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Dziyana Nazaruk

Kelli Rouser

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The Use of Mobile Apps to Increase Physical Activity Level: A Systematic Review

Dziyana Nazaruk*, Kelli Rouser

Health Policy and Community Health, Georgia Southern University, Savannah, USA
*Corresponding author: dnazaruk@georgiasouthern.edu

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Abstract **Background:** About 82% of the U.S. adult population owns a smartphone. More than half of that population downloaded a fitness or health app to increase the physical activity level. The current review included studies that have utilized mobile apps in conjunction with other intervention strategies to increase physical activity levels. **Methods:** The search was conducted in five electronic databases. Studies were included if they were randomized controlled trials, utilized mobile apps, physical activity was the primary outcome, written in English, and conducted between the years of 2007 and 2019. **Results:** Thirteen studies were included in the final review. Results indicated that multi-component interventions reported significant improvements in physical activity across all age groups. The most substantial behavior change effects were observed in interventions that combined apps with health coaching, individualized text messages, and self- monitoring component. The overall results indicated that 8 out of 13 included studies reported statistically significant improvement in physical activity level with mobile app utilization in multi-component interventions. **Conclusion:** This review suggests that mobile apps have the potential to effectively deliver physical activity interventions, by providing tailored-based approach, unlimited accessibility, and monitoring. Therefore, future studies must focus on the effective delivery of evidence-based physical activity interventions through mobile apps in various populations.

Keywords: *physical activity, mobile apps, smartphone, exercise*

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1. Introduction

Regular physical activity has been proven to result in a lower risk of mortality from all causes [1]; however, very few adults meet the recommendations for physical activity. Globally, low level of physical activity is responsible for numerous health and economic burdens. It has been estimated that 7% of type 2 diabetes, 6% of heart disease, 10% of colon cancer, and 10% of breast cancer can be attributed to physical inactivity. Overall, physical inactivity is accountable for 9% of all premature mortality [2]. The prevention of these non-communicable diseases is an essential goal for the public health community worldwide. Given the numerous benefits of physical activity [3], there is a need to design interventions that can cost-effectively reach a large population. In addition, utilizing various motivation techniques [4], offering realistic goal-setting [5], providing regular feedback [6], and using primary care setting as one of the outlets to promote health-related behaviors [7,8,9] can result in a sustainable increase in physical activity.

Mobile phones are a quintessential part of people's lives and have become hubs for a rapidly evolving digital lifestyle [10]. According to previous research, 82% of the U.S. adult population owned an app-enabled mobile phone [11]. More than half of this population of users have downloaded a fitness or health app that assist in monitoring, recording, and tracking progress to exercise adherence [12]. With the number of users steadily on the rise, the field of mobile health provides the opportunity to increase disease prevention and management using mobile technology [1]. The use of apps in health promotion and disease prevention has enabled researchers to apply health behavior techniques that have proven to facilitate change among a large population [13].

Multiple factors can affect one's health, such as diet and other lifestyle behaviors. Therefore, the efficacy of the mobile phones utilization to improve health through the increase of physical activity level remains unclear. Previous systematic reviews have aimed to synthesize evidence for efficiency; however, they included additional factors that could influence behavior change, such as diet and sedentary behaviors. One systematic review attempted to evaluate the potential effectiveness of mobile-phone-based approaches to promote physical activity however the emphasis was put on the use of the technology in its entirety including SMS messaging, e-mail, and websites [14]. To our knowledge, no systematic review to date has focused primarily on the usability of mobile apps to increase the physical activity level. The objective of this study was to address the gaps in the literature by presenting evidence of the use and efficacy of mobile apps to increase the physical activity.

2. Methods

A comprehensive search of five electronic databases including PubMed, PsychINFO, CINAHL, Science Direct, and Web of Science was conducted from March through June 2019. A keyword search was performed using the following search string: (Mobile apps OR app OR smartphone) AND (Physical activity OR Fitness OR Exercise).

2.1. Inclusion and Exclusion Criteria

To be considered for this review, studies were required to analyze randomized controlled trials that utilized mobile apps for physical activity as the primary outcome between the years of 2007 and 2019. International studies were also eligible for inclusion but had to be written in English. Studies that did not examine a control group and those where physical activity was not reported were excluded. Finally, studies were also excluded if pre-existing conditions were a factor.

