International Journal of Public Health (2019) 64:679–690
https://doi.org/10.1007/s00038-019-01210-7

REVIEW

What is the role of smartphones on physical activity promotion? A systematic review and meta-analysis

Natan Feter[1] · Tiago Silva dos Santos[1] · Eduardo Lucia Caputo[1,2] · Marcelo Cozzensa da Silva[1]

Received: 1 April 2018 / Revised: 17 January 2019 / Accepted: 21 January 2019 / Published online: 13 February 2019

Abstract

Objectives To identify and evaluate the effect of interventions that used cell phones as a means to promote physical activity (PA).

Methods The databases searched were MedLine/PubMed, Scopus, SPORTDiscus, PsycINFO, Science Direct, Lilacs, and SciELO. After removing duplicates, applying exclusion criteria, and checking the reference lists, 45 studies were reviewed. The Downs and Black (D&B) scale measured methodological quality, and a random effect model was used to compute the meta-analysis of PA by the reported unit (minutes per day or steps per day), delivery agent (application (APP), SMS, or other), and PA measurement (questionnaire, accelerometer, pedometer).

Results Mobile phone-based PA interventions were efficient in increasing both minutes [10.49; CI (3.37–17.60); $p = 0.004$] and steps per day [735.17; CI (227.72–1242.61); $p = 0.005$] in adults when compared to baseline. Furthermore, APP-based interventions were able to increase the number of steps ($p = 0.04$) and minutes per day of PA ($p = 0.04$) in adults. Also, 85% of included manuscripts were classified as moderate- to high-quality articles.

Conclusions Mobile phone-based PA interventions, inclusive those delivery by APP, were effective to increase minutes and steps per day in adults.

Keywords Physical activity · Interventions · Mobile devices · Adults

Introduction

The high burden of physical inactivity has been the subject of several studies in the area of epidemiology (Kohl et al. 2012; Lee et al. 2012; Reis et al. 2016) and according to Sallis et al. (2016) is responsible for more than 5 million deaths per year in world. In this sense, combating physical inactivity (PI) has been one of the main objectives of health organizations (Bauman et al. 2013; Hallal et al. 2012; WHO 2010), mainly due to its association with chronic non-communicable diseases (CNCD), such as obesity, diabetes, cardiovascular diseases, depression, and others (Humphreys et al. 2014; Strohle 2009; Wicker et al. 2015). Another important point to highlight is the economic burden caused due to adopting an inactive lifestyle. Data released by Ding et al. (2016) estimate that PI cost about $53 billion to health systems worldwide in 2013, evidencing the need for more health promotion and prevention actions.

To improve health promotion effects, it is necessary to understand the reasons that lead to the adoption of inactive behavior. It is possible to highlight in this issue the increasing use of cell phones and smartphones, historically associated with PI and sedentary behavior (Kim et al. 2015; Rosenberg et al. 2010). Nevertheless, this type of device represents a useful tool for daily task practices and even for leisure and social interaction, making it essential for majority of the population. Pratt et al. (2012) indicated a high growth in access to mobile devices between 1997 and 2009 (from 0.01 to 4.3% of the population in low-income countries, from 0.21 to 23.8% in middle-income countries, and from 11.2 to 51.9% in high-income countries). In a study conducted in the USA, Lepp et al. (2013) verified the

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00038-019-01210-7) contains supplementary material, which is available to authorized users.

✉ Natan Feter
natanfeter@hotmail.com

[1] Federal University of Pelotas, Pelotas, Brazil

[2] University of Sydney, Sydney, Australia

total minutes spent using mobile devices in men (298.9 min/day) and women (313 min/day), which represents one-fifth of the 24 h a day.

As a result of this increase in mobile device usage, Roberts et al. (2014) suggested that structural features, including stylized ringtones, attractive graphics, and ease of online accessibility may induce or even enhance the use of mobile devices. In this way, the use of such gadgets can become an allied tool since greater access to this type of equipment in a large part of the population (Fukuoka et al. 2010; Roberts et al. 2014; Thorsteinsen et al. 2014) and the emergence of new applications for the monitoring of physical activity (PA) practice can be utilized beneficially.

Thus, Pratt et al. (2012) suggested that interventions based on the use of new information and communication technologies, especially mobile devices, have similar effects when compared to planned PA interventions. Also, this suggested intervention has lower costs, which represents greater ease of execution, especially in low- and middle-income countries. Thus, the objective of the present study is to identify the effect of smartphone-based interventions in PA promotion.

Methods

The PRISMA statement for reporting systematic reviews was used to ensure that the methodology and results were conducted and reported systematically (Moher et al. 2009; electronic supplementary material).

Literature search

This systematic review sought intervention studies that aimed to promote a physically active lifestyle. The search was completed in October 2018 and included the following databases: MedLine/PubMed (English), Scopus (English), SPORTDiscus (English), PsycINFO (English), Lilacs (English and Portuguese), and SciELO (Portuguese). The search in these databases included the keywords related to physical activity (e.g., physical exercise, physical activity, motor activity) and to cell phone and mobile devices (e.g., smartphone, mobile devices, motion sensor, cell phone, app, application, mobile phone). In databases where the main language was Portuguese, the correct equivalent in that language for each keyword was used. Moreover, there were no language and time limitations. All search strategies are available as a supplemental file.

All articles were included in this study and exported to EndNote reference management software (×7 version), and duplicates were excluded. Initially, two independent reviewers (NF and TSS) checked all titles and abstracts identified in the electronic databases to include eligible articles for the full-text analysis. Moreover, both reviewers checked the reference lists of published systematic reviews and meta-analyses about smartphone and PA promotion available on MedLine to identify additional articles. Both reviewers then reviewed the potential eligible articles for inclusion. In the case of disagreement between the first two reviewers, a third independent reviewer (ELC) helped to resolve the issue by consensus. Figure 1 presents the PRISMA flow diagram of this methodology.

Eligibility criteria

The following eligibility criteria, according to the PICOS (Population, Intervention, Comparator, Outcomes, and Study design) question, were considered for inclusion of articles in this systematic review.

Population

The review included adults (> 18 years) with no restriction based on physical or cognitive condition. Studies including individuals with risk factors (e.g., high cholesterol, overweight, obesity, diabetes, etc.) or known cardiometabolic diseases (e.g., Type 2 diabetes, coronary heart disease, heart failure, etc.) were eligible for inclusion.

Intervention

The review included studies with physical activity interventions (RCT or not) that used either SMS or an APP to promote PA. Also, based on concepts of Caspersen et al. (1985), interventions composed by any form of physical exercise were not considered. There was no restriction on intervention duration.

Comparator

Control groups and baseline measurements were comparators for intervention effect values. Control groups that included any type of physical exercise interventions were not included.

Outcomes

Physical activity level measured by questionnaire, pedometer, or accelerometer was the primary outcome. To be included in the meta-analysis, the outcome should be reported as steps per day or minutes per day. Studies that reported PA in other forms (e.g., days per week, MET per minute per week) were included only in the systematic review.

