SD = 8.3) years, 38.3% male, 83.4% overweight/obese) were randomized to 1 of 3 groups. The *Promotion* group evaluated the effects of weekly emailed tips emphasizing social network interactions for walking (e.g., encouragement, informational support); the *Activity* group evaluated the incremental effect of adding an evidence-based online fitness walking intervention to the weekly tips; and the *Social Networks* group evaluated the additional incremental effect of providing access to an online networking site for walking, and prompting walking/activity across diverse settings. The primary outcome was mean change in accelerometer-measured moderate-to-vigorous physical activity (MVPA), assessed at 3 and 9 months from baseline.

Results—Participants increased their MVPA by 21.0 mins/week, 95% CI [5.9, 36.1], $p = .005$, at 3 months, and this change was sustained at 9 months, with no between-group differences.

Conclusions—Although the structure of procedures for targeting social networks varied across intervention groups, the functional effect of these procedures on physical activity was similar. Future research should evaluate if more powerful reinforcers improve the effects of social network interventions.

Trial Registration Number—NCT01142804

Keywords

exercise; walking; environment; social support; social media; clinical trial

Introduction

Physical inactivity is a pandemic that contributes to 5.3 million premature deaths worldwide each year [1]. Social networks, or people who know or interact with each other, have been shown to influence physical activity in epidemiological and intervention research across diverse populations [2–4]. Interventions targeting social networks are recognized as a cost-effective strategy for altering population-level physical activity, and the American Heart Association and the Centers for Disease Control and Prevention endorse further evaluation of social network interventions [5, 6]. However, recent systematic reviews indicate that social network interventions for physical activity and other health behaviors have had modest effects [7, 8]. These findings suggest a need to learn more about how to engineer social networks to increase active living.

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Ecological models suggest that social networks, in interaction with individual and environmental factors, explain variation in physical activity [9, 10] but these models provide little specification about *how* to engineer activity-supportive social networks. The Social Networks for Activity Promotion (SNAP) model extends prior ecological models by specifying that social networks can be engineered to support physical activity through three reciprocally interacting pathways (Figure 1) [11]. First, expanding people's access to activity-supportive *Physical Environments* (i.e., built or natural physical settings such as walking paths or parks), or activity-supportive *Virtual Environments* (i.e., online settings such as online networking sites for walking), may increase exposure to *Social Network Environments* (i.e., new and existing social contacts via in-person and online interaction modes). These contacts may support regular activity through *Social Network Interactions* (i.e., behaviors that function to prompt or reinforce activity [12, 13]), including activity-related encouragement or praise; providing tangible resources, assistance, or companionship for activity; modeling active lifestyles; and monitoring and refining activity relative to measurable standards [11]. Second, simply engaging in more frequent physical activity may bring people into incidental contact with activity-supportive *Physical/Virtual* and *Social Network Environments* and *Social Network Interactions* [12, 14, 15]. Third, expanding access to *Social Network Interactions* for physical activity may lead to greater exposure to *Physical/Virtual* and *Social Network Environments* that support continued activity [16, 17]. In sum, changing an individual's physical and/or virtual environment, an individual's behavior, or the behavior of those surrounding an individual, could lead to social networks that sustain active living.

Little research has examined the incremental effects of different procedures for engineering social networks on physical activity and health outcomes. Understanding the incremental contributions of procedures targeting each SNAP pathway could increase the effectiveness and cost-efficiency of physical activity interventions and policies. Therefore, we conducted a randomized trial to investigate the incremental effects of procedures targeting different SNAP pathways on objectively-measured physical activity and health-risk factors. Consistent with prior theory and research [9, 10], we hypothesized that more comprehensive interventions, targeting multiple pathways to building social networks, would yield greater improvements in physical activity and health outcomes.

Methods

Study Design

A 3-arm parallel-group randomized trial was conducted in three small city/town sites within the Harrisburg-Carlisle-Lebanon combined statistical area in Pennsylvania; namely, Harrisburg, Lebanon, and the Harrisburg-West Shore region. Participants within each site were randomly assigned to one of three 12-week interventions based on the SNAP model [11]. As shown in Figure 1, the *Promotion* group evaluated the effects of weekly emailed tips emphasizing social network interactions for walking (i.e., staff-provided encouragement and informational resources); the *Activity* group evaluated the incremental effect of adding an evidence-based online fitness walking intervention to the weekly tips; and the *Social Networks* group evaluated the additional incremental effect of providing access to an online

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networking site for walking, and prompting social networking for walking/activity across diverse settings. Procedures for each study arm represented a *subset* of possible procedures in the SNAP model, and were selected based on their potential for dissemination across regions varying in physical activity infrastructure. Assessments were conducted at baseline, and at 3 and 9 months after the baseline assessment. We hypothesized that the *Social Networks* group would increase their physical activity more than the *Activity* group, and that both of these groups would increase their activity more than the *Promotion* group [11]. The study protocol is described further elsewhere [11], and was approved by the Pennsylvania State University College of Medicine Institutional Review Board. All participants gave written informed consent.

Participants—Eligibility criteria included age of 35–64 years; physically inactive, i.e., <150 minutes/week of self-reported moderate-to-vigorous-intensity physical activity (MVPA) for exercise [18, 19]; able to speak English; able to engage in moderate-intensity physical activity; and Internet access. Participants were also required to live in adjacent census tracts over an area not exceeding a 5-minute drive time from the geographic center of the three study sites, to facilitate in-person social interactions among participants randomized to the *Social Networks* group [20, 21]. Exclusion criteria included BMI >39.9; systolic blood pressure ≥160 mm Hg or diastolic blood pressure ≥100 mm Hg; diabetes, pulmonary, or cardiovascular disease; ≥5 drinks of alcohol/day; pregnancy; and planned relocation. Those with more than one medical risk factor (e.g., high cholesterol, hypertension) required a physician's documented approval to participate.

To recruit participants, a list of households in each of the study sites with at least one person within the study's age range was generated from a commercial marketing database (InfoUSA). Study information was sent to the identified households via a commercial mailing service, and directed participants to a web-based screener [11].

