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Original

EFECTO DE UNA APLICACIÓN MÓVIL ADAPTADA A LA ACTIVIDAD FÍSICA EN ADULTOS SANOS: UNA PRUEBA ALEATORIA CONTROLADA

EFFECT OF A TAILORED MOBILE APP ON PHYSICAL ACTIVITY IN HEALTHY ADULTS: A RANDOMIZED CONTROLLED TRIAL

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RESUMEN

Objetivos: Aunque las aplicaciones de móviles son una herramienta prometedora que promueve cambios en la Actividad Física (AF) diaria, los últimos meta-análisis mostraron poca evidencia de su efectividad y advirtieron un número limitado de pruebas aleatorias controladas. Además, la investigación señaló que los usuarios de las aplicaciones tienden a abandonar prematuramente la intervención en el programa. El objetivo de esta prueba aleatoria controlada fue evaluar el efecto de las aplicaciones hechas a medida comparándolo con el feedback recibido del podómetro simple en AF (resultado inicial) y la permanencia. Material y métodos: Los participantes fueron 30 adultos (40% hombres y 60% mujeres), con edades entre los 35 y los 60 años (45,33 ± 7,6). Se asignaron aleatoriamente a un grupo de control (CG, N-15), o a un grupo experimental (EG, N-15). Los participantes del EG recibieron su programa de una aplicación vinculada a una plataforma web y se beneficiaron del feedback diario de recuento de pasos, con metas adaptadas individualmente por semana, consejos de comportamiento e información de salud. Los participantes del CG sólo se beneficiaron del recuento diario de pasos en sus teléfonos inteligentes. El número de pasos por semana evaluó la actividad física. Se recogieron al inicio, en la semana 6 y en la semana 12. El número de semanas que los participantes se conectaron con sus App móviles evaluaron la permanencia. Resultados: Las estadísticas no paramétricas indicaban que i) el EG mantenía su adhesión al programa (11.46±1.18 semanas) más que el CG (4.40±3.41 semanas) y ii) todos los EG (N=15) alcanzaron 52,373 pasos en la 6ª semana y 49,958 en la 12ª semana, mientras que solo el 47% de los CG (N=7) alcanzó 24,256 pasos en la 6ª semana del programa. Conclusiones: Los adultos se incorporan mejor a la actividad física diaria cuando se benefician de un programa personalizado dirigido de una App móvil.

Palabras clave: adherencia; ejercicio; teléfono móvil; motivación; actividad física.

ABSTRACT

Objectives: Although mobile App are a promising tool to promote changes in daily Physical Activity (PA), recent meta-analysis showed modest evidence for their effectiveness and noted the limited number of randomized controlled trials. Furthermore, research pointed that App users tend to give up prematurely program intervention. The aim of this randomized controlled trial was to evaluate the effects of a tailored App compared with a single pedometer feedback on PA (primary outcome), and on intervention adherence. Methods: The participants were 30 adults (40% men and 60% women), aged between 35 and 60 years (45.33 ± 7.6). They were randomly assigned to a control group (CG, N=15), or to an experimental group (EG, N=15). Participants from the EG received personalized information from a tailored mobile App. They benefited from daily walking step-count feedback, individually adapted goals per week, behavioral advices and health information. Participants from the CG only benefited of daily walking step-count from a native mobile App (a single pedometer). The number of walking steps per week assessed physical activity. Data were collected at baseline, week 6 and week 12. The number of weeks the participants connected their mobile App assessed intervention adherence. Results: Non-parametric statistics indicated significant effects: (i) the EG maintained their adherence to the program (11.46±1.18 weeks), more than the CG (4.40±3.41 weeks); (ii) the all EG (N=15) reached 52,373 steps in the 6th week and 49,958 steps in the 12th week, whereas only 47% of the CG (N=7) reached 24,256 steps in the 6th week of the program. Conclusions: Healthy adults adhere better to daily physical activity when they benefit from a personalized program a tailored App delivered.