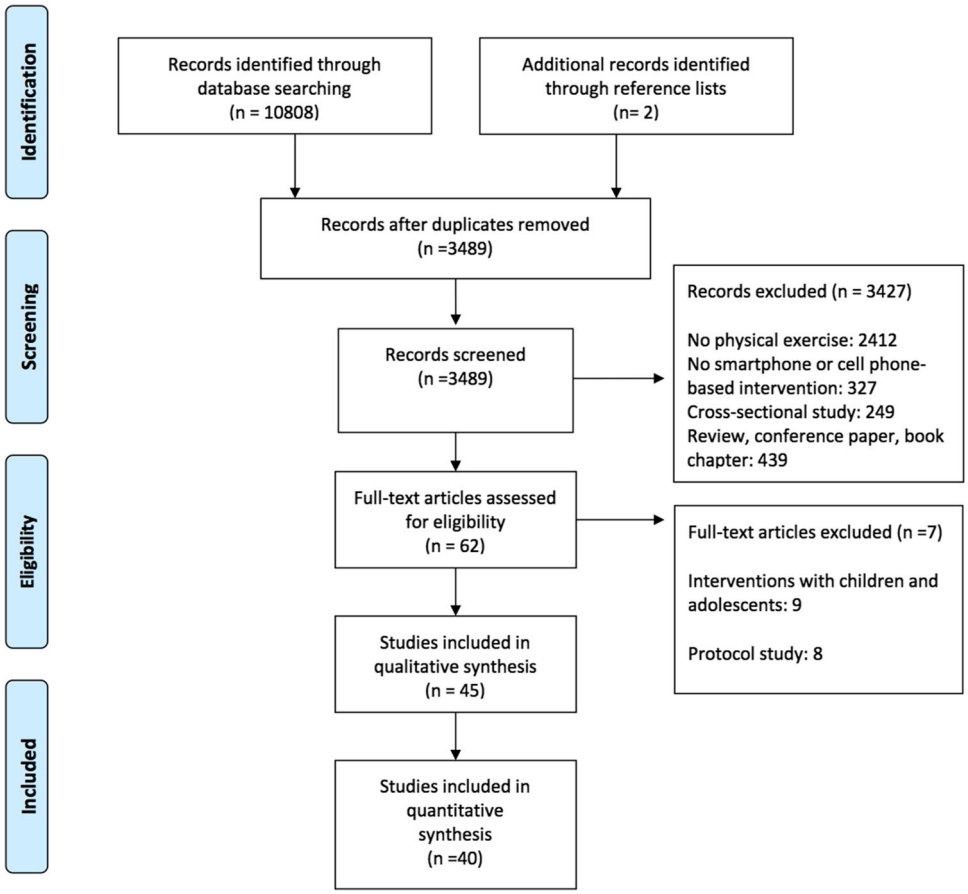

Fig. 1 Flow diagram of articles selection stages

Study design

Experimental studies published in any language were considered.

Quality of evidence

After selecting all articles, the Downs and Black (1998) and Centre for Evidence-Based Medicine's level of evidence (Howick et al. 2011) scale was used to evaluate the quality of articles. The Downs and Black scale was designed to analyze randomized and non-randomized clinical trials and consists of 27 questions about writing, external and internal validity and statistical power of the manuscripts. Each domain has its own maximum score, and the sum of them generates a total score ranging from 0 to 32 points.

According to the literature (Fukuoka et al. 2010; Roberts et al. 2014), studies that reach scores above 50% of the maximum value have moderate methodological quality. Likewise, Willems et al. (2015) defined studies that scored equal to or greater than 19 points, reflecting two-thirds of the maximum achievable score, should be considered with high methodological quality.

Data extraction

Two researchers (NF and TSS) independently conducted all data extraction using standardized spreadsheets developed by the research group and previously tested at the beginning of the review, and when there was disagreement between them, a third researcher (ELC) was consulted to reach a consensus. The sample size was obtained from each study as well as means and ranges for population age and follow-up time. Regarding intervention characteristics, data were extracted from delivery agent, PA measurement strategy, number and types of groups, and the key findings. For quantitative analysis, the amount of physical activity measured in steps or minutes per day (mean and standard deviation) was extracted from each group.

Statistical analyses

Data were reported as mean difference (MD) and 95% confidence interval (CI). The use of mean differences ("difference in means") was based on the adequateness of this standard statistic when outcome measurements in all studies are made on the same scale. However, we reported subgroup analysis as standardized mean differences (SMD)

because studies measured the same outcome (physical activity), but across a variety of scales (e.g., minutes per week, steps per day, MET min per week). When a study had more than one intervention, the interventions were included in the analysis individually.

The Higgins I^2 statistic was calculated to estimate the statistical heterogeneity between the studies. Values above 75% and $p < 0.10$ were used to indicate high heterogeneity (Higgins et al. 2003). A random-effects model was conducted in the presence of high or low statistical heterogeneity for the between-interventions meta-analyses. The meta-analysis was conducted using Review Manager software (RevMan 5.3, Nordic Cochrane, Denmark). For all analyses, the significance level was set at $p < 0.05$. Furthermore, a subgroup analyses based on delivery methods and PA measurement strategies were conducted to identify their effect on PA promotion (DerSimonian and Laird 1986). Publication bias was assessed using Egger's test (Egger et al. 1997).

Results

Systematic review

We found 10,808 manuscripts in the databases, which were added to the library. After applying inclusion and exclusion criteria in titles and abstracts, 62 original articles were retained for the next step: reading the full text.

Characteristics of the intervention studies are included in the review as available Table 1 and electronic supplementary material. Among the 45 studies included in the systematic review, samples were composed of an median of 77 individuals, ranging from 20 (Duscha et al. 2018) to 32,229 (Mitchell et al. 2018) and with a mean age of 40.7 ± 14.4 years. The mean interventions' duration was 12.9 (± 11.4) weeks, and the most used delivery method was APP (69%).

Seventeen interventions were performed with healthy individuals (OHurling et al. 2007; Fjeldsoe et al. 2009; Cheung et al. 2012; Kirwan et al. 2012; Suggs et al. 2013; King et al. 2013; Maher et al. 2015; Thorsteinsen et al. 2014; Hebden et al. 2014; Blake et al. 2015; Naimark et al. 2015; Partridge et al. 2015; Rabbi et al. 2015; Cowdery et al. 2015; Rospo et al. 2016; Choi et al. 2016; Harries et al. 2016), and ten with participants diagnosed with any non-communicable chronic disease (Nguyen et al. 2009; Bond and Thomas 2015; Cadmus-Bertram et al. 2015; Hartman et al. 2016; Paul et al. 2016; Wang et al. 2016; Bender et al. 2017; Duscha et al. 2018; Ormel et al. 2018; Park et al. 2018).

Evaluation of manuscript quality

Concerning the qualitative evaluation of the studies added to the systematic review, the average score obtained by the Downs and Black scale was 23 ± 4 points (electronic supplementary material). The maximum score reached among the evaluated articles was 29 points (Glynn et al. 2014; Walsh et al. 2016). Also, 35 studies were added to this review and meta-analysis scored at least 19 points, presenting moderate or even high methodological quality. In addition, among the analyzed articles, 87% (41) were characterized as randomized clinical trials. Among these, the mean quality score was 24 ± 4 points, confirming the methodological quality expected in this type of study.