Randomization—Randomization was conducted separately for each site. At baseline, participants within each site were asked to list the names of all known family/household members or friends/acquaintances participating in the study. If a participant indicated knowing one or more participants at baseline (17.9% of total sample), the participant was clustered with the identified participants into a single randomization unit (units ranged from 2–3 people) to minimize treatment contamination [22]. Participants were subsequently grouped into 12 strata by: (a) acquaintance with other participants/gender (three levels: cluster of acquainted participants, unacquainted males, unacquainted females); (b) age (two levels: above and below sample median age for each site); and (c) aerobic fitness (two levels: above and below sample median fitness level for each site) [22]. After randomly sequencing each participant/cluster in each stratum, computer-generated permuted block randomization (block size of three with equal allocation; determined by a statistician) was used to randomize each participant/cluster to the three study groups.

Intervention

Common elements—Participants in all three groups received a 12-week online intervention that emphasized fitness walking. All participants were encouraged to walk three

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or more times per week for at least 30 minutes per session, and to supplement their walking with other activity modes. All participants also received weekly 1-page "tips of the week" emailed by program staff, which targeted social network interactions by providing encouragement and informational resources for walking/physical activity (e.g., tips on walking safety, engaging walking companions, serving as an active role model).

Promotion group—In the *Promotion* group, aside from receiving the weekly emailed tips, there was no contact between program staff and participants for 12 weeks.

Activity group—The *Activity* group participants, in addition to receiving the weekly tips, received a 12-week evidence-based online fitness walking program [23]. Based on the SNAP model [11], we hypothesized that engaging in this walking program could bring participants into incidental contact with social network environments, i.e., in-person or online social contacts who might prompt or reinforce physical activity (Figure 1).

The *Activity* group program began with a one-on-one in-person introductory skill-building session with modeling demonstrations by staff, practice, and corrective feedback on brisk walking and stretching skills. To improve walking speed relative to a specific distance, participants were given a wrist stopwatch, and instructed in the use of a free site (www.mappedometer.com/) to measure walking mileage. To assist with general self-monitoring of walking, participants were also instructed in the use of a program-provided Yamax SW-200 pedometer and a walking log. A program manual that summarized content from the introductory meeting was provided. Following the introductory meeting, participants were prompted via email each week to submit walking logs detailing their walking frequency, pedometer steps, and walking duration and mileage to program staff. Within one day of receipt of walking logs, participants received emailed written and graphical feedback, following pre-specified algorithms, which showed how their walking steps and speed compared both to their prior weekly performance and to other participants [23]. The feedback also provided tailored walking goals for the forthcoming week, following previously used procedures [23]. In addition to tailored goals encouraging participants to increase their walking frequency from the prior week (if they did not walk ≥3 times), or to maintain their current frequency, participants were given tailored, progressively more challenging goals to walk each mile in a specific number of minutes and seconds (i.e., 10–20 seconds faster than the participant's average minutes/mile in the prior week). Progressing to a more challenging goal was contingent upon meeting the prior week's walking goals without exceeding a rating of "5" on the 10-point Borg revised rating of perceived exertion scale [24], and on completing walks without pain/discomfort [23].

Social networks group—The *Social Networks* group participants received all procedures described for the *Activity* group. However, procedures for this group also aimed to increase exposure to virtual and physical settings that could help participants build social networks to sustain active living [11]. Therefore, *Social Networks* group participants were given access to a private online social networking site for program participants, and were provided with weekly feedback on their efforts to engage in walking in physical settings where they could make contact with new and existing network members for physical activity (Figure 1).

As with the *Activity* group, the *Social Networks* group program began with a one-on-one in-person introductory session, but the *Social Networks group's* session and program manual additionally incorporated instruction on using a private online social networking site for walking. A separate online networking site was established for each of the three city/town sites to permit tailoring to neighborhood-specific resources/walking routes, and to facilitate social interactions among participants living in close geographical proximity. For the Harrisburg site, we used Ning Networks (www.ning.com). For the Lebanon and Harrisburg-West Shore sites, based on Harrisburg participants' feedback recommending that we use a site (e.g., Facebook) that many participants were already using, we used a private Facebook group (www.facebook.com). All participants randomized to the *Social Networks* group for each study site (Figure 2) were included on their respective site-specific online networking site.

To facilitate meeting other participants in the *Social Networks* group, four "meet the group" walks in participants' neighborhoods were led by program staff in the first 2 weeks of the program. Participants were then asked to post self-led walking or physical activity events on the online networking site and to join other members' events. Because few Harrisburg participants posted or joined events on the online networking site, we offered participants in the Lebanon and Harrisburg-West Shore sites the opportunity to be entered into a drawing for a $25 gift card given every 2 weeks if they posted/joined physical activity events on the networking site. Participants were also asked to contribute to a discussion board on the online networking site where program staff posted a new discussion topic weekly (e.g., favorite walking locations), and to invite friends and family members to join the networking site and group walks.

Participants were asked to self-monitor (yes vs. no) if they performed 12 social networking actions across the online networking site (e.g., posting/joining walks, contributing to discussion board), and diverse in-person physical settings (e.g., joining walking group, joining fitness facility/class), each week. These networking activity reports were submitted weekly to program staff members, along with participants' walking activity logs. Participants received weekly graphical feedback on their number of social networking actions relative to their own past performance and other program participants, and were praised if they performed one or more new networking action(s) in the prior week. Following pre-specified algorithms, participants were given tailored goals to attempt at least one of the 12 networking actions not yet attempted in the forthcoming week, with suggested goals based on prior goal achievement [11]. Although program-provided feedback ended after 12 weeks, the online social networking site for each study location remained active for one year following the 12-week intervention phase.

Measures

Participants received $20, $30, and $40, respectively, for attending the baseline, 3-month, and 9-month assessments conducted by trained staff at a clinical research center. The primary outcome was accelerometer-measured MVPA. Secondary outcomes included aerobic fitness, body mass index (BMI), waist circumference, and blood pressure. All

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assessments were single-blinded (participants), except for aerobic fitness, which was double-blinded (participants, staff).

Physical activity outcomes—The Actigraph GT3X accelerometer (Actigraph, Pensacola, FL), which has high reliability and has been extensively validated [25, 26], was used to measure MVPA. Participants wore the Actigraph for 7 consecutive days, and intensity of movement per minute was recorded. A valid accelerometer hour was defined as not exceeding 30 consecutive 'zero' values and a valid day consisted of at least 10 valid hours. If there were not at least 5 valid days or 66 valid hours across 7 days, participants were asked to re-wear the accelerometer, which resulted in a 5.7% re-wear rate across all assessments. Using established activity count "cut-points" [26], total minutes of MVPA (3 metabolic equivalents (METS) or greater) were obtained for each participant, and divided by the participant's number of valid days to obtain the average number of MVPA mins/day. The summary variable used in analyses, average daily minutes of MVPA, was multiplied by 7 to obtain estimated minutes of MVPA per week.