2.2. Data Extraction

The database search after duplicates were removed yielded 2020 potentially relevant articles. From those articles, a screening of the abstract was conducted, and 1,880 articles were excluded. Of the remaining 140 articles, the full text was assessed, and 122 of those were excluded from the study because they were not randomized controlled trials. The remaining 13 studies that analyzed randomized controlled trials that assessed an adult population and adolescent populations were included in the final review (Figure 1). Data extraction was conducted using a standard procedure developed for this study (Table 1), and similar to the one used in other systematic review [14]. The information from each study was extracted based on source, study design and duration, intervention components, outcomes measures, and results.

Table 1. Characteristics of the mobile apps-based interventions included in the review

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
Direito et.al 2015 New Zealand	*Study design:* 3-arm, parallel, RCT Stand-alone approach *Duration:* 8 weeks	N- 51 Ages: 14-17 M (47%) F (53%)	*Intervention components:* App features: (1) an immersive app (Zombies, Run), (2) a nonimmersive app (Get Running), or (3) usual behavior (control)	*Outcomes Measures:* 1. A field test of CRF 2. Height/ weight status measured 3. Self-reported physical activity and related psychological variables 4. Actigraph (to provide an objective assessment of the free-living PA), 5. Booklet detailing their accelerometer use	*Results:* There was no significant intervention effect on the primary outcome using either of the apps. Compared to the control, time to complete the fitness test was –28.4 seconds shorter (95% CI –66.5 to 9.82, P=.20) for the immersive app group and –24.7 seconds (95% CI –63.5 to 14.2, P=.32) for the nonimmersive app group. No significant intervention effects were found for secondary outcomes.	*Effect:* No
Glynn et al, 2014 Ireland	*Study design:* 2-group RCT Multi-component Approach *Duration*: 8 weeks	$N = 77$ Ages: 44.1 years/>16 years 36% (M), 64% (F)	*Intervention components:* App features: Commercially available app: Used the Accupedo-Pro Pedometer app. Goal setting functionality and goal setting achievement feedback, self-monitoring of step counts and calories burnt, automatic performance feedback through graphic display of step-count history *Intervention group* Received physical activity goals and information on the benefits of exercise, smartphone app and instruction on how to use it, telephone mentoring	*Outcome measures:* 1. Physical activity (pedometer) 2. Weight status: objectively measured height and weight 3. Blood pressure: Monitor 4. Quality of life: Questionnaires	*Results:* *Physical activity*: Significant between-group increase in mean steps/day in IG at 8 week follow-up (1631 ± 3842; $p = 0.03$). *Weight status* No significant changes in body weight. No significant changes in BMI. *Blood pressure (BP)* No significant changes in blood pressure. *Quality of life* No significant changes in quality of life.	*Effect:* *Physical activity:* *Yes* *Weight Status:* No *Blood Pressure:* No *Quality of Life:* No

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
			sessions with physical activity goal setting *Control group* Received physical activity goals and information on benefits of exercise but app not made visible on their smartphone and no instructions on how to use the app to achieve these goals			
Harries et. al. 2016 United Kingdom	*Study design:* 3 groups RCT Multi-component Approach *Duration:* 6 weeks	N- 152 Ages: 18-40 Adult Males	*Intervention components:* Test three hypotheses: H1: those with access to social feedback will have higher step-counts than those receiving no feedback H2: those receiving social norms feedback will have higher step-counts than those that only receive feedback on their own walking H3: those only receiving feedback on their own walking will have higher step-counts than those receiving no feedback Randomization was to three groups: no feedback (control); personal feedback on step-counts; group feedback comparing step-counts against those taken by others in their group App features: The design of the version of the app provided to the two treatment groups was distinct from previous apps in three key ways: 1. There was no requirement for additional equipment 2. This app measured activity continually and without the need for any user action. In addition, it ensured that the app measured the physical activity inherent in routine, everyday activities, as well as more purposeful exercise. 3. The formal goal-setting, training and coaching was replaced by self-generated, informal targets that resulted from users'	*Outcome measures:* The primary outcome measures: Steps per day, was assessed using longitudinal multilevel regression analysis. Control variables included attitude to physical activity and perceived barriers to physical activity	*Results:* The study provided support for H1 and H3 but not H2. Receipt of either form of feedback explained 7.7 % of between-subject variability in step-count ($F = 6.626$, $p < 0.0005$). Compared to the control, the expected step-count for the individual feedback group was 60 % higher (effect on log step-count = 0.474, 95 % CI = 0.166–0.782) and that for the social feedback group, 69 % higher (effect on log step-count = 0.526, 95 % CI = 0.212–0.840). The difference between the two feedback groups (individual vs social feedback) was not statistically significant	*Effect:* *Steps per day:* Yes for H1 and H3