Any evidence of publication bias was not observed when APP-based ($p = 0.426$) and SMS-based ($p = 0.201$) interventions were analyzed. Indeed, when the studies were analyzed by outcome (minutes per week: $p = 0.051$; steps per day: $p = 0.257$), they also did not present statistically significant evidence of publication bias.

Meta-analysis

Among the 45 studies included in the systematic review, 89% (40) were included in quantitative analysis. From these, 54% (24) used a control group and 29% (13) utilized SMS as a form of intervention delivery.

Initially, the results presented that when compared to a control group, the smartphone-based interventions increase on average 12.02 min per day of PA in adults [CI (5.45–18.60); $p = < 0.001$; $I^2 = 72\%$; Fig. 2a]. Regarding PA reported in steps per day, smartphone-based interventions lead to an average increase of 1999.59 steps per day [CI (1036.49–2962.69); $p < 0.001$; $I^2 = 88\%$; Fig. 2b]. Also, individuals in intervention groups had an average of 275.02 MET min per week higher than control groups [CI (48.90–501.14); $p = 0.02$; $I^2 = 84\%$; Fig. 2c].

Subgroup analysis was done based on delivery agent (i.e., SMS, APP) and physical activity measurement (i.e., questionnaire, pedometer, accelerometer) (Fig. 3). The analysis showed that studies based on APP use had a statistically positive effect on steps per day [SMD 0.18; CI (0.01–0.35); $p = 0.04$; $I^2 = 82\%$] and minutes per day [SMD 0.31; CI (0.01–0.60); $p = 0.04$; $I^2 = 96\%$]. Nevertheless, MET min per week [SMD 0.07; CI (− 0.59 to 0.74); $p = 0.83$; $I^2 = 96\%$] was significantly improved by interventions. Also, interventions that did not use any other form of feedback instead of APP achieved significant improvement in PA level in adults [SMD 0.36; CI (0.21–0.52); $p < 0.001$; $I^2 = 86\%$; electronic supplementary material].

Table 1 Characteristics of the intervention studies included in the review

Author	Country	Sample/age (mean ± SD)	Physical activity measurement	Study duration/delivery agent	Conclusions
Abbaspoor et al. (2018)	Iran	100/28.4 ± 3.6	Questionnaire	10 weeks/SMS	Intervention increased PA
Bender et al. (2017)	USA	45/58.0 ± 10.0	Accelerometer	3 months/APP	Intervention increased PA
Blake et al. (2015)	UK	296/38.8 ± 10.2	Questionnaire	12 weeks/SMS + e-mail	Intervention increased PA
Bond and Thomas (2015)	USA	30/47.5 ± 13.5	Accelerometer-like motion sensor	3 weeks/APP	Intervention increased PA
Cadmus-Bertram et al. (2015)	USA	51/60 ± 7.1	Accelerometer	16 weeks/Fitbit + calls	Intervention increased PA
Cheung et al. (2012)	China	88/35.4 ± 11.6	Pedometer	12 weeks/SMS + pedometer	Intervention increased PA
Choi et al. (2016)	USA	35/33.7 ± 2.6	Accelerometer; questionnaire	12 weeks/APP + SMS	Intervention not increased PA
Cowdery et al. (2015)	USA	40/median:32.0	Accelerometer; questionnaire	12 weeks/APP + e-mail	Intervention not increased PA
Dodd et al. (2018)	Australia	162/30.9 ± 5.7	Questionnaire	36 weeks/APP	Intervention not increased PA
Duscha et al. (2018)	USA	20/69.4 ± 8.4	Pedometer	12 week/APP + e-mail + calls	Intervention not increased PA
Fanning et al. (2012)	USA	116/41.4 ± 7.6	Accelerometer	12 week/APP	Intervention increased PA
Fjeldsoe et al. (2009)	Australia	185/28 ± 6	Questionnaire	12 weeks/SMS + calls	Intervention increased PA
Fukuoka et al. (2010)	USA	41/48	Pedometer	3 weeks/APP + Pedometer	Intervention increased PA
Garcia-Ortiz et al. (2018)	Spain	833/51.9 ± 12.1	Accelerometer; Questionnaire	12 months/APP	Intervention not increased PA
Gilson et al. (2016)	Australia	44/51.9 ± 12.1	Activity tracker	20 weeks/APP	Intervention not increased PA
Glynn et al. (2014)	Ireland	139/44.1 ± 11.5	Pedometer	8 weeks/APP	Intervention increased PA
Harries et al. (2016)	USA	152/18–40	Questionnaire	6 week/APP	Intervention increased PA
Hartman et al. (2016)	USA	54/59.5 ± 5.6	Accelerometer	6 weeks/APP + Calls	Intervention increased PA
Hebden et al. (2014)	Australia	51/22.9 ± 4.6	Questionnaire; accelerometer	12 weeks/APP + SMS + E-mail	Intervention increased PA
Hurling et al. (2007)	UK	77/40.4 ± 7.6	Questionnaire; accelerometer	9 weeks/APP + e-mail	Intervention increased PA
King et al. (2016)	USA	95/60.0 ± 9.3	Accelerometer; questionnaire	8 weeks/APP	Intervention increased PA
Kirwan et al. (2012)	Australia	200/39.7 ± 12.5	Pedometer	3 months/APP	Intervention not increased PA
Maher et al. (2015)	Australia	110/35.6 ± 12.4	Pedometer; Questionnaire	8 weeks/APP + e-mail	Intervention increased PA
Mitchell et al. (2018)	Canada	32,229/ 33.7 ± 11.6	Built-in smartphone accelerometer	12 weeks/APP	Intervention increased PA
Naimark et al. (2015)	Israel	85/47.9 ± 12.3	Questionnaire	14 weeks/APP	Intervention increased PA
Nguyen et al. (2009)	USA	43/68 ± 11	Accelerometer	6 weeks/SMS + calls	Intervention increased PA
Ormel et al. (2018)	Netherlands	32/33.6 ± 11.2	Questionnaire	12 weeks/APP	Intervention increased PA

Table 1 (continued)

Author	Country	Sample/age (mean ± SD)	Physical activity measurement	Study duration/delivery agent	Conclusions
Park et al. (2018)	South Korea	356/50.4 ± 9.5	Questionnaire	12 week/APP	Intervention increased PA
Partridge et al. (2015)	Australia	250/27.7 ± 4.9	Questionnaire	12 week/APP + SMS + e-mail + calls	Intervention increased PA
Paul et al. (2016)	UK	23/56.0 ± 10.0	Accelerometer	6 weeks/APP	Intervention increased PA
Rabbi et al. (2015)	USA	17/28.3 ± 6.9	Daily diary	3 weeks/APP	Intervention not increased PA
Recio-Rodriguez et al. (2016)	Spain	833/51.9 ± 12.1	Accelerometer; questionnaire	3 months/APP	Intervention increased PA
Rospo et al. (2016)	USA	33/43.3	Pedometer	2 weeks/APP	Intervention increased PA
Sharma et al. (2017)	India	400/18–64	Questionnaire	12 months/SMS + calls	Intervention increased PA
Stephens et al. (2017)	USA	62/median: 20	Questionnaire	3 months/APP + SMS	Intervention not increased PA
Stuckey et al. (2011)	Canada	26/56.6 ± 6.9	Pedometer	8 weeks/APP	Intervention increased PA
Suggs et al. (2013)	UK	158/39.5 ± 11.8	Questionnaire	12 weeks/SMS + e-mail	Intervention decreased PA
Thorsteinsen et al. (2014)	Norway	21/55.3 ± 11.2	Electronic form	12 weeks/SMS + *Web site*	Intervention not increased PA
van Drongelen et al. (2014)	Netherlands	502/40.9 ± 8.4	Questionnaire	6 months/APP	Intervention increased PA
Walsh et al. (2016)	Ireland	55/20.5 ± 2.1	App-in pedometer	5 weeks/APP	Intervention increased PA
Wang et al. (2016)	USA	67/48.2 ± 11.7	Accelerometer	6 weeks/SMS + Fitbit	Intervention increased PA