Aerobic fitness was estimated using a submaximal graded treadmill test, according to the guidelines of the American College of Sports Medicine [27]. Participants initially walked on a flat grade for 3 minutes at a low speed (~1.5–2 mph) at ~40% of their predicted maximum heart rate (220-age) as a warm-up. Subsequently, participants walked at 3-minute intervals over five pre-established stages gradually increasing in speed (up to a maximum of 3.5 mph) and elevation (up to a maximum of 7.5%) or until they reached fatigue or 85% of their predicted maximum heart rate. Heart rate was monitored with a Polar FS1 heart rate monitor (Polar Electro Inc, Lake Success, NY). Aerobic power (VO_2max) was estimated using the relationship between heart rate and exercise intensity [27].

Health outcomes—BMI was calculated based on height, measured to the nearest 0.1 cm with a calibrated Seca 242 digital stadiometer (Chino, CA) and weight, measured to the nearest 0.1 kg with a calibrated physician's Detecto 439 scale (Webb City, MO). Waist circumference was measured to the nearest 0.1 cm at the level of the iliac crest using a Gulick II tape measure (model 67020; FitnessMart, Gays Mills, WI) [27]. The average of 2 measurements was recorded for height, weight, and waist circumference. Resting blood pressure was assessed according to the American Heart Association guidelines [28], using a calibrated hospital-grade device (model 42NTB-E1; Welch Allyn, Inc, Skaneateles Falls, NY) after a 5-minute period of rest while seated. The average of 3 blood pressure measurements was recorded.

Process evaluation—Consistent with recommendations to assess the extent to which interventions were implemented as planned [29], we used prior-validated questions [23] and records to assess participants': (1) *receipt* of intervention; (2) *participation* in intervention (i.e., number of walking logs returned, number of walking sessions completed divided by number prescribed, participation in social networking and other program activities; and (3) *satisfaction* with intervention. We also assessed treatment contamination at post-program by asking participants to list the names of known study participants in a different intervention group.

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Statistical Analysis

Power analysis—We anticipated an effect size (Cohen's *d*) of *d* = .60 for both the *Social Networks* and the *Activity* groups relative to the *Promotion* group [23, 30, 31] on the primary outcome of MVPA. For a secondary comparison of the *Social Networks* and the *Activity* groups, we anticipated an effect size of *d* = .45 [23, 32]. Assuming a total initial sample size of 308, 20% attrition at 9 months, and a 2-sided, 0.05-level test, we estimated at least 90% power for the primary comparisons of the *Social Network*s and the *Activity* groups to the *Promotion* group on the primary outcome. Similarly, we estimated at least 80% power for the secondary comparisons of the *Social Networks* and the *Activity* groups [33]. Because the average participant cluster size approximated 1, there was minimal design effect, and we therefore did not further adjust the sample size to account for clustering.

Data analytic plan—Baseline sample characteristics were examined using descriptive statistics, and ANOVA and chi-square tests, as appropriate. Data were screened for normality, and several extreme values were truncated to the 99th percentile [34]. Multi-level linear mixed effects models were used to evaluate the effect of the three intervention groups on primary (objectively-measured MVPA) and secondary (aerobic fitness, body weight/composition, and blood pressure) outcomes. Each regression model included the interaction between intervention group and time, to assess if there was a differential effect by intervention group over time. If the interaction was not significant, we refitted the models excluding the interaction terms. The covariates included in the regression models as fixed effects were time (baseline, 3 months, 9 months), site (Harrisburg, Lebanon, Harrisburg-West Shore; site covariates also automatically accounted for site-related seasonal differences), gender, race (non-White, White non-Hispanic), age, income, and education. Cluster-specific and subject-specific random effects were included in the models to account for intra-class correlation due to cluster randomization and within-subject correlation across repeated measures. Mixed effects models were implemented for the full sample, and then repeated in exploratory subgroup analyses for participants with lower and higher objectively-measured MVPA at baseline. A cut-off point of 90 mins/week of MVPA (less than vs. equal to/more than) was used to define the Lower and Higher Activity subgroups based on evidence of increased health risks with less than 90 mins/week of MVPA [35]. Coefficient estimates were reported for all models. All mixed effects models followed an intent-to-treat principle, using all available data, with an alpha of .05. Unlike analysis of variance, mixed effects models can retain cases having partially missing data (e.g., at baseline, or 3- or 9-month follow-up) [36]. Therefore, with the exception of analyses of MVPA where 2.6% of sample was excluded due to having missing accelerometer data at all assessment points, all randomized participants were included in the multi-level analyses. Differences between groups in process evaluation measures (intervention receipt, participation, and satisfaction) were examined using ANCOVA and logistic regression, adjusted for age, gender, race, education, income, and intervention site. Analyses were conducted using SAS 9.3 and SPSS 22.0 for Windows.

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Results

Sample Characteristics

Participants were recruited between August-September 2010 for the Harrisburg site, between January-February 2011 for the Lebanon site, and between July-August 2011 for the Harrisburg-West Shore site. All 3- and 9-month assessments took place within 1-month of the exact-scheduled follow-up point, and the final 9-month assessment was completed in July, 2012. Of the 308 participants recruited at baseline, 88% and 84%, respectively, completed the 3- and 9-month assessments (Figure 2). There were no significant differences in attrition across intervention groups (3 months, $p = .48$; 9 months, $p = .94$).

Most participants were middle-aged, female, White, and college-educated, and 83.4% were overweight/obese (Table 1). All participants self-reported less than 150 mins/week of MVPA for exercise at study screening, but consistent with other clinical trials [37, 38] and with national accelerometry data [39], mean accelerometer-measured MVPA at baseline was near the threshold of 150 mins/week. Participants in the 3 intervention groups did not differ significantly at baseline on all measured variables, except for race/ethnicity, where the *Promotion* and *Activity* groups had more White non-Hispanic participants than the *Social Networks* group.

Physical Activity and Health Outcomes

Group-by-time interaction and group effects—For the full sample, there were no significant group-by-time interaction effects (p's = .61 – .93), nor were there significant group effects (Table 2) for all measured outcome variables, indicating that outcomes did not differ by intervention group over time, or by intervention group alone, collapsing across time. These non-significant group-by-time interaction effects and non-significant group effects were replicated in exploratory subgroup analyses of participants with higher and lower physical activity at baseline.