Keywords: adherence; exercise; mobile-phone; motivation; physical activity.

INTRODUCTION

Because the sedentary lifestyle is well established since years in the all world (Guthold et al., 2018; Bull et al., 2020), it is a major challenge to take in charge healthy adult way of life and daily physical activity (PA). This study aimed at investigating the effect of a tailored-App on healthy adults' adherence to PA in France.

Systematic reviews (e.g., Juwono et al., 2020) reported that PA programs provided by physical educators are effective in increasing levels of PA if they are face-to-face and individually tailored considering personal factors. Nevertheless, face-to-face intervention requires time, transportation and other associated costs, so that group format interventions were most commonly provided. Furthermore, studies indicated that up to 70% of patients do not perform home PA as prescribed and that adherence tends to decline over time (Beinart et al., 2013). In general, the rate of participants completing exercise programs ranged from 65% to 86% (Picorelli et al., 2014). Because daily PA and long-term adherence to program is essential for maintaining health benefits, internet-based interventions and smartphone technologies have been considered to have potential to change daily behaviour towards PA (Bort-Roig et al., 2014; Coughlin et al., 2016; Fanning et al., 2012; Muntaner et al., 2016; Romeo et al., 2019; Stuckey et al., 2017; Sullivan & Lachman, 2017; Yerrakalva et al., 2019).

First, one of the major advances is that objective measures of real-life PA are now available through pedometers embedded in smartphone technology whereas previous studies on regular PA were based on self-declared PA (Muntaner et al., 2016). Nevertheless, in most of studies daily step counts feedback from a pedometer was not enough to encourage adults to substantially increase their PA (Fanning et al., 2012). Mobile Apps have been designed to complement feedback from pedometers, and to monitor and sustain daily PA (e.g., Kim & Glanz, 2013; Kinnafick et al., 2016). The most useful strategies to encourage PA improvement are goal setting, feedback, self-monitoring and social support (Bort-Roig et al., 2014; Antezana et al., 2020). Feedback consisted of displaying quantified data including distance travelled, steps taken, and calories consumed. Nevertheless, developers may not understand motivational theory or behavioural theory, which hinders the development of effective Apps (Antezana et al., 2020).

Second, although scientists argued that a PA program should be theoretically founded (King et al., 2013; Kinnafick et al., 2016), very few App used a theoretical underpinning (Bort-Roig et al., 2014; Stuckey et al., 2017). For an example, in Kinnafik's study, the design was referred to the self-determination theory perspective: need supportive SMS or neutral SMS were sent to support PA. Both, the control and the experimental groups reported increases in intrinsic motivation from pre- to post-intervention, but the moderate PA intensity was greater in the group benefited from theoretically founded need supportive SMS. To investigate the underpinned factors of PA adherence, a cross-sectional observational study (Van Koppen et al., 2016) demonstrated that factors negatively influencing adherence appeared to be related to low self-efficacy and unbeneficial illness beliefs. Thus, people adherence to regular PA should benefit from App if its design considers theoretical factors such as self-perception and knowledge about PA and health.

Third, despite the vast amount of research published in the field of PA interventions over the past decades, only few studies assessed effect of mobile App on PA in a randomized control trial. The largest systematic review (Bort-Roig et al., 2014) discussed 26 articles on smartphone applications aiming at promoting PA since 2007; 17 of them implemented and evaluated an intervention that used native mobile features, and/or an external device linked to an App. Nevertheless, only five articles used steps counts as outcome measure to assess PA intervention effects, and only four reported increases (800-1104 steps a day) between pre- and post-test. Furthermore, a very recent randomized controlled trial reported a non-significant reduction after 12 weeks of App intervention, and no significant difference between the groups was observed (Bergling et al., 2020). Finally, despite fitness technology seems to have the potential to significantly impact PA (Sullivan & Lachman, 2017), recent meta-analysis provides modest evidence supporting the effectiveness of smartphone apps to increase physical activity (Romeo et al., 2019).