Studies that used SMS service in direct communication with the sample did achieve a significant increase at PA informed in steps per day [SMD 0.34; CI (0.02–0.66); $p = 0.04$; $I^2 = 8\%$]. On the other hand, when the main outcome was reported in minutes per day, SMS-based interventions were not effective in promoting PA [SMD 0.42; CI (− 0.07 to 0.90); $p = 0.09$; $I^2 = 80\%$]. There were insufficient data available to perform meta-analysis with studies that used both SMS and APP as delivery agents.

Furthermore, studies that measured PA using questionnaires [SMD 0.47; CI (0.06–0.87); $p = 0.02$; $I^2 = 78\%$; minutes per day], pedometers [SMD 0.36; CI (0.18–0.54); $p < 0.001$; $I^2 = 0\%$; steps per day] and accelerometer [SMD 0.28; CI (0.01–0.55); $p = 0.04$; $I^2 = 87\%$; minutes per day] achieved statistical significance in relation to the program effect. However, interventions that measured PA by accelerometers did not significantly increase steps per day [0.12; CI (− 0.09 to 0.32); $p = 0.27$; $I^2 = 86\%$] in their sample (Fig. 4).

Discussion

Main findings

The main findings observed from this meta-analysis were that smartphone-based interventions focused on PA promotion are able to increase either minutes or steps per day in adults. Therefore, these results allow a preliminary view on the positive impact of these interventions, and considering the current scenario of physical inactivity as evidenced by Andersen et al. (2016), the study and discussion of this type of action become essential for a better improvement of quality of interventions in different cultural and economic contexts.

Possible explanations

Previously, Schoeppe et al. (2016) performed a systematic review on efficacy of interventions that use apps to improve diet, physical activity, and sedentary behavior. The authors highlighted the need for studies comparing the

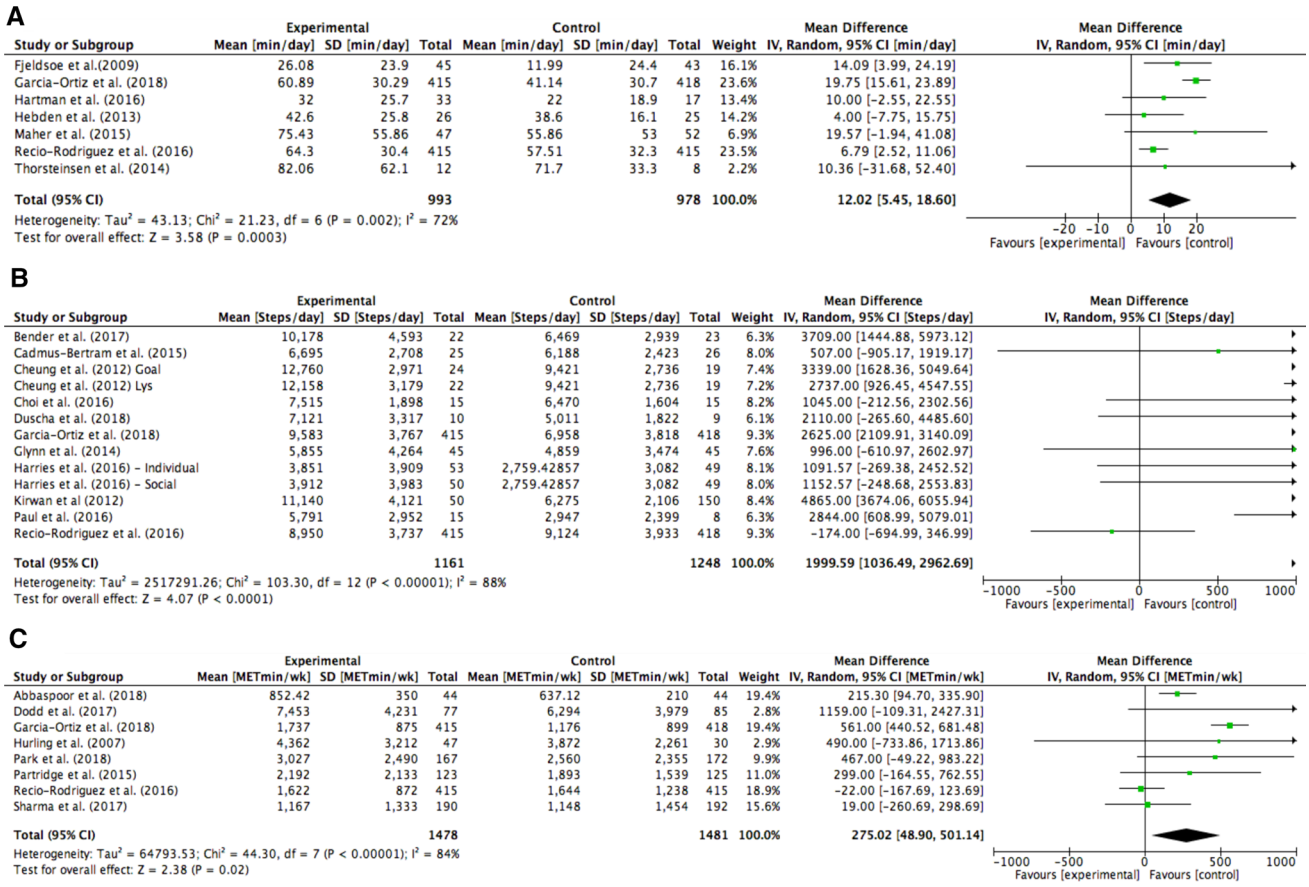

Fig. 2 Effect of smartphone-based interventions to promote physical activity in adults (age > 18 years). Values are expressed in minutes per week (**a**), steps per day (**b**), and metabolic equivalent of task per minute per week (**c**) compared to control group

efficacy of APP-only-based intervention with multi-component interventions that use apps in combination with other intervention strategies (e.g., calls, SMS). Here, we exposed that interventions using only an APP as delivery agent had a significant benefit on PA promotion; however, interventions that used APP plus calls, e-mails, or both did not achieve the same improvement.

In this way, the several studies included in this review sought to discuss the role that cell phones can play in daily routines, as well as to demonstrate their effects in regular PA practice in different populations. Also in this sense, Bort-Roig et al. (2014) sought to assess the feasibility of measuring PA through smartphones and discuss their influence in practice. The authors considered the use of this type of tool as a new field to be studied and also demonstrated a wide range of innovative intervention strategies to be used, emphasizing the potential that this technology has for promoting PA. One strength of mobile device use is the easy access to a variety of types of APP, with diverse functions.