Time effects—There were significant time effects for the full sample, indicating that outcomes changed over time, collapsing across intervention group (Table 2). Between baseline and 3 months, MVPA improved by 21.0 mins/week, 95% CI [5.9, 36.1]. Waist circumference and systolic blood pressure also improved. At 9 months, participants maintained all 3-month improvements, and also improved from baseline on aerobic fitness and BMI.

Time effects for MVPA and aerobic fitness were more pronounced among participants with lower MVPA at baseline (Figure 3). The Lower Activity subgroup increased their MVPA from baseline by 60.2, 95% CI [45.1, 75.3] and 42.7, 95% CI [26.2, 59.2] mins/week at 3 and 9 months, respectively, compared to no significant change in MVPA from baseline in the Higher Activity subgroup. Similarly, from baseline to 3 months, the Lower Activity subgroup's change in aerobic fitness was about 5 times greater than the Higher Activity subgroup, whose aerobic fitness was unchanged. Both subgroups demonstrated similar improvements in aerobic fitness by 9 months. The direction and magnitude of change for

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other outcomes for the Lower and Higher Activity subgroups was similar to the full sample (Table 2). No serious adverse events were observed/reported for any participant.

Process Evaluation

Figure 4 shows that receipt of planned intervention components exceeded 98% across all intervention groups, while participation varied by program component.

Walking adherence—Participants returned a mean of 9.1 (SD = 3.7) of 12 possible weekly walking logs. Of the 36 prescribed walking sessions (≥ 30 mins), participants completed 71.6% (SD = 32.1) over the 12 week program, 79.3% (SD = 29.2) in the first 6 weeks of the program, and 61.5% (SD = 38.9) in the final 6 weeks. ANCOVA indicated no significant differences in participation between the *Activity* and *Social Networks* groups.

Social networking participation—Participants in the *Social Networks* group performed a mean of 3.9 (SD = 2.6) of the 12 social networking activities targeted over the 12-week intervention (Figure 4). Between the 3- and 9-month assessments, 8.7% of participants posted a discussion comment on the study's online networking site; no other online networking activities were observed.

Intervention satisfaction—Most participants (91.8%) agreed that they would recommend the program to others, and most (69.8%) agreed that they would sign up for another 12 weeks of the program. Logistic regression indicated no significant between-group differences.

Treatment contamination—As treatment contamination was 8.1% at post-program, we conducted sensitivity analyses to examine the intervention effect on primary and secondary outcomes among the subgroup of participants not reporting treatment contamination. Results from mixed model analyses indicated no difference in the significance of study findings.

Discussion

Little is known about the incremental contributions of different procedures for building social networks on change in physical activity and health-related outcomes. In contrast to study hypotheses, providing informational tips (*Promotion*) was just as effective as more comprehensive interventions that additionally incorporated walking feedback (*Activity*) and access to an online social networking site with networking feedback (*Social Networks*). At the 3-month assessment, participants in all groups improved from baseline on MVPA, systolic blood pressure, and waist circumference. At 9 months, participants maintained the post-program improvements, and also improved from baseline on aerobic fitness and BMI. Although there were no differential effects by intervention group, interventions were most effective among Lower Activity participants, who increased their MVPA by 60 mins/week on average at 3 months—an amount associated with reduced cardiovascular disease risk [40].

The lack of differential effects between intervention groups does not appear to reflect unusually high or low participation rates across specific groups (Figure 4). The overall

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walking adherence rate of 72% did not differ between the *Activity* and *Social Networks* groups, and was comparable to prior walking interventions [41]. Within the *Social Networks* group, participation in the social networking activities was similar to participation levels observed in prior interventions. For instance, 64% of *Social Networks* participants posted at least once on the study's social networking site, compared to posting rates of about 57% and 45% in two other networking interventions with middle-aged adults [42, 43]. *Social Networks* participants also reported attempting more of the weekly walking tips, such as engaging walking companions and serving as active role models, than participants in the *Promotion* and *Activity* groups. This suggests that the additional social intervention components provided only to *Social Networks*' participants were delivered with sufficient fidelity to produce measurable behavioral effects in this group—even if these effects did not translate to better physical activity or health outcomes relative to the other two groups.

Confidence in results showing no differential physical activity or health outcomes across intervention groups is strengthened by multiple sources of replication within the study. First, the pattern of null group differences was replicated across all objectively-measured outcomes at both the 3- and 9-month assessments. Second, subgroup analyses across the Lower and Higher Activity participants again indicated null group differences for all objectively-measured outcomes. Third, participants in all groups reported similar program satisfaction; 92% indicated that they would recommend the program to others. These findings suggest that while the structure of procedures for targeting social networks varied across intervention groups, the functional effect of these procedures was similar.

The lack of differential effects among the three intervention groups suggests that all groups —which each had weekly treatment contact—may have functioned equivalently as a prompt for physical activity. Consistent with this hypothesis, a systematic review of walking interventions found that the number of treatment contacts appeared to have greater influence on outcomes than the type or duration of contacts [44]. Similarly, in three clinical trials that compared a multi-component intervention containing an online networking site and physical activity feedback to a lower-intensity comparison group with similar contact frequency, all groups had equivalent physical activity increases [45–47]. These findings suggest that online networking sites and graphical/written feedback, when implemented similarly to the present study and to prior studies, may provide no incremental benefit beyond simpler informational prompts for increasing physical activity.

The incremental contribution of individual treatment components to objectively-measured outcomes has rarely been evaluated. Because most social network and physical activity interventions have compared a single multi-component intervention to a less intense comparison condition, little is known about the effects of adding or subtracting specific components on treatment outcomes. Increasingly, however, research evaluating the incremental contribution of intervention components is being recommended to establish a cumulative science of behavior change [48]. By understanding how each component contributes to outcomes, it is possible to eliminate unneeded procedures that may add unnecessarily to a study's developmental costs (e.g., complex feedback graphs), while refining the effectiveness of lower-cost procedures that could be widely disseminated.