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
			engagement with the feedback.			
Hebden et al. 2014 Australia	*Study design*: 2-group RCT Multi-component Approach *Duration*: 12 weeks	*N* = 51 Ages: 18–35 20% (M) 80% (F)	*Intervention components:* Behavior change theory: Transtheoretical model App features 4 apps (one per behavior); physical activity self-monitoring, servings of fruit and vegetables, energy and fat content of take away meals and tailored advice *Intervention group* Used the apps, received SMS text and email messages and internet forums *Control group* Printed diet booklet with instructions from dietician.	*Outcomes measures:* Self-report, questionnaire for Physical activity, Sedentary behavior, Diet Weight status (objectively measured height and weight)	*Results:* *Diet* No between- group change in fruit and vegetable intake or consumption of takeaway meals. *Physical activity* Significant between-group increase in light intensity activity in IG at 13 week follow-up (34.2 ± 35.1, $p = 0.001$). No between group differences for self-reported MET minutes of physical activity. *Sedentary behavior* No significant changes in sedentary behavior. *Weight status* No significant changes in weight status.	*Effect:* *Diet:* No effect Physical activity: Yes *Sedentary behavior:* No *Weight status:* No
King et.al, 2016 USA	*Study design:* 3-arm parallel RCT Stand-alone Approach *Duration*: 8 weeks	N- 95 underactive adults Ages:45 and older	*Intervention components:* An analytically framed app, a socially framed app, an affectively framed app, or a diet tracker control app	*Outcomes measures:* Daily physical activity and sedentary behavior Measures: Smartphone's built-in accelerometer and daily self-report measures.	*Results:* Analytic app: d = 0.89, CI = 0.27, 1.51), while more variable responses were observed among users of the other two motivationally framed apps. Social app users also had significantly lower overall amounts of sedentary behavior relative to the other three arms (*P* values for between arm differences = .02. 001; Social vs. Control app: d = 1.10,CI = 0.48,1.72; Social vs. Affect app: d = 0.94, CI = 0.32, 1.56; Social vs. Analytic app: d = 1.24, CI = 0.59, 1.89). Additionally, Social and Affect app users reported lower overall sitting time compared to the other two arms (*P* values for between arm differences < .001; Social vs. Control app: d = 1.59,CI = 0.92, 2.25; Social vs. Analytic app: d = 1.89,CI = 1.17, 2.61; Affect vs. Control app: d = 1.19,CI = 0.56, 1.81; Affect	*Effect:* *Sedentary behavior:* Yes
Maher et.al. 2015 Australia	*Study design:* 2-group RCT Multi-component Approach *Duration*:	N- 110 Adults Ages 18- 65 Random Recruited in teams of 3-8 friend	*Intervention components:* Behavior Change Theory: 1. Fun Theory 2. The Theory of Planned Behavior *Intervention group*	*Outcomes Measures:* The primary outcome measure was self-reported total weekly MVPA. This was assessed using the Active Australia Survey	*Results:* At the 8-week follow-up, the intervention participants had significantly increased their total weekly MVPA by 135 minutes relative to the control group (P=.03), due primarily to increases in	*Effect:* *Total MVPA:* Yes *Physical activity*: No