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Overall, previous studies on the effects of mobile App on PA are not consistent (Direito et al., 2015; Stuckey et al., 2017; Romeo et al., 2019; Yerrakalva et al., 2019). Because the app was not theoretically founded, and/or the program was not personalized, or/and the study design without control group was not convincing (Bort-Roig et al., 2014; Romeo et al., 2019), more studies are needed for more conclusive data. The aim of the current randomized controlled trial was to assess the effect of a tailored and theoretically founded mobile App compared to a single pedometer feedback on PA and intervention adherence. The App design was based on the self-determination theory (Deci & Ryan, 2000) and on the self-regulation theory (Maes & Karoly, 2005), combining individualized goals, real-time feedback, behavioral strategies and health information. Thus, the primary hypothesis was that adults who benefited from the tailored App would report greater adherence rate to a 12-week PA program, in comparison to a control group who received only a step count from a pedometer. Second, it was expected that the mobile App users would significantly increase their daily PA from the first to the 12[th] week of the program.

METHODS

Participants

Participants were recruited from a pool of patients at a medical center within the Brest area (France). The inclusion criteria were: no health-related problem, both sexes aged 18 to 60 years, being professionally active. To avoid the confounding effect of some participants being unable to use a mobile phone, participants also had to have an existing mobile phone contract. Before the beginning of the study, four of them declined to participate and six of them dropped out due to technical difficulties with their smartphone. Finally, 30 healthy adults (12 men and 18 women) aged between 35 and 60 years (45.33 ± 7.6) were randomly assigned to a control group (CG; N=15), or to an experimental group (EG; N=15). For that a person not involved in participant recruitment compiled a computer-generated random allocation schedule.

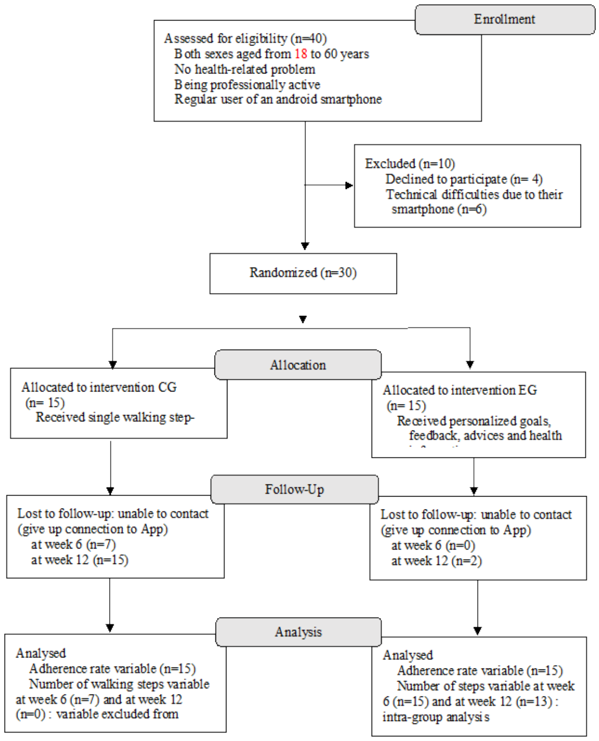

Figure 1. Flow chart of participants through the study

The research ethics committee of the local University Hospital approved this study. All participants gave written informed consent before data collection began (according to Declaration of Helsinki).