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Unlike prior studies, the current study was designed to isolate the incremental effect of targeting online and in-person social networking activities, above the effects of walking feedback and informational prompts. Evaluating the incremental benefit provided by networking activities is warranted, given the growing number of studies incorporating online social networks to promote preventive health behaviors [7, 8]. To facilitate online and in-person social connections, we recruited participants with similar characteristics (i.e., living in same neighborhoods, middle-aged, interested in walking) [49]. However, in the context of multiple competing contingencies, including job responsibilities and childcare, only 16% of participants posted walking/activity events on the online networking site, and few joined the events. Use of the online networking site ceased after the 12-week intervention phase ended. Other studies with diverse age groups have reported similar challenges engaging participants in online networking sites [38, 43, 46]. These findings suggest the need to address barriers to online networking participation to optimize the effects of networking sites.

Among in-person networking activities, strategies capitalizing on existing networks (e.g., asking friends/family members to walk) resulted in greater participation than strategies involving contact with new networks (e.g., leading or joining community walks), consistent with prior findings [50]. Given evidence that existing networks of friends and family members exert the greatest influence on health behaviors [51, 52], future interventions may benefit from targeting increased physical activity in existing networks. In addition to online networking sites, a promising strategy for targeting existing networks is to use mobile apps and activity sensors to provide real-time updates through existing networks on each network member's activity level [53, 54]. These updates could enable activity-supportive norms and prompts to automatically be transmitted without requiring network members to walk/exercise together in-person or engage in time-consuming online interactions, which can present logistical barriers [53, 54]. However, successfully engineering activity-supportive norms requires that more participants be physically active than sedentary. Within social networking interventions, insufficiently active people typically enroll, and then participation and interest tend to decline over time [8]—compromising the ability to engineer long-term activity-supportive norms and prompts. On a societal level, most people's existing social networks are predominantly sedentary [1]. Given humans' adaptive tendency to conform to behaviors adopted by population majorities [4, 55], harnessing existing social networks to increase physical activity likely requires increasing network members' reinforcement for activity.

To maximize the effectiveness of reinforcers for physical activity, the SNAP and other models suggest that these reinforcers should be strong enough to compete with the reinforcement provided by alternate sedentary activities [10, 11]. Since most participants had modest increases in MVPA, it appears that the reinforcement obtained for physical activity was insufficient. Much remains to be learned, however, about how to establish reinforcers that are sufficiently powerful, yet economically sustainable, across dynamically evolving environments. Future interventions may benefit from moving beyond written/graphical feedback and exploring effects of potentially more powerful reinforcers such as money, healthy palatable food, or time saved by walking. Features that may enhance the effects of these reinforcers, such as their quantity, schedule (e.g., intermittent, continuous), and context/setting, along with participants' internal states (e.g., emotions, deprivation/

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satiation) should also be explored [56]. The emergence of real-time monitoring technologies could improve the ability to precisely fine-tune reinforcers to match situational demands. These refinements to reinforcers should be investigated for behaviors at each level of the SNAP model, including building/accessing supportive environments, increasing physical activity, and engaging in social network interactions to support increased activity.

Strengths of this study included its use of objective outcomes and process evaluation measures, and inclusion of a 9-month follow-up. Of 10 other clinical trials that included online social networking sites and assessed change in adults' physical activity, most used self-report physical activity outcomes and none included follow-up beyond post-program with objective measures [38, 42, 45–47, 57–61]. Among study limitations, the sample had limited ethnic, racial, and socioeconomic diversity. Furthermore, the sample's relatively high objectively-measured baseline activity levels, although comparable to nationally representative accelerometry data [39], may indicate self-selection bias. Due to the lack of an untreated control group, it is also unclear to what extent the observed changes in all groups reflected subject self-selection, secular trends, or measurement reactivity—as all participants completed extensive measures [62]. Finally, including an untreated control group may have enhanced the ability to detect between-group effects. However, prior research already provides substantive evidence that walking and technology-based interventions produce better outcomes than untreated control groups [44, 57, 58]. Therefore, this study aimed to contribute toward understanding the incremental contribution of intervention procedures on outcomes—a growing priority area for accelerating scientific progress [48].

Overall, this study found that an online social networking site and behavioral feedback added no incremental benefit to informational tips, with all study arms achieving equivalent, modest increases in physical activity and health outcomes that were sustained at 9-month follow-up. More research is needed to confirm these findings in representative samples, and to assess if increasing reinforcement for the SNAP model's activity promotion behaviors could increase physical activity on a larger scale. By increasing the societal prevalence of physical activity, we may be able to harness physical activity change in existing network members to shape active living in current and future network members [51, 52].

Acknowledgments

This study was supported by the National Heart, Lung, and Blood Institute, National Institutes of Health, through grant K99/R00 HL088017 (Principal Investigator: Dr. Rovniak). Support was also provided by the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through grants UL1 TR000127 (Drs. Kong and Kraschnewski) and KL2 TR000126 (Dr. Kraschnewski). Dr. Matthews received support from Penn State's Population Research Institute, which receives core funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development through grant R24-HD41025. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung, and Blood Institute or the National Institutes of Health. We thank Connie Bechtel, BS, CSCS, NASM-CPT, Charity Sauder, MS, Erica Bates, MD, LeAnn Denlinger, MD, Ellen Duveneck, MD, Erik Lehman, MS, and Matthew Solovey for their assistance in conducting this study.

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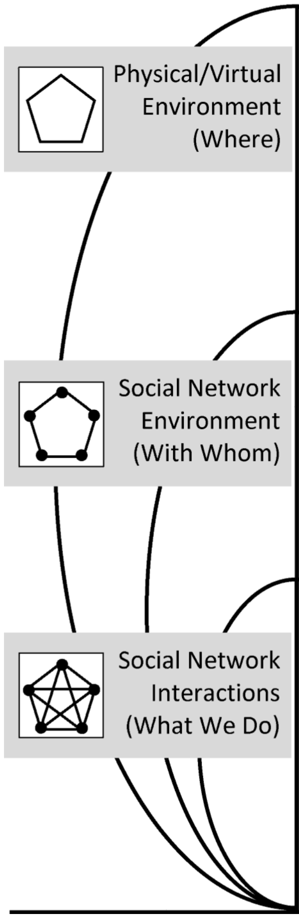