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
	8 weeks		Received access to the full Active Team app and were mailed a pedometer. *Control Group* Participants were placed on a waiting list to receive access to the intervention (app and pedometer) at completion of the study and were told that their health would be monitored over the ensuing 5 months.	(AAS) Secondary outcomes included examining the physical activity types/intensities separately all derived from the AAS) and quality of life (Assessment of Quality of Life-6D (AQoL-6D) scale [27], a 20-item instrument assessing six health-related domains)	walking time (155 min/week increase relative to controls, P<.001). However, statistical differences between groups for total weekly MVPA and walking time were lost at the 20-week follow-up. There were no significant changes in vigorous physical activity, nor overall quality of life or mental health quality of life at either time point. High levels of engagement with the intervention, and particularly the self-monitoring features	*Quality of Life:* No
Martin et.al., 2015 USA	*Study design:* 2- arm (tracking and texting) RCT Stand-alone Approach Duration: 5 weeks	N- 48 Adults 18-69 Random	*Intervention components:* Sequential randomization to individually evaluate the tracking and texting components of the intervention was used. After establishing baseline activity during a blinded run-in (week 1), in phase I (weeks 2 to 3) researchers randomized 2:1 to unblinded versus blinded tracking. The activity data were only visible to those who were unblinded, as further described below. In phase II (weeks 4 to 5), researches randomized unblinded participants 1:1 to "smart texts" versus no texts.	*Outcomes Measures:* Primary Outcomes: 1. The mean change in accelerometer measured daily step count assessed from baseline through phase I and II. 2. Attainment of the prescribed 10 000 steps/day goal. Secondary Outcomes: 1. Activity outcome measures were changes in total daily activity time and aerobic time 2. Participant satisfaction **Measures:** Participants used their own smartphones Physical Activity Tracking- FitBit Orb Participants' satisfaction – online survey	*Results:* *Baseline Characteristics* There were no significant baseline differences between groups *Primary Outcome: Change in Steps/Day* The blinded group showed a progressive downward trend over the whole time period, particularly in the change from phase I to II. This downward drift was not observed in either of 2 other trial groups. The unblinded arm trajectory was characterized by a maintenance of baseline activity levels, whereas the biggest shift in trajectory was noted in the text-receiving arm. This group had a clear upward trend in physical activity in response to smart texts. *Secondary Outcomes: Total and Aerobic Activity Times* In phase I, the unblinded and blinded groups were not significantly different in modifying their total activity times, whereas there was a borderline significant smaller decrease in aerobic time in unblinded patients (differential 8 minutes; 95% CI, 0 to 16; P=0.05). In phase II, activity times continued to decrease in the blinded group and remained relatively stable in the unblinded–no texts group. In contrast, the unblinded-texts group increased its total activity time by 21 min/day (23% increase) and aerobic time by 13 min/day (160% increase), which was highly statistically significant compared to the	*Changes in Steps/ Day:* Yes *Total and Aerobic Activity Times:* No *Exploratory Interaction*: No

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
					other groups. *Exploratory Subgroup Interaction Testing* The respective P values for the interaction of the phase I and II intervention (smart texts) were null for most patient. However, there was a trend for significant interaction by sex (P=0.06), and by CHD status ((P=0.03) *Satisfaction* On post-trial surveys, participants largely expressed feelings of satisfaction and enthusiasm for future trial participation. Quantitatively, participants assigned the activity tracker a mean score of 4.0 of 5.0, and text messages 3.8 of 5.0 (4=good;	*Interaction by sex:* Yes
Naimark et al, 2015 Israel	*Study design:* 2-arm RCT Multi-component Approach *Duration:* 14 weeks	N- 85 Mean age: 47.5	*Intervention components:* *Intervention group:* Received access to the app without any face-to-face support *Control group:* Continued their standard lifestyle.	*Outcomes measures:* Measurements were taken at baseline and after 14 weeks and included weight and waist circumference. Nutritional knowledge, diet quality, and physical activity duration were obtained using online questionnaires. The new Web-based app was developed based on current US Department of Agriculture and Israel Ministry of Health recommendations for healthy lifestyle. The app provides tools for monitoring diet and physical activity while instructing and encouraging healthy diet and physical activity.	*Results:* The mean change in physical activity was 63 (SD 20.8) minutes in the app group and -30 (SD 27.5) minutes in the control group (P=.02). The mean weight change was -1.44 (SD 0.4) kg in the app group and -0.128 (SD 0.36) kg in the control group (P=.03). Knowledge score increased significantly in the app group, 76 (SD 7.5) to 79 (SD 8.7) at the end of the study (P=.04) compared with the control group. Diet quality score also increased significantly at the end of the study, from 67 (SD 9.8) to 71 (SD 7.6; P<.001) in contrast to the control group. Success score (represents the success in maintaining healthy lifestyle) was higher among the app group (68%) compared with 36% in the control group (P<.001). The app frequency of use was significantly related	*Effect:* *Physical activity:* Yes *Weight change:* Yes *Knowledge:* Yes *Diet quality score:* Yes *Success score:* Yes *App frequency use:* Yes
Partridge et. al, 2015, Australia	Study design: 2-arm, parallel-group RCT Multi-component Approach	N- 214 Young adults Random	*Intervention components:* *Theory used:* The Transtheoretical Model of Behavior Change *Intervention group:*	*Outcomes measures:* Outcome measures: Demographic information: Online survey Body weight and	*Results:* Adherence to coaching calls and delivery of text messages was over 90%. At 12 weeks, the intervention group were 2.2 kg (95% CI 0.8-3.6) lighter	*Effect:* *Weight status:* Yes