The findings related in this review allow us to conclude that interventions using new communication technologies may be useful tools when it comes to promoting PA practice. As stated by Harries et al. (2016), some minimal features made APP-based interventions effective in increasing PA level in adults: APP running automatically, low financial investment (no additional devices are needed), and promotion of engagement through simple curiosity. Being on continuously, APP measures walking inherent in PA practice that is not usually considered as 'exercise.' Besser and Dannenberg (2005) explained this curiosity provides encouragement to those who were not previously aware that day-to-day walking could be seen in this way.

When the studies that identified the effect of smartphone use as a tool for PA promotion (measured in minutes per day) were analyzed, this meta-analysis evidenced a positive effect [SMD: 0.599; CI (0.363–0.834); $p < 0.001$; $I^2 = 23.0\%$]. Similar results can be found in the study conducted in the UK by Hurling et al. (2007), where authors observed an increase in 138 min per week in the PA level ($p < 0.001$) after 9 weeks of intervention based on PA practice through contact via an APP installed on participants' smartphones. Similarly, Bond and Thomas (2015) in the USA found an increase in the level of light PA ($p < 0.05$) and moderate-to-vigorous PA ($p < 0.01$)

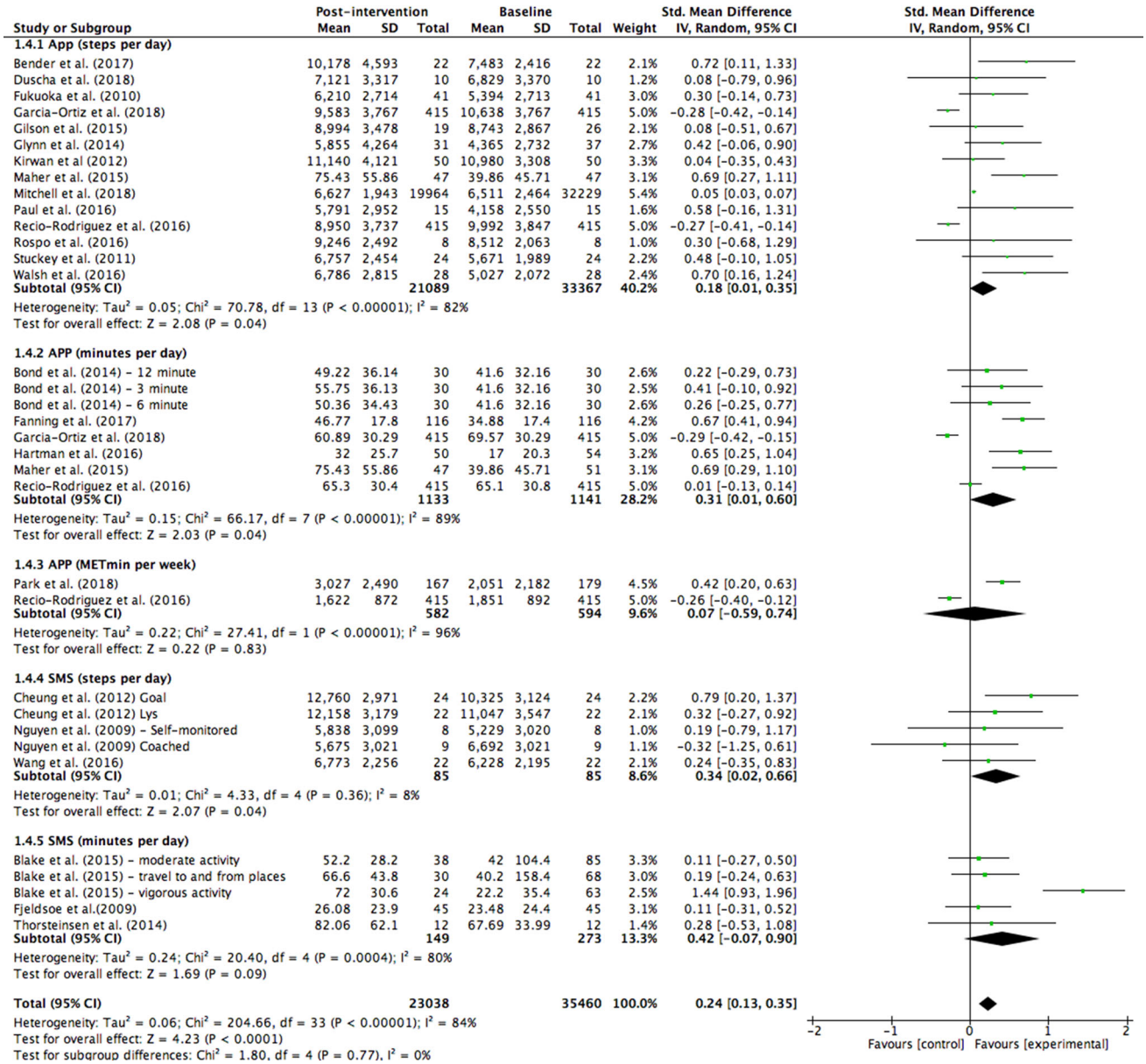

Fig. 3 Subgroup analysis based on delivery agents. Effect of smartphone-based interventions to promote physical activity in adults (age > 18 years)

compared to baseline values. In another case, a 12-week intervention in Norway by Thorsteinsen et al. (2014) used cell phones and SMS to assess the level of PA in healthy adults residing in that country and identified an increase in minutes of PA from week 1 (473.8) to the last week of the intervention (574.4).

When analyzing the data on steps per day, it was observed that the programs produced a positive effect in increasing PA among samples [0.238; CI (0.050–0.425); $p = 0.013$; $I^2 = 0.0\%$]. These results are in line with those observed by Fukuoka et al. (2010) who found that incentive messages delivered by an APP increased the participants' number of steps by 20%. At the end of the intervention period, it was possible to verify an increase of approximately 800 steps per day ($p < 0.001$). Likewise, Wang et al. (2016) observed an augment of approximately 550 steps in subjects who made use of an application that sent key messages of support and incentive to PA practice. On the other hand, the study by Cheung et al. (2012) presented a rise of 1066 steps per day on average in individuals participating in a Hong Kong intervention that was basically based on sending SMS to support the practice of PA.