Design and Procedure

The experimental study design included randomized parallel group with or without a personalized program. A tailored-App delivered an individually adapted 12-week program (i.e., goals, behavioral strategies, health information and daily number of steps feedback) based on motivational and behavior change theoretical frameworks (i.e., self-determination and self-regulation frameworks). The first week of the 12-week program was used as a baseline period during which participants were requested to continue with their normal PA. Participants from the CG should be able to an App providing daily step-count on their mobile phones. Participants from the EG were informed that they would benefit from daily step-count feedback, individually adapted goals per week depending on their previous score, advices and heath information. All of the participants were asked to connect their mobile phones to the web daily for data transmission to the project's local server. They could call project

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staff with any technical problems or difficulties with the App during the feasibility study period. Data storage allowed data monitoring throughout the study. An interdisciplinary staff composed of an exercise scientist, a medical scientist, and an engineer, collaborated in designing a smartphone application for the intervention. The intervention consisted in delivering goals, information, behavioral strategies and feedback to individuals via a tailored-App. All of these specifications took place in a "five-step-strategy": Diagnosing, Initiating, Monitoring, Maintaining, and Evaluating (Kermarrec et al., 2015). First, the diagnosing step is used to provide instructions on the general use of the App, and to collect data including age, size, weight, gender, and physical self-esteem. Self-esteem is considered as an important psychological construct guiding motivated behavior and more specifically attitude toward PA (Ninot et al., 2001). Thus, the mobile App included an operational measure of physical self-esteem and its self-perception subdomains: sport competence, perceived strength, physical condition, and attractive body (*id.*). The psychological measure and the number of walking steps during the first week served as inputs for the program delivering.

Second, the initiating step aimed at providing personalized goals. At the beginning of each week, users received optimally challenging goals. If-then rules and ad-hoc equation considering precedent number of steps and self-esteem measure were implemented to provide personalized goals. More precisely, participants were provided with three goal options of varying difficulty (e.g., 33 000 steps, or 34 500 steps, or 36 000 steps) and were invited to make choices (Deci and Ryan, 2000).

Figure 2. The tailored-App daily current screens

Third, the monitoring step consisted of advices based of self-regulation framework (Maes and Karoly, 2005). The mobile App provided information on healthy behaviors and offered a set of behavioral strategies. These strategies for increasing daily PA are listed on a specific screen and the user is invited to choose some of them. Twice a day brief health information about benefits of PA (e.g., 1 minute of PA = 10 minutes for life) are displayed. Thus, challenge, knowledge about health and behavioral strategies are assumed to stimulate self-regulation, planning and monitoring daily PA (Castalonguay et al., 2018).

Fourth, personalized feedback delivered by the app was thought to help in maintaining motivation and PA. Feedback content depends on scores and on the user's psychological profile. Thanks to a system of if-then rules, if a user had low physical self-esteem, and if he reached the assigned goals, the feedback should be mastery-oriented (e.g., Congratulations! An increase of 15% compared to the previous weeks! Good Job! You're walking your way to a healthy lifestyle!).

Fifth, evaluation was thought as an important source of motivation and self-regulated behaviors. The App displayed the gap between the chosen goal and the current walking steps (see fig. 1). Whenever he wanted, the user could see on the same screen his total just-in-time, previous days scores, and the target at the end of the week.

Finally, considering the available Apps in the literature (Antezana et al., 2020), the tailored App introduced in this study is new because: a) it is theoretically founded, based on motivational *and*

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behavior change theoretical frameworks (i.e., self-determination and self-regulation frameworks) ; b) consequently the tailored app offered a large span of intervention strategies (i.e., goals, users' choices, feedback and health information; c) although available Apps also furnished goals and feedback on outcomes, this App offered personalized goals and feedback depending on outcomes *and* psychological profile (i.e., self-esteem measure).

Measures

PA (number of steps) were collected via the smartphone's built-in pedometer and transmitted to the project's local servers each evening for data storage. This allowed data collection while the program progressed (data number of steps per week). For this study, numbers of steps from week 1, 6 and 12 were analyzed.

In previous studies, the most current adherence measure was the proportion of participants completing exercise programs, the mean of exercise sessions per week or the total number of exercise sessions during the study period (e.g., Picorelli et al., 2014). In the current study, the number of weeks the participants connected their smartphone to the server was considered as a relevant behavioural measure for adherence to the program. When a participant did not connect to the server for more than two weeks, the platform was not able to register the pedometers scores. In this case, the participant was declared as giving up the program.