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
	Duration: 12 weeks		TXT2BFiT Program 1. Messages were matched to stage-of-change for each of the individual lifestyle behaviors 2. Personalized coaching calls 3. Weekly emails 4. Password-protected access to purpose-designed mobile phone apps that provided education and allowed self-monitoring , community blog, and support resources available on a password-protected website designed for the study 5. Participants were also mailed a printed 18-page booklet containing the two-page control handout summarizing the Australian National Dietary and Physical Activity Guidelines **Control group:** Participants received 1. The mailed two-page handout, 2.The introductory call at week 0 to introduce the program (no coaching given) 3. 4 text messages (one every 3 weeks, during weeks 1 to 12) that restated information in the handout 4. Access to a website with only electronic versions of the two-page handout, consent form, study information statement, and contact information.	height: Measured and self-reported Intake of sugar-sweetened beverages, daily fruits/vegetables, weekly take-outs meals: Self-reported Physical Activity: The short-form International Physical Activity Questionnaire (IPAQ) that was completed online Engagement: Text message replies and number of coaching calls completed	than controls (*P*=.005). Intervention participants consumed more vegetables (*P*=.009), fewer sugary soft drinks (*P*=.002), and fewer energy-dense takeout meals (*P*=.001) compared to controls. Intervention group also increased their total physical activity by 252.5 MET-minutes (95% CI 1.2-503.8, *P*=.05) and total physical activity by 1.3 days (95% CI 0.5-2.2, *P*=.003) compared to controls.	*Vegetable consumption :* Yes *Fewer energy-dense meals:* Yes *Physical activity:* Yes
Quiñonez et.al, 2016 Netherlands	*Study design:* 3- arm RCT Multi-component Approach *Duration:* 6 months	N- 373 Adults Mean age: 38.69	*Intervention components:* *Theoretical Method:* Determinants: Awareness, Ability factors, Self-efficacy Conditions: 1.Computer 2. Mobile Phone 3.Control Both interventions had exactly the same content. The mHealth intervention was specifically developed for use with a mobile phone, while the eHealth version was developed for use with a computer. The data was collected at	*Outcomes measures:* Demographics: Baseline questionnaire Outcome variable-Physical Activity: International Physical Activity Questionnaire (IPAQ) Sociocognitive variables: Adapted measures from previous studies and a 5-point Likert answering scale (1= low to 5= high) Intervention completion: Log file data	*Results:* Participants receiving feedback messages (eHealth and mHealth together) were significantly more physically active after 6 months than participants in the control group (B=8.48, df=2, P=.03, Cohen d=0.27). Researchers found a small effect size favoring the eHealth condition over the control group (B=6.13, df=2, P=.09, Cohen d=0.21). The eHealth condition had lower dropout rates (117/138, 84.8%) than the mHealth condition (81/108, 75.0%) and the control group (91/127, 71.7%).	*Effect:* *Physical activity:* Yes *Dropout rate*: No *Usability and appreciation :*