The findings in this review allow us to conclude that interventions using new communication technologies may be useful tools when it comes to promoting PA practice. Nonetheless, the effects observed so far still require more

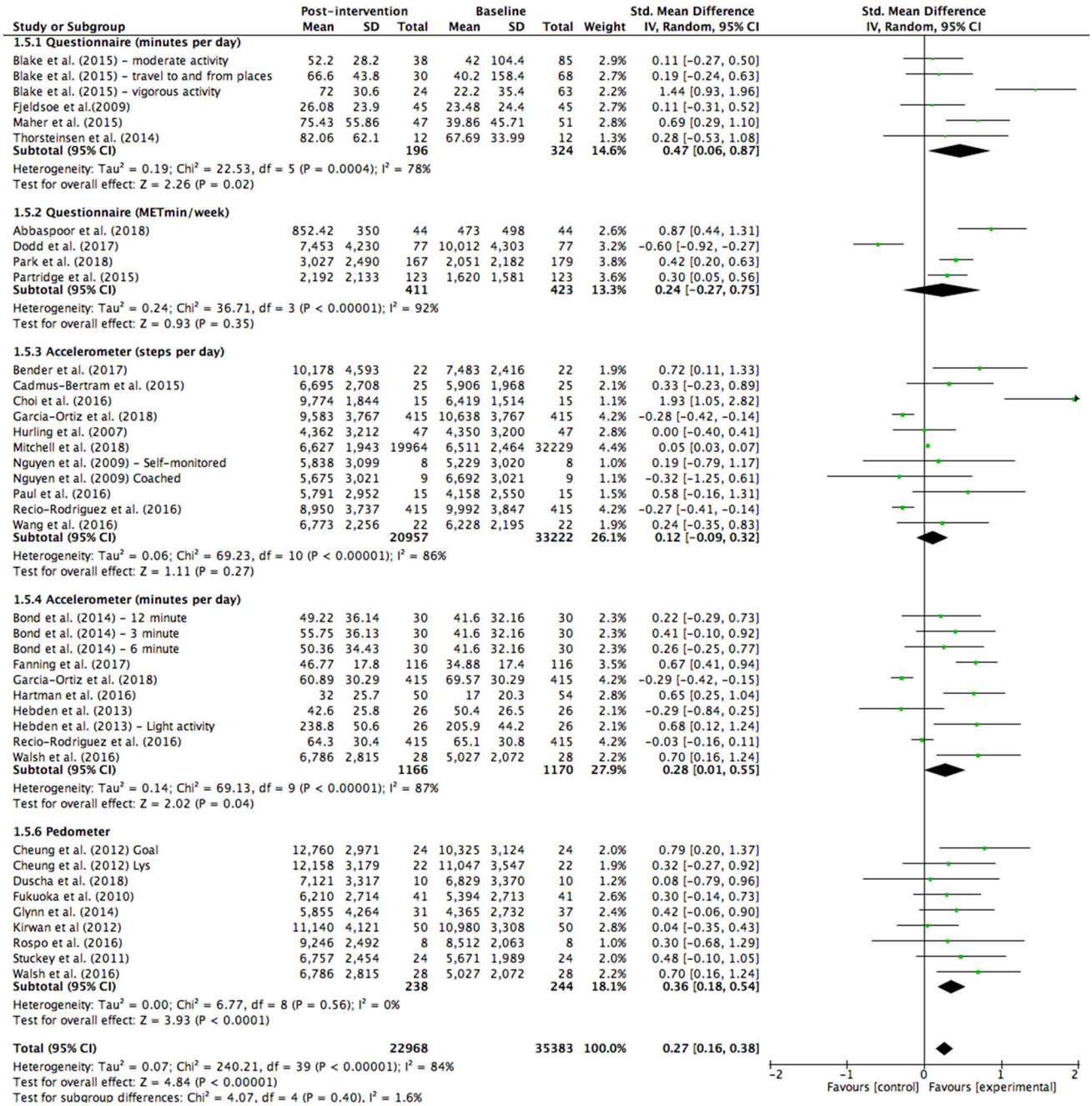

Fig. 4 Subgroup analysis based on instruments to measure physical activity. Effect of smartphone-based interventions to promote physical activity in adults (age > 18 years)

attention, mainly due to the fact that there is no such study in developing countries.

Limitations

The present findings may have been influenced by some limitations. First, only 27.7% of analyzed studies measured PA using accelerometers, which is accepted as an objective measurement. Nevertheless, interventions that adopted this device to measure PA level also achieved statistical significance on PA promotion. Indeed, is it important to mention that when PA was reported in minutes per day, the interventions could lead to significant improvement in PA level, regardless of how it was measured (e.g., questionnaire, accelerometer).

Another point to be highlighted is the high heterogeneity among studies ($I^2 \geq 80\%$). One possible explanation is the large sample size range at analyzed studies (20–32,229

individuals) and different periods of intervention (2–54 weeks). These factors, allied with the sampling process of the population to be analyzed, could exert an important influence on the final effect of the interventions.

Regarding studies' quality, only one article (Cadmus-Bertram et al. (2015) that scored less than 19 points at Downs and Black scale was added in meta-analysis. In order to check its effect on our results, a secondary analysis without data from that intervention was conducted. The analysis reported it was significant change in overall effect of smartphone-based interventions on PA promotion in adults [2131.15; CI (1106.46–3155.83); $p < 0.001$; $I^2 = 89\%$; steps per day].

Also, our results are based on data available from different continents: Americas, Asia, Oceania, and Europe. When subgroup analysis was conducted based on those continents, we observed that there was a significant effect in all those regions (electronic supplementary material). It is important to mention there was no study conducted in Africa added in this review. Hallal et al. (2012) stated that 57.7(56.6–57.4)% of adults from this region reported walking for at least 10 min consecutively on 5 or more days per week. This prevalence is significantly lower compared to other regions, such as Americas, Eastern Mediterranean, Europe, and western Pacific. Then, low-cost interventions aiming to promote walking in this region should be strongly considered, especially when analyzing its cost-effectiveness.

In Ghana, Sarfo and colleagues did a two-arm cluster pilot randomized controlled trial of 60 stroke survivors to assess the feasibility and preliminary efficacy of using a Bluetooth device with a smartphone for monitoring and reporting blood pressure measurements and medication intake for 3 months (Sarfo et al. 2018). Control of systolic blood pressure (< 140 mm Hg) at 3 months was 66.7% in the intervention group and 46.7% in the control group ($p = 0.12$). The medication possession ratio, a measure of adherence to medications, was larger in the intervention group than in the control group.

On the other hand, the ease of carrying out this type of intervention is worth mentioning, given the low cost required for its implementation. As mentioned earlier, a large part of the world's population has access to cell phone devices, including smartphones, thus becoming viable in both high-income and developing countries. Nevertheless, 94% of studies included in the present review were conducted in developed countries. This reports the necessity already presented by Hallal et al. (2012) for a greater debate and elaboration of projects for this public health problem in the population of these countries. For Heath et al. (2012), since there are still disparities in the level of PA in subgroups of populations, public health professionals need to tailor policy and environmental efforts and programs to promote opportunities for PA everywhere, with specific attention on initiatives in disadvantaged subgroups.

There is moderate- to high-quality evidence on literature that PA practice can be promoted through smartphone-based interventions, especially those using applications and SMS as delivery agents. Based on the results presented in this systematic review and meta-analysis and the widespread use of smartphones, mobiles, and wearable devices, public health professionals have to tailor policy and environmental efforts. This work is necessary in order to promote equal opportunities for PA practice, particularly in disadvantaged subgroups, and thereby reduce health inequality.