Ecological Level	Primary Intervention Procedures	Intervention Group: Social Networks	Intervention Group: Activity	Intervention Group: Promotion
Physical/Virtual Environment (Where)	Access to publicly accessible built and natural physical settings and/or online settings (physical/virtual environment; depicted by pentagon at left) is a key step in initiating social contacts with others to support walking/physical activity. *Procedures:*			
	• Provide access to *online social networking site* to help participants arrange walks with others or obtain support.	✓		
	• Participants receive weekly feedback on their *use of online networking site, and in-person community fitness settings*.	✓		
Social Network Environment (With Whom)	As different people (social network environment; depicted by dots at left) enter physical/online public settings and walk/move around, they may be exposed to new or existing social contacts via in-person/online interaction modes.[a] *Procedures:*			
	• Participants attend *staff-provided* skill-shaping session.	✓	✓	
	• Participants receive weekly *staff-provided* feedback on their *walking* quantity and speed.	✓	✓	
Social Network Interactions (What We Do)	Modeling, behavioral monitoring, encouragement/praise, assistance/companionship (social network interactions; depicted by lines at left) may function to prompt/reinforce walking in both in-person and online interaction modes.[b] *Procedures:*			
	• *Modeling* of skills in training session; *behavioral monitoring* and *encouragement/praise* via weekly feedback.	✓	✓	
	• Weekly walking *encouragement* via 1-page "tips of the week;" tips provide *assistance* for establishing a walking routine and enlisting walking *companions/support*.	✓	✓	✓

Figure 1.

Social Networks for Activity Promotion (SNAP) model and intervention procedures. *Note.* This study tested the incremental effects of different *intervention procedures* that placed more vs. less emphasis on each ecological level, while acknowledging that all ecological levels interact. Intervention procedures most relevant to each ecological level are highlighted in italics. [a]In addition to the contacts with program staff resulting from engagement in walking, evidence suggests that participants who walk in public settings may incidentally come into contact with other people who could reinforce their walking (e.g., pleasant conversations with neighbors, shopkeepers, or gym staff) [10, 12]. However, this program did not formally arrange these social contacts. [b]We hypothesized that the program-provided social network interactions would function to prompt and reinforce walking. However, other family/friend social network interactions could function to discourage walking (e.g., criticism for walking) [10, 11].

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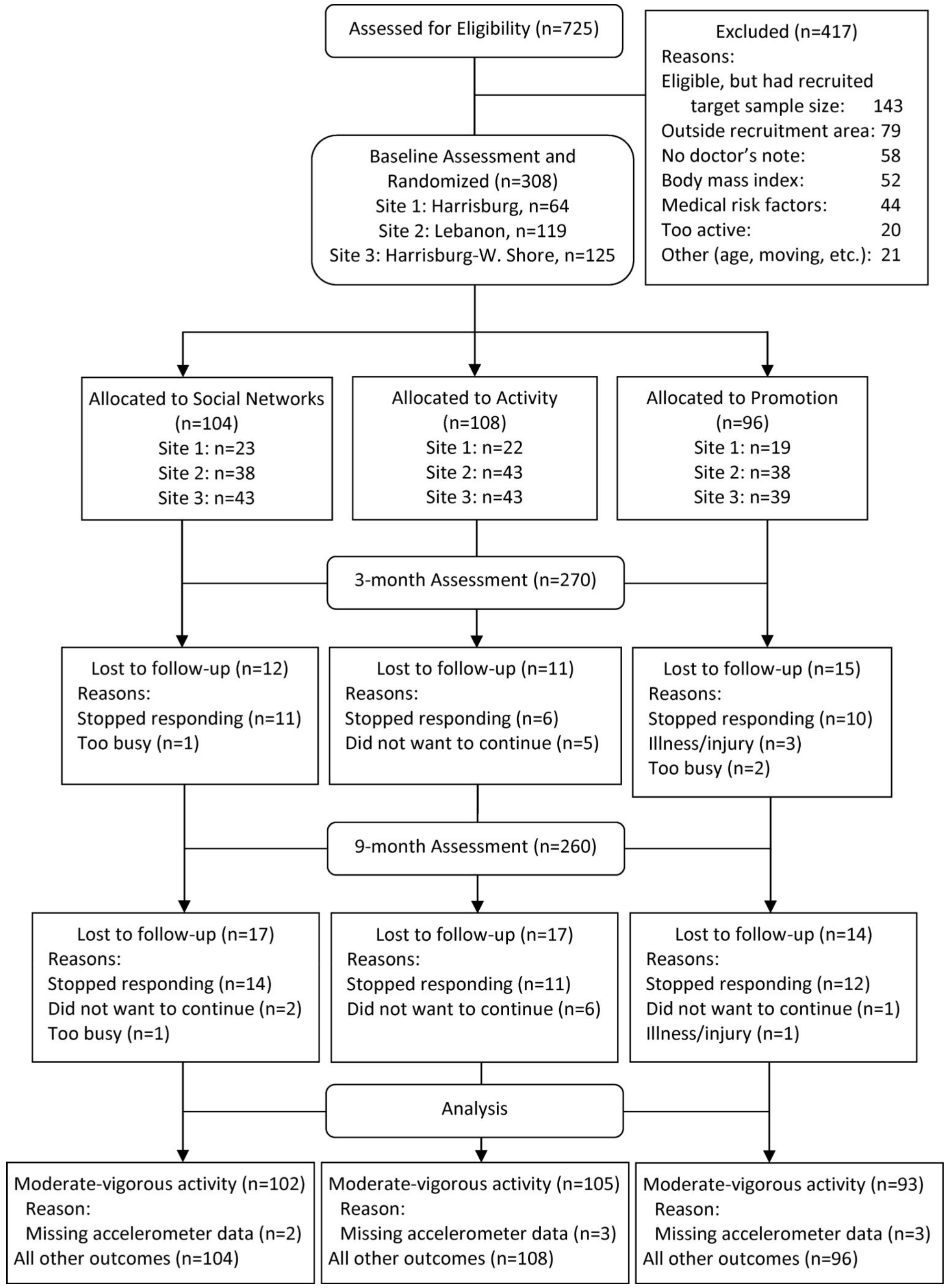

Figure 2.

Consort diagram: flow of participants through trial.