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
			5 points in time (baseline, after 1 week, after 2 weeks, after 3 weeks, and after 6 months).		Furthermore, in terms of usability and appreciation, the eHealth condition outperformed the mHealth condition with regard to participants receiving (t_{182}=3.07, P=.002) and reading the feedback messages (t_{181}=2.34, P=.02)	Yes
Stephens et.al, 2017 USA	*Study design:* 2-arm RCT Multi-component Approach *Duration:* 3 months	N- 62 Young Adults Ages: 18-25	*Intervention components:* *Theoretical Method:* Self-Efficacy Theory Social Cognitive Theory *Intervention Group:* Smartphone +Health Coach Group 1. Participants were given an additional 30-40 minute counseling session on energy balance, nutrient density of foods, sugar-sweetened beverage consumption, and physical activity; 2. Participants were also guided to download and use the Lose it! application. Participants were encouraged to log all food and exercise into the daily log in the application. The application also offered social networking through a "friend" feature, which allowed individuals to view peer weight loss and physical activity participation, and also allowed the interaction between peers. 4. Individualized text messages were delivered to the participant's Smartphone from a health coach. *Control group:*The control group was asked to not utilize any Smartphone applications focused on weight loss for the duration of the study. They received the Lose It! application with a training session at their 3-month visit.	*Outcomes measures:* Body weight: Tanita BS-549 scale with the participant in light clothing Height: a wall stick measurement. BMI: was calculated using weight in kilograms/height in meters squared. Waist circumference: was measured two times and then averaged according to the obesity guidelines. Physical Activity: the Godin Leisure-Time Exercise Questionnaire. Nutrition data: was collected using the National Cancer Institute's ASA-24 Self-efficacy for healthy eating and exercise: were evaluated with two questionnaires: 1. The Self-Efficacy for Healthy Eating 2. The Self-Efficacy for Exercise Scale	*Results:* Participants in the smartphone + health coach group lost significantly more weight (P = .026) and had a significant reduction in both BMI (P = .024) and waist circumference (P < .01) compared with controls. All participants assigned to the Smartphone group logged exercise and diet. Of those participants that logged on >50% of days, 3 (50%) logged physical activity on >75% of days and 7 (38%) logged diet on >75% of days. Results indicated the significant relationship between number of physical activity days logged and weight loss (0.03 kg weight loss per additional day of PA logging, p=0.026). The 6 participants who logged PA > 50% of the time lost 1.57 kg more than those who did not. When the threshold was reduced to 25% days logged, the 9 participants logging PA ≥25% of the time lost 1.43 kg more than those logging PA < 25% of the time. The same directional trends were observed with increased logging frequency for food, as well, but these were not significant (p=0.226), possibly due to overall good compliance with food logging.	*Effect:* *Weight:* Yes *# of physical activity days a logged in and weight loss:* Yes *Frequency for food logging:* No
Wang et.al, 2015 USA	*Study design:* 2- arm RCT Multi-component Approach Duration: 6 weeks	N-67 Overweight/ Obese , Sedentary Adults Mean age: 48.2 years Range: 19-66	*Intervention components:* Intervention group: Self-monitoring with Fitbit One plus SMS text messaging prompts. Comparison group: self-monitoring with Fitbit One only	*Outcomes measures:* PA assessments: Actigraph GT3X+ and Fitbit One. Demographics: Baseline questionnaire Attitude/ Behaviors pertaining to each intervention	*Results:* Mixed-model repeated-measures analysis of primary measures indicated a significant within-group increase of +4.3 (standard error [SE] = 2.0) min/week of moderate- to vigorous intensity PA (MVPA) at 6-week follow-up (p = 0.04) in the comparison group (Fitbit only), but no study	*Effect:* *Physical activity:* Yes

Author Year Country	Study Design/ Duration	Sample	Intervention Components	Outcomes Measures	Results	Effect of the Study
				component: Follow-up questionnaire	group differences across PA levels. Secondary measures indicated the SMS text messaging effect lasted for only 1 week: the intervention group increased by +1,266 steps (SE = 491; p = 0.01), +17.8 min/week MVPA (SE = 8.5; p = 0.04), and +38.3 min/week total PA (SE = 15.9; p = 0.02) compared with no changes in the comparison group, and these between-group differences were significant for steps (p = 0.01), fairly/very active minutes (p < 0.01), and total active minutes (p = 0.02).	
Woundenberg et.al, 2018 Netherlands	*Study design:* 2- arm RCT Multi-component Approach *Duration:* 1 month (7 days of baseline, 7 days of intervention after 1 month)	N- 190 adolescents Years: 11-14	*Intervention components:* *Theoretical method:* Self-Determination Theory and Self-Persuasion Theory *Intervention group:* The most influential adolescents (based on peer nominations of classmates) in each classroom were trained to promote physical activity among their classmates. Participants received a research smartphone to complete questionnaires and an accelerometer to measure physical activity (steps per day) at baseline, and during the intervention one month later *Control group:* No intervention	*Outcomes measures:* *Physical Activity:* Wearable accelerometer as number of steps per day, and The Fitbit Flex was used to measure physical activity. *Selection of Influence Agents:* The most central participants were determined based on closeness centrality by entering all the sociometric nominations in the KeyPlayer package (version 1.0.3 [39]) in R (RStudio version 1.0.136). The KeyPlayer package uses a 'greedy search algorithm' to identify a specified number of influence agents that collectively represent the most central subgroup, adjusting for overlapping nominations within each classroom network *Athletic competence:* Physical subscale of the self-perceived competence scale *SNI Evaluation*: Questionnaire	*Results:* A multilevel model tested the effectiveness of the intervention, controlling for clustering of data within participants and days. No intervention effect was found	*Effect:* *Intervention effect:* No