Statistical Analysis

Data were statistically analyzed using SPSS (Released 2012. IBM SPSS, Version 21.0. Armonk, NY: IBM Corp.). Numbers of steps from week 1, 6 and 12, and the adherence (i.e., number of weeks) were considered as dependent variables. These variables were reported as mean and standard deviation, and percentages.

The Shapiro-Wilks normality tests indicated that the data were not normally distributed. Thus, for all the statistical analyses, data were compared using non-parametric tests, the Wilcoxon test and the Mann–Whitney *U*-test as appropriate.

RESULTS

Participants movement through the study is displayed in figure 1. At baseline (week 1), no significant differences on the number of steps between the EG and the CG were observed (table 1).

A sedentary lifestyle has been defined according to various criteria such as a number of walking-steps per day or per week. Considering walking steps mean and standard deviation in week 1, most of the participants should be considered as sedentary people (i.e., walking less than 50,000 steps per week).

Table 1. Number of steps per week: mean, standard deviation and Mann Whitney U tests

12-week program	Week1	Week6	Week12	Number of weeks
	N=30	N=22	N=13	
EG	28,510 (11,974)	52,373 (34,013)	49,958 (47,739)	11.46 (1.18)
CG	22,469 (16,036)	24,256 (19,146)	/	4.40 (3.41)
Total	25,489 (14,241)	43,426 (32,491)	/	7.93 (4.38)
U	85	22.5	/	4
P	.254	.034	/	.000

Concerning the adherence (number of weeks), the sample's mean was 7.93±4.38 weeks. For the CG, the adherence rate was 4.40±3.41 weeks versus 11.46±1.18 weeks for the EG (table 1). Seven participants from the CG and fifteen participants from the EG maintained their adherence to the program up to the sixth week. Thirteen from the fifteen participants in the EG achieved the entire 12-weeks program, whereas no participant from the CG persisted in using his/her mobile to assess his/her number of steps per day and per week over 12 weeks. Finally, the Mann-Whiney U test indicated that the adherence in the EG was significantly higher than in the CG ($U = 4$, $p<.01$).

Regarding the number of steps per week, significant differences between the two groups ($U= 22.5$, $p<.05$) were observed from the sixth week of the program: all the EG (N=15) reached a mean of 52,373 steps per

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week, whereas 47% of the CG (N=7) reached a mean of 24,256 steps per week indicating that participants from the EG achieved the target of 50,000 steps per week from the sixth week.

Concerning progression within the EG, the Wilcoxon signed-rank test showed that a 12-week program using the tailored App promoted a statistically significant change in the number of steps per week between the first and the sixth week (Z = -2.385, p = 0.017), between the first and the twelfth week (Z = -1.992, p = 0.046), but not between the sixth and the twelfth week (Z = -0.664, p = 0.507).

DISCUSSION

The present study designed and tested a tailored mobile App. This study showed that the App had significant effect on weekly number of steps and on adherence to a 12-week program in healthy adults. Participants from the EG maintained their adherence to the program more than participants from the CG. They enhanced PA from the first to the sixth week, and maintained PA during 12 weeks.

Reviews in PA programs evidenced declining levels of adherence over time (Picorelli et al., 2014; Romeo et al., 2019). In the current study, benefit on adherence for the EG (11.46 ± 1.18 weeks) compared to the CG (4.40 ± 3.41 weeks) is clear. Previous studies reported that the rate of participants completing exercise programs ranged from 58% to 86% (Bort-Roig et al., 2014). Thanks to the tailored-App, only two participants from the EG dropped out; 86 % of them maintained their adherence. Furthermore, only 40% of Apps people installed in their smartphone have been used over 30 days (Muntaner et al., 2016). This information may help to understand why participants from the CG persisted for only 4.40 weeks (30,8 days) in using an App providing single daily step-count.