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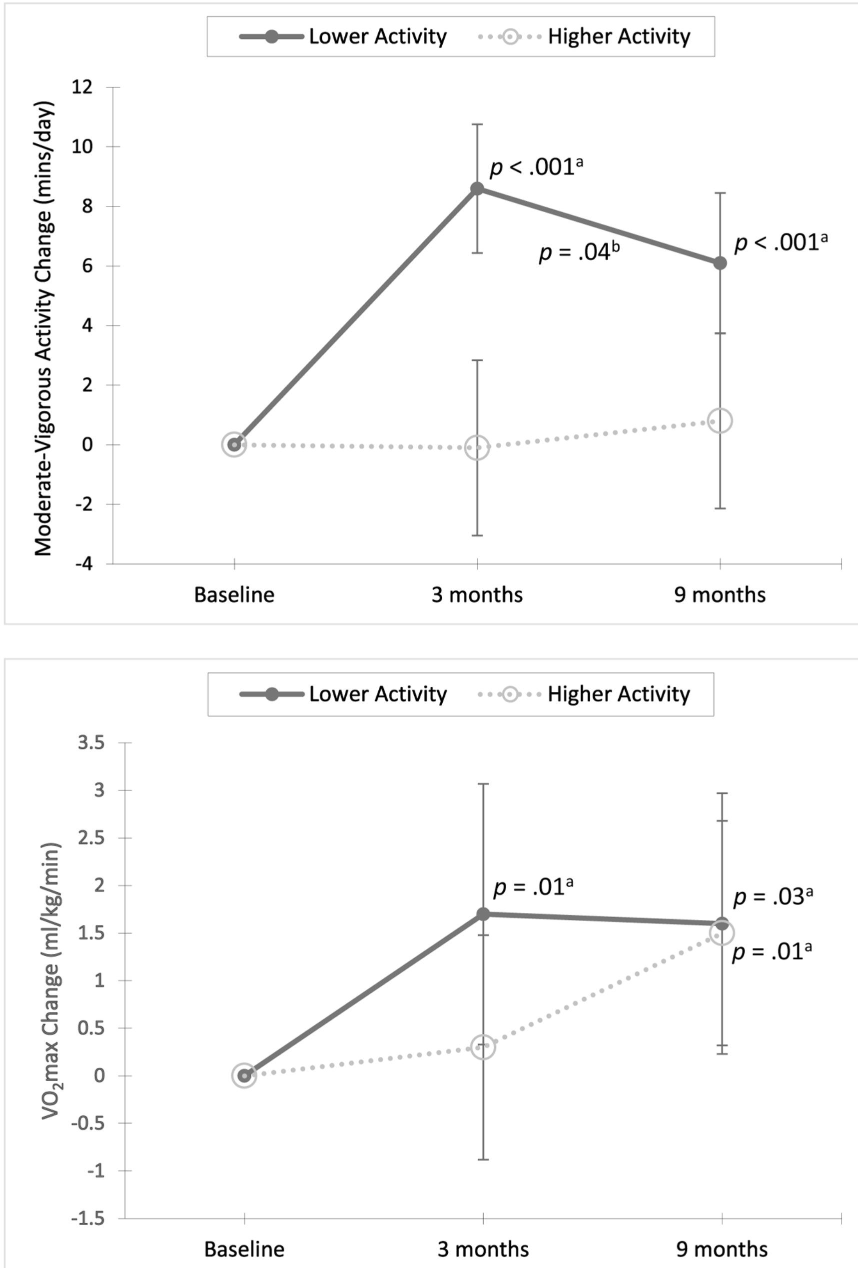

Figure 3.

Mean change (estimate [95% CI]) in physical activity outcomes for subgroups with lower (*n* = 101) vs. higher (*n* = 189) moderate-to-vigorous physical activity (MVPA) at baseline. [a] indicates a significant change from baseline. [b] indicates a significant change between the 3 to 9 month assessments. There were no significant differences in the distribution of Lower vs. Higher Activity participants by treatment condition. The proportion of Lower Activity participants was 32.6% in the *Promotion* condition, 33.0% in the *Activity* condition, and 38.8% in the *Social Networks* condition (Pearson Chi-Square, $p = .60$).

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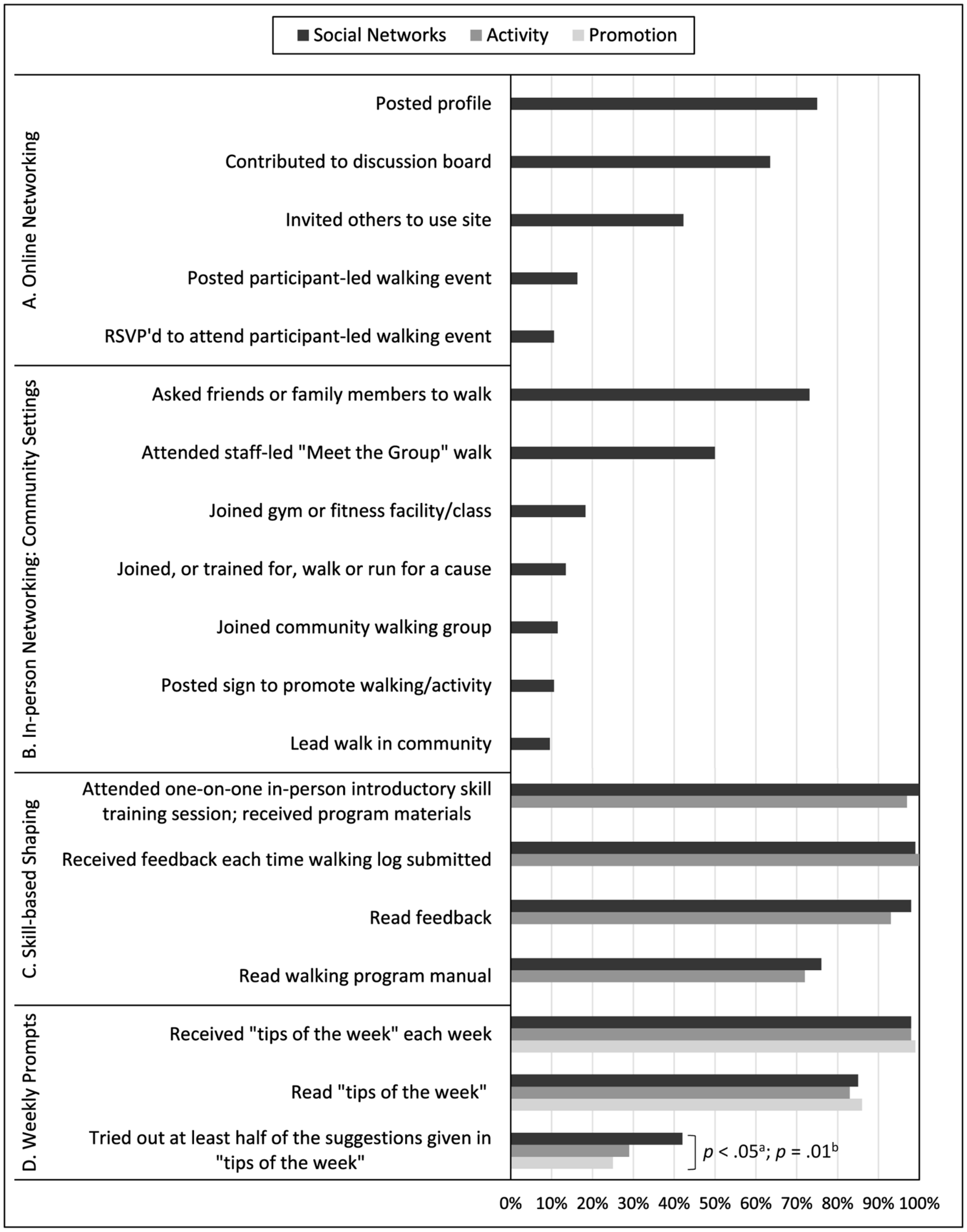