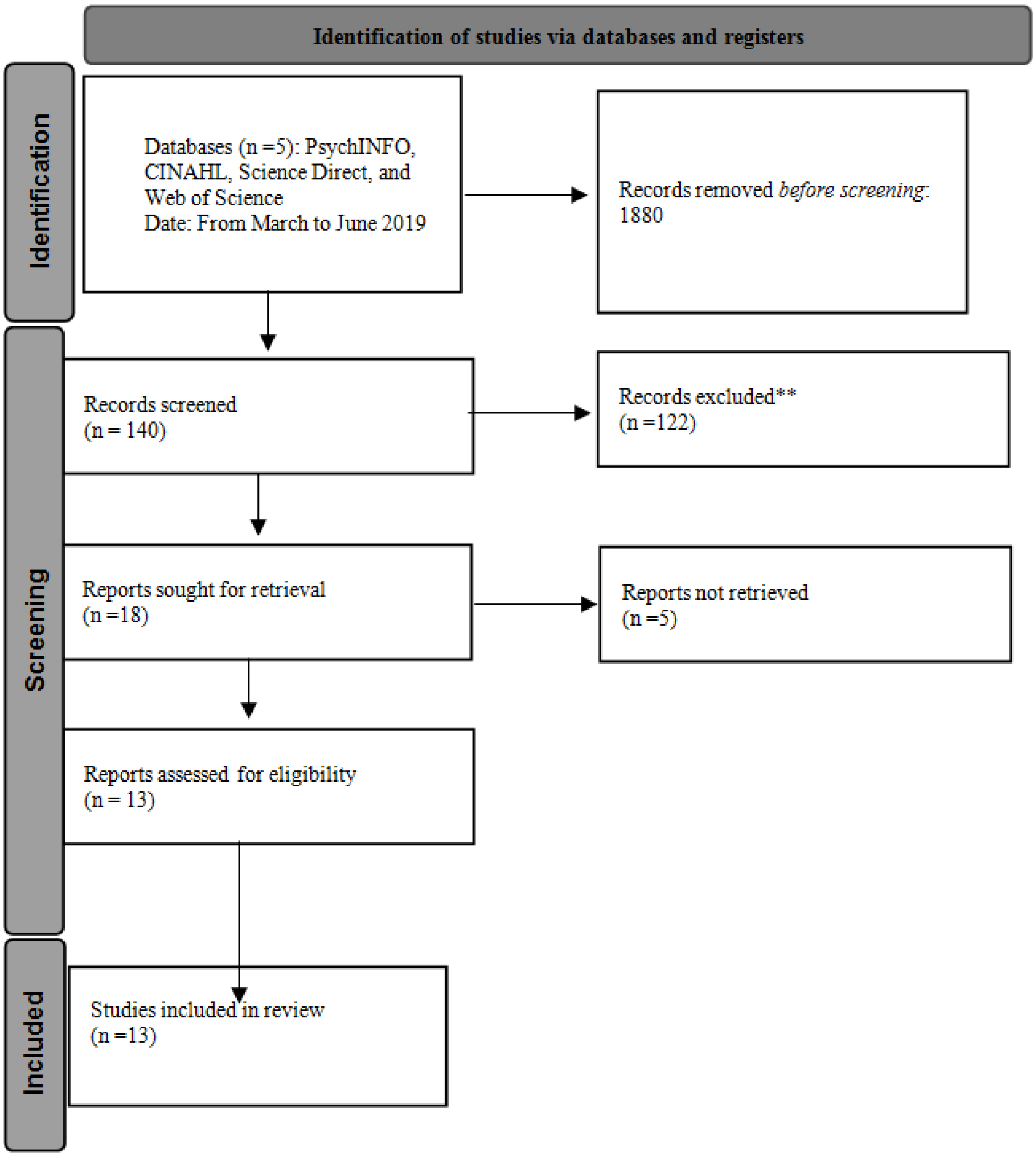

Figure 1. Flowchart of study selection process (*From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71)

3. Results

A total of 13 randomized controlled trials were included in this review [15-27]. Four studies were conducted in North America [19,21,25,26], four in Europe [16,17,24,27], four studies were conducted in Australia and New Zealand [15,18,20,21], and one study in the Middle East [22]. Two studies targeted adolescents [15,27], and the remaining eleven focused on adults [16-26]. The duration of the interventions ranged from one to six months [15-27]. The primarily targeted health behavior was physical activity. The secondary targeted health behaviors were dietary intake and weight status. Some studies also included additional outcome measures such as body mass index (BMI), blood pressure, and heart rate. Ten out of thirteen studies utilized multi-component interventions which included strategies such as health coaching, counseling sessions, individual feedback via text messages, and also the use of digital-physical activity tracking devices such as “Fitbits” and pedometers [16,17,18,20,22-27]. Six studies reported interventions that utilized a theoretical component such as Social Cognitive Theory, Transtheoretical Model, and Control Systems Theory of self-regulation, Self Determination Theory, Theory of Planned Behavior, the I-Change Model, and the Fun theory [18,20,23,24,25,27].