The results also indicated that the program the App delivered were sufficiently powerful to significantly increase number of walking-steps per week (+23,863 between week 1 and 6; +21,448 steps between week 1 and 12). This result is more convincing than increases observed in similar studies (Bort-Roig et al., 2014; Direito et al., 2015; Fanning et al., 2014; Muntaner et al., 2016; Yerrakalva et al., 2019). For instance, a program combining instructions, pedometers, and text messaging (Kim and Glanz, 2013) succeeded in promoting PA (i.e., +4755 steps between the first and the 6th week) but with a lower progression, in a similar sample of inactive adults (N=30). Bergling et al. (2020) reported a non-significant effect of App intervention after 12 weeks (Bergling et al., 2020). Furthermore, the results highlight that the app favored a significant increase between week 1 and 6, and maintained number of walking-steps between week 6 and 12.

These findings point the importance of a theory-based design process (Antezana et al., 2020). The design process of the tailored-App has been guided by a five-step-strategy (Kermarrec et al., 2015) theoretically founded on the Self-Determination Theory (SDT) and the Self-Regulation Theory (SRT). First, SDT scientists (Deci and Ryan, 2000) suggest that all individuals have three key psychological needs (autonomy, competence and relationship), with consequences on self-determined motivation to engage in PA (for a meta-analysis, see Juwono et al., 2020). In the App, the need for autonomy was supported by promoting choices between a set of goals or a range of behavioral strategies. Because people also need to feel competent or effective, the App provided personalized challenging targets and frequent feedback about progression toward the target. Second, the SRT advocated by Maes and Karoly (2005) is one of the most popular theories of behavior change. In this study, goals, knowledge (researchers also called them beliefs, e.g., Beinart et al., 2013), metacognition and behavioral strategies are considered as the key components within the self-regulation process. Metacognition is defined as cognition about themselves, leading to knowledge about their own capabilities. If someone believes that he is not able to walk more than 5,000 steps a day, he spontaneously gives up a goal of 10,000 steps a day. In contrast, the program provided individually adapted goals. Consequently, the device helped the users to reach the chosen goal by suggesting behavioural strategies (e.g., walking during you're phoning; walking to get the next bus stop). According to the SDT (Juwono et al., 2020), the program could also be founded on the need for relationship. Future development of mobile App supported PA should consider this social support resource (Antezana et al., 2020), such as sharing goals between teammates or friends.

This study has some limitations: a) first, the small sample size that has also been pointed in other studies (Direito et al., 2015; Yerrakalva et al., 2019); b) second, as participants were self-recruited, they may not be fully representative of healthy adults; and c) third, the lack of direct measure of motivation components (e.g. intrinsic and extrinsic motivation scale). We also assumed that motivation to connect to the mobile App is not the most usual indicator to the adherence to an exercise program. In the current study, technical difficulties could also explain why a user dropped out of the program. Furthermore, the study assessed the overall effect of various intervention strategies embedded into a tailored App, but it did not identify which strategy was the most effective for participant engagement. According to a recent study, users have preferences for intervention strategies and features (DeSmet et al., 2019).

CONCLUSIONS

Recent review highlighted that adherence to a PA program is a very complex phenomenon influenced by program characteristics and personal factors (Picorelli et al., 2014). Our study tried to considered a part of them, focusing the relationship between some psychological factors and the way the program is delivered. Although there has been a recent rise in mobile device applications aimed at promoting regular PA and related health behaviors, few of them have been drawn from psychology or behavioral science theory, and have promoted personalized goals and feedbacks, or have been systematically assessed within an experimental protocol including a CG. In the present study, the comparisons between the EG and a CG assess relevance, applicability and feasibility of the tailored-App: the program was sufficiently potent to significantly increase walking steps per 6 weeks. Nevertheless, future tailored-App design should take in account the difficulty to promote PA increase during a 12-weeks long time program.

Finally, this research has implications for coaches and physical educators that could employ mobile App to complement their face-to-face practice, because combining App with other interventions seems to be more effective (Yerrakalva et al., 2019).