Figure 4.

Parts A and B: Percentage of participants in *Social Networks* group participating at least once in online and in-person activities to build social networks for physical activity, during 12-week program (n = 104). All activities self-reported weekly by participants. Data for all online networking activities, and for attending the staff-led "Meet the Group" walks were also tracked weekly by program staff; staff-provided data for these outcomes are used here. Parts C and D: Percentage of participants at 3-month assessment (n = 270) reporting that they "agreed" or "strongly agreed" that they had received/used specific program components. Data for attendance at the introductory skill training session were provided/

tracked by program staff. All participants attended this session, except for three participants who dropped out immediately post-randomization. [a] indicates a significant difference between the *Social Networks* (reference category) and the *Activity* groups (OR = .52, 95% CI [.27, .98]). [b] indicates a significant difference between the *Social Networks* (reference category) and the *Promotion* groups (OR = .41, 95% CI [.21, .81]).

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Table 1

Comparison of Baseline Characteristics Across the 3 Study Arms

Characteristics	Total (*N* = 308)	Social Networks (*n* = 104)	Activity (*n* = 108)	Promotion (*n* = 96)	*P*
Demographic characteristics					
Age (yrs)	50.3 (8.3)	50.5 (8.0)	50.4 (8.5)	50.0 (8.6)	.90
Male (%)	38.3	39.4	35.2	40.6	.70
White non-Hispanic (%)	91.9	85.6	95.4	94.8	.02
Less than college education (%)	42.0	33.7	45.8	46.9	.25
Household income <$50,000 (%)	25.7	24.0	23.4	30.2	.62
Objectively-measured physical activity and health risk factors					
MVPA[a] (mins/day)	21.6 (16.4)	20.1 (15.0)	21.8 (16.5)	23.1 (17.8)	.45
VO_2max (ml/kg/min)	34.7 (12.0)	34.6 (11.8)	34.8 (12.6)	34.8 (11.7)	.99
Body mass index (kg/m^2)	29.8 (4.7)	29.6 (4.8)	29.6 (4.9)	30.1 (4.5)	.75
Waist circumference (cm)	98.6 (14.4)	97.6 (14.7)	98.4 (14.0)	100.0 (14.6)	.53
Systolic blood pressure (mm Hg)	126.0 (14.7)	125.2 (15.0)	126.1 (15.4)	126.9 (13.8)	.71

Note. Data reported as means and standard deviations (in parentheses) or percent.

[a]For MVPA (moderate-to-vigorous physical activity), the baseline *N*-size was 290 (*Social Networks*, *n* = 98; *Activity*, *n* = 100; *Promotion*, *n* = 92), due to missing accelerometer data.

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Table 2

Change in Objectively-measured Physical Activity and Health Risk Factors from Baseline to 9-month Follow-up: Group and Time Effects

Physical Activity and Health Risk Factors	Group Effects						Time Effects					
	Activity vs. Promotion		Social Networks vs. Promotion		Social Networks vs. Activity		Baseline to 3 months		Baseline to 9 months		3 months to 9 months	
	Est [95% CI]	*P*	Est [95% CI]	*P*	Est [95% CI]	*P*	Est [95% CI]	*P*	Est [95% CI]	*P*	Est [95% CI]	*P*
MVPA (mins/day)[a] (*n* = 300)	−0.3 [−4.4, 3.8]	.89	−2.5 [−6.6, 1.6]	.23	−2.2 [−6.1, 1.7]	.28	3.0 [0.8, 5.2]	.005	2.5 [0.3, 4.7]	.02	−0.5 [−2.7, 1.7]	.65
VO_2max (ml/kg/min) (*n* = 308)	0.0 [−2.9, 2.9]	.99	−0.0 [−2.9, 2.9]	.99	−0.0 [−2.9, 2.9]	.99	0.7 [−0.3, 1.7]	.12	1.4 [0.4, 2.4]	.003	0.7 [−0.3, 1.7]	.16
Body mass index (kg/m^2) (*n* = 308)	−0.1 [−1.5, 1.3]	.82	−0.5 [−1.9, 0.9]	.46	−0.3 [−1.7, 1.1]	.60	−0.1 [−0.3, 0.1]	.25	−0.2 [−0.4, −0.0]	.005	−0.1 [−0.3, 0.1]	.09
Waist circumference (cm) (*n* = 308)	−0.1 [−3.4, 3.2]	.98	−1.7 [−5.0, 1.6]	.33	−1.6 [−4.9, 1.7]	.34	−1.3 [−1.9, −0.7]	<.001	−1.5 [−2.1, −0.9]	<.001	−0.2 [−0.8, 0.4]	.58
Systolic BP (mm Hg)[b] (*n* = 308)	0.7 [−2.6, 4.0]	.67	−2.2 [−5.5, 1.1]	.21	−2.9 [−6.2, 0.4]	.09	−1.4 [−2.8, −0.0]	.04	−4.4 [−5.8, −3.0]	<.001	−3.0 [−4.4, −1.6]	<.001

Note. Data reported as estimates (Est) and 95% confidence intervals [CI]. Given no significant group-by-time interaction effects, *p*-values for group effects were collapsed across time; estimates reported for group effects indicate average increase/decrease of first-listed group relative to second-listed group across all assessment points. *P*-values for the time effects were collapsed across the three intervention groups [36]. All analyses adjusted for age, gender, race, education, income, and intervention site.

[a]MVPA indicates moderate-to-vigorous physical activity.

[b]BP indicates blood pressure.