Interventions delivered solely via an app all showed an increase in physical activity, but there were only significant changes noticed in one study [19]. All the multi-component interventions showed improvements in physical activity level [16,17,18,20,22-27]; however, five out of ten did not find statistical significance between comparison and control group [17,18,20,25,27].

Only two studies targeted children or adolescents [15,27]. Out of the two, the study that utilized stand-alone approach did not find a statistically significant difference in the fitness level between the intervention and control groups [15]. The multi-component intervention based on the social network support was also unable to find a statistically significant difference between the intervention and control groups. However, it could be explained by the limited availability of the research material because the intervention only lasted one week [27].

3.1. Theory Utilization

Of the six studies that utilized the theoretical component, only two showed statistically significant changes [23,24]. Quinonez and colleagues used theoretical methods from the I-Change Model. The intervention utilized the following theoretical methods: consciousness-raising and feedback on performance, action planning, preparatory planning, and coping planning, and reinforcement. Results indicated that participants receiving feedback messages (eHealth and mHealth together) were significantly more physically active after six months than participants in the control group [23]. Partridge et al. utilized the Transtheoretical Model of Behavior Change. Messages were matched to stage-of-change for each of the individual lifestyle behaviors. Researchers found that adherence to coaching calls and delivery of text messages was over 90%. At 12 weeks, the intervention group were 2.2 kg lighter than control, consumed more vegetables, fewer sugary soft drinks, and fewer energy-dense takeout meals compared to controls. Most importantly, the intervention group increased their total physical activity by 252.5 MET-minutes and overall physical activity by 1.3 days compared to controls [24].

4. Discussion

In this review, only three studies used stand-alone interventions where the mobile app was the only component [15,19,21]. The remaining studies used apps in conjunction with other intervention strategies [16,17,18,20,22-27]. It was observed that multi-component interventions reported significant improvements in physical activity across all age groups. This indicates that multi-component interventions may yield stronger intervention effects. The most substantial behavior change effects were observed in interventions that combined apps with health coaching or individualized text messages [16,20,23,25]. Although the integration of apps in multi-component interventions likely produce substantial increases in physical activity; future testing is needed.

This study also indicated that physical activity interventions that included a self-monitoring component were able to generate a substantial increase in physical activity [16,18,20,26], which is consistent with previous research [28]. These apps can alert people to their levels of inactivity and motivate them to make subtle changes to increase physical activity.

Most of the app interventions in this review targeted adults [16-26] with only two targeting children and adolescents [15,27]. Because technology and mobile devices are such an integral part of adolescents' lives; it is imperative that future studies are conducted that focus on children.

Overall, eight out the 13 studies reported significant improvements in physical activity [16,19,21-27]. The findings from this review indicate that mobile apps can be a useful tool in promoting physical activity and other healthy behaviors. There are many advantages to utilizing smartphone apps over different intervention strategies such as counseling and health coaching. They can quickly provide access to intervention programs by offering self-monitoring, feedback, and social support.

Lastly, since the primary care setting is a useful outlet for education and the promotion of physical activity [7,8,29,30,31], it could be utilized to prescribe evidence-based smartphone apps interventions to various populations. However, this topic should be investigated further.

4.1. Strengths and Limitations

Strengths of this systematic review included a comprehensive search strategy that ensured the accuracy of the reviewed data. Another advantage is the scope of this review was limited to app interventions that targeted physical activity as the primary outcome. Lastly, this review only included randomized control trials.

One of the weaknesses of this review was the variation in terms of sample size, intervention components, and duration of the studies. However, the overall conclusion was that a large sample size, multiple intervention components, and longer period of the intervention would have a more significant impact on the level of physical activity.

5. Conclusion

Considering the fact that 82% of the U.S. adult population owned an app-enabled mobile phone [11], and more than half of this population utilizes fitness or health app [12], this review provides the support that mobile apps can be an effective channel in promotion and maintenance of the physical activity which is consistent with previous studies [32,33]. However, the success of the mobile app intervention will be primarily based on the quality of the intervention design. Besides, this review suggests that multi-component interventions appear to have a more significant effect than stand-alone interventions. Therefore, future studies should examine the efficacy of multi-component interventions that combine multiple intervention strategies, including theory utilization.

In conclusion, this review suggests that mobile apps have the potential to effectively deliver physical activity interventions, by providing tailored-based approach, unlimited accessibility, and monitoring. Therefore, future studies must focus on the effective delivery of evidence-based physical activity interventions through mobile apps in various populations.

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