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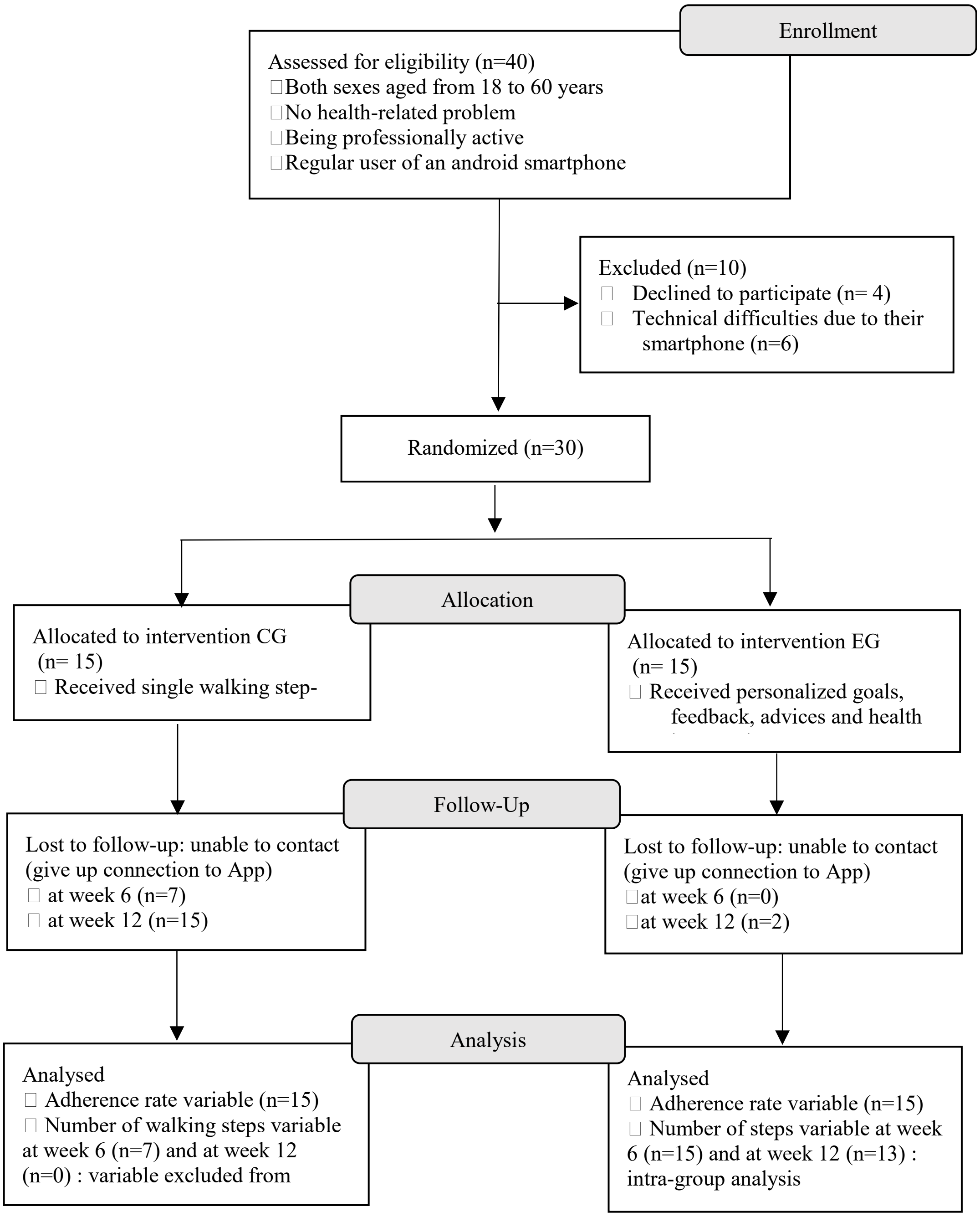

Figure 1. Flow chart of participants through the study