Compliance with ethical standards

Conflict of interest Authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

Abbaspoor Z, Amani A, Afshari P, Jafarirad S (2018) The effect of education through mobile phone short message service on promoting self-care in pre-diabetic pregnant women: a randomized controlled trial. J Telemed Telecare. https://doi.org/10.1177/1357633X18791419

Andersen LB, Mota J, Di Pietro L (2016) Update on the global pandemic of physical inactivity. Lancet 388:1255

Bauman AE, Murphy N, Matsudo V (2013) Is a population-level physical activity legacy of the London 2012 Olympics likely? J Phys Activity Health 10:1–3

Bender MS, Cooper BA, Park LG et al (2017) A feasible and efficacious mobile-phone based lifestyle intervention for Filipino Americans with type 2 diabetes: randomized controlled trial. JMIR Diabetes 2:2. https://doi.org/10.2196/diabetes.8156

Besser LM, Dannenberg AL (2005) Walking to public transit: steps to help meet physical activity recommendations. Am J Prev Med 29:273–280

Blake H, Suggs LS, Coman E, Aguirre L, Batt ME (2015) Active8! technology-based intervention to promote physical activity in hospital employees. Am J Health Promot AJHP. https://doi.org/10.4278/ajhp.140415-quan-143

Bond DS, Thomas JG (2015) Measurement and intervention on physical activity and sedentary behaviours in bariatric surgery patients: emphasis on mobile technology. Eur Eat Disord Rev 23:470–478. https://doi.org/10.1002/erv.2394

Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG (2014) Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med 44:671–686

Cadmus-Bertram LA, Marcus BH, Patterson RE, Parker BA, Morey BL (2015) Randomized trial of a fitbit-based physical activity intervention for women. Am J Prev Med 49:414–418. https://doi.org/10.1016/j.amepre.2015.01.020

Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100:126

Cheung PPY, Chen S, Wong EMY (2012) Using mobile phone messages in pedometer-based intervention for working adults in Hong Kong. Asian J Exerc Sports Sci 9:76–85

Choi JW, Lee J, Vittinghoff E, Fukuoka Y (2016) mHealth physical activity intervention: a randomized pilot study in physically inactive pregnant women. Matern Child Heal 20(5):1091–1101. https://doi.org/10.1007/s10995-015-1895-7

Cowdery J, Majeske P, Frank R, Brown D (2015) Exergame apps and physical activity: the results of the ZOMBIE trial. Am J Heal Educ. https://doi.org/10.1080/19325037.2015.1043063

DerSimonian R, Laird N (1986) Meta-analysis in clinical trials. Control Clin Trials 7:177–188

Ding D et al (2016) The economic burden of physical inactivity: a global analysis of major non-communicable diseases. Lancet 388:1311–1324

Dodd JM, Louise J, Cramp C et al (2018) Evaluation of a smartphone nutrition and physical activity application to provide lifestyle advice to pregnant women: the SNAPP randomized trial. Matern Child Nutr 14:e12502. https://doi.org/10.1111/mcn.12502

Downs SH, Black N (1998) The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health 52:377–384

Duscha BD, Piner LW, Patel MP et al (2018) Effects of a 12-week mHealth program on functional capacity and physical activity in patients with peripheral artery disease. Am J Cardiol 122(5):879–884

Egger M, Smith GD, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. BMJ 315:629–634

Fanning J, Mullen SP, McAuley E (2012) Increasing physical activity with mobile devices: a meta-analysis. J Med Internet Res 14:e161. https://doi.org/10.2196/jmir.2171

Fjeldsoe BS, Marshall AL, Miller YD (2009) Behavior change interventions delivered by mobile telephone short-message service. Am J Prev Med 36:165–173. https://doi.org/10.1016/j.amepre.2008.09.040

Fukuoka Y, Vittinghoff E, Jong SS, Haskell W (2010) Innovation to motivation—pilot study of a mobile phone intervention to increase physical activity among sedentary women. Prev Med 51:287–289. https://doi.org/10.1016/j.ypmed.2010.06.006

Garcia-Ortiz L, Recio-Rodriguez JI, Agudo-Conde C et al (2018) Long-term effectiveness of a smartphone app for improving healthy lifestyles in general population in primary care: randomized controlled trial (evident II study). J Med Internet Res 6:4. https://doi.org/10.2196/mhealth.9218

Gilson ND, Pavey TG, Vandelanotte C et al (2016) Chronic disease risks and use of a smartphone application during a physical activity and dietary intervention in Australian truck drivers. Aust N Z J Public Health 40:91–93. https://doi.org/10.1111/1753-6405.12501

Glynn LG, Hayes PS, Casey M et al (2014) Effectiveness of a smartphone application to promote physical activity in primary care: the SMART MOVE randomised controlled trial. Br J Gen Pr 64(624):e384–e391. https://doi.org/10.3399/bjgp14X680461

Hallal PC, Bauman AE, Heath GW, Kohl HW 3rd, Lee IM, Pratt M (2012) Physical activity: more of the same is not enough. Lancet 380:190–191. https://doi.org/10.1016/s0140-6736(12)61027-7

Harries T, Eslambolchilar P, Rettie R et al (2016) Effectiveness of a smartphone app in increasing physical activity amongst male adults: a randomised controlled trial. BMC Public Health 16:925. https://doi.org/10.1186/s12889-016-3593-9

Hartman SJ, Nelson SH, Cadmus-Bertram LA, Patterson RE, Parker BA, Pierce JP (2016) Technology- and phone-based weight loss intervention: pilot RCT in women at elevated breast cancer risk. Am J Prev Med. https://doi.org/10.1016/j.amepre.2016.06.024

Heath GW et al (2012) Evidence-based intervention in physical activity: lessons from around the world. Lancet 380:272–281

Hebden L, Cook A, Ploeg HP et al (2014) A mobile health intervention for weight management among young adults: a pilot randomised controlled trial. J Hum Nutr Diet 27(4):322–32. https://doi.org/10.1111/jhn.12155

Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ Br Med J 327:557

Howick J et al (2011) The 2011 Oxford CEBM evidence levels of evidence (introductory document). Oxford Center for Evidence Based Medicine, Oxford

Humphreys BR, McLeod L, Ruseski JE (2014) Physical activity and health outcomes: evidence from Canada. Health Econ 23:33–54. https://doi.org/10.1002/hec.2900

Hurling R et al (2007) Using internet and mobile phone technology to deliver an automated physical activity program: randomized controlled trial. J Med Internet Res 9:e7. https://doi.org/10.2196/jmir.9.2.e7

Kim S-E, Kim J-W, Jee Y-S (2015) Relationship between smartphone addiction and physical activity in Chinese international students in Korea. J Behav Addict 4:200–205

King AC, Hekler EB, Grieco LA et al (2013) Harnessing different motivational frames via mobile phones to promote daily physical activity and reduce sedentary behavior in aging adults. PLoS One 8:e62613. https://doi.org/10.1371/journal.pone.0062613

King AC, Hekler EB, Grieco LA et al (2016) Effects of three motivationally targeted mobile device applications on initial physical activity and sedentary behavior change in midlife and older adults: a randomized trial. PLoS One 11:e0156370

Kirwan M, Duncan MJ, Vandelanotte C, Mummery WK (2012) Using smartphone technology to monitor physical activity in the 10,000 steps program: a matched case–control trial. J Med Internet Res 14:e55

Kohl HW 3rd et al (2012) The pandemic of physical inactivity: global action for public health. Lancet 380:294–305. https://doi.org/10.1016/S0140-6736(12)60898-8

Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, Lancet Physical Activity Series Working Group (2012) Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 380:219–229. https://doi.org/10.1016/S0140-6736(12)61031-9

Lepp A, Barkley JE, Sanders GJ, Rebold M, Gates P (2013) The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of College students. Int J Behav Nutr Phys Act 10:79. https://doi.org/10.1186/1479-5868-10-79

Maher C, Ferguson M, Vandelanotte C et al (2015) A web-based, social networking physical activity intervention for insufficiently active adults delivered via facebook app: randomised controlled trial. JMIR 17(7):e174. https://doi.org/10.2196/jmir.4086

Mitchell M, White L, Lau E et al (2018) Evaluating the carrot rewards app, a population-level incentive-based intervention promoting step counts across two Canadian provinces: quasi-experimental study. J Med Internet Res 6:e178. https://doi.org/10.2196/mhealth.9912

Moher D, Liberati A, Tetzlaff J, Altman DG, Group P (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 6:e1000097

Naimark JS, Madar Z, Shahar DR (2015) The impact of a web-based app (eBalance) in promoting healthy lifestyles: randomized controlled trial. J Med Internet Res 17:e56

Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO (2009) Pilot study of a cell phone-based exercise persistence intervention

post-rehabilitation for COPD. Int J Chronic Obstr Pulm Dis 4:301–313
Ormel HL, van der Schoot GGF, Westerink N-DL et al (2018) Self-monitoring physical activity with a smartphone application in cancer patients: a randomized feasibility study (SMART-trial). Support Care Cancer. https://doi.org/10.1007/s00520-018-4263-5
Park S-W, Lee I, Kim JI et al (2018) Factors associated with physical activity of breast cancer patients participating in exercise intervention. Support Care Cancer. https://doi.org/10.1007/s00520-018-4427-3
Partridge SR, McGeechan K, Hebden L et al (2015) Effectiveness of a mHealth lifestyle program with telephone support (TXT2BFiT) to prevent unhealthy weight gain in young adults: randomized controlled trial. JMIR Mhealth Uhealth 3(2):e66. https://doi.org/10.2196/mhealth.4530
Paul L, Wyke S, Brewster S et al (2016) Increasing physical activity in stroke survivors using STARFISH, an interactive mobile phone application: a pilot study. Top Stroke Rehabilit 23:170–177. https://doi.org/10.1080/10749357.2015.1122266
Pratt M, Sarmiento OL, Montes F, Ogilvie D, Marcus BH, Perez LG, Brownson RC (2012) The implications of megatrends in information and communication technology and transportation for changes in global physical activity. Lancet 380:282–293. https://doi.org/10.1016/S0140-6736(12)60736-3
Rabbi M, Pfammatter A, Zhang M et al (2015) Automated personalized feedback for physical activity and dietary behavior change with mobile phones: a randomized controlled trial on adults. J Med Internet Res. https://doi.org/10.2196/mhealth.4160
Recio-Rodriguez JI, Agudo-Conde C, Martin-Cantera C et al (2016) Short-term effectiveness of a mobile phone app for increasing physical activity and adherence to the Mediterranean diet in primary care: a randomized controlled trial (EVIDENT II study). J Med Internet Res. https://doi.org/10.2196/jmir.6814
Reis RS, Salvo D, Ogilvie D, Lambert EV, Goenka S, Brownson RC (2016) Scaling up physical activity interventions worldwide: stepping up to larger and smarter approaches to get people moving. Lancet 388:1337–1348. https://doi.org/10.1016/s0140-6736(16)30728-0
Roberts J, Yaya L, Manolis C (2014) The invisible addiction: cell-phone activities and addiction among male and female college students. J Behav Addict 3:254–265
Rosenberg DE, Norman GJ, Wagner N, Patrick K, Calfas KJ, Sallis JF (2010) Reliability and validity of the Sedentary Behavior Questionnaire (SBQ) for adults. J Phys Act Health 7:697–705
Rospo G, Valsecchi V, Bonomi AG, Thomassen IW, van Dantzig S, La Torre A, Sartor F (2016) Cardiorespiratory improvements achieved by American College of sports medicine's exercise prescription implemented on a mobile app. J Med Internet Res 4:e77
Sallis JF et al (2016) Progress in physical activity over the Olympic quadrennium. Lancet 388:1325–1336. https://doi.org/10.1016/S0140-6736(16)30581-5
Sarfo F, Treiber F, Gebregziabher M et al (2018) PINGS (Phone-based Intervention under Nurse Guidance after Stroke): interim results of a pilot randomized controlled trial. Stroke 49:236–239. https://doi.org/10.1161/STROKEAHA.117.019591
Schoeppe S, Alley S, Van Lippevelde W et al (2016) Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. Int J Behav Nutr Phys Act 13:127. https://doi.org/10.1186/s12966-016-0454-y
Sharma M, Banerjee B, Ingle GK, Garg S (2017) Effect of mHealth on modifying behavioural risk-factors of non-communicable diseases in an adult, rural population in Delhi, India. MHealth 3:42. https://doi.org/10.21037/mhealth.2017.08.03
Stephens JD, Yager AM, Allen J (2017) Smartphone technology and text messaging for weight loss in young adults: a randomized controlled trial. J Cardiovasc Nurs 32:39
Strohle A (2009) Physical activity, exercise, depression and anxiety disorders. J Neural Transm (Vienna) 116:777–784. https://doi.org/10.1007/s00702-008-0092-x
Stuckey M, Russell-Minda E, Read E et al (2011) Diabetes and technology for increased activity (DaTA) study: results of a remote monitoring intervention for prevention of metabolic syndrome. J Diabet Sci Technol. https://doi.org/10.1177/193229681100500416
Suggs S, Blake H, Bardus M, Lloyd S (2013) Effects of text messaging in addition to emails on physical activity among university and college employees in the UK. J Health Serv Res Policy 18:56–64
Thorsteinsen K, Vitterso J, Svendsen GB (2014) Increasing physical activity efficiently: an experimental pilot study of a website and mobile phone intervention. Int J Telemed Appl 2014:746232. https://doi.org/10.1155/2014/746232
van Drongelen A, Boot CRL, Hlobil H et al (2014) Evaluation of an mHealth intervention aiming to improve health-related behavior and sleep and reduce fatigue among airline pilots. Scand J Work Environ Health 40(6):557–568
Walsh JC, Corbett T, Hogan M et al (2016) An mHealth intervention using a smartphone app to increase walking behavior in young adults: a pilot study. J Med Internet Res. https://doi.org/10.2196/mhealth.5227
Wang JB et al (2016) Mobile and wearable device features that matter in promoting physical activity. J Mob Technol Med 5:2–11. https://doi.org/10.7309/jmtm.5.2.2
Wicker P, Coates D, Breuer C (2015) Physical activity and subjective well-being: the role of time. Eur J Public Health 25:864–868
Willems LM et al (2015) Effectiveness of nonpharmacologic interventions in systemic sclerosis: a systematic review. Arthritis Care Res 67:1426–1439
World Health Organization (2010) Global recommendations on physical activity for health. World Health Organization, Geneva