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A systematic review on the use of mHealth to increase physical activity in older people

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ABSTRACT

Physical activity (PA) is important for maintaining good physical health. WHO recommends 150 min of PA per week to the older population but many older people do not meet this recommendation. The increasing use of mobile technology among elderly provides an opportunity to increase PA. This systematic review was aimed at the usability, acceptability and effectiveness of mHealth (including smartphone, mobile phone, tablet apps, mobile text messages) to increase PA in older people above the age of 55. A literature search related to mHealth, PA and older people was conducted in PubMed, Embase, Web of science and COCHRANE library. The search generated 829 articles, after the screening of articles and reference lists, ten studies were included in the review. Included studies were diverse in the aspects of study design, intervention mode, duration, frequency of reminders and assessment measures. The results of this review indicated that mHealth interventions with motivational back up may be usable, acceptable and beneficial for the maintenance and improvement of PA in the short term. However, the findings are inconclusive about the difference in effectiveness between simple (mobile text message) and complex mHealth interventions (app monitoring with sensors), the optimal frequency for activity reminders and on the long term effectiveness of mHealth.

Contents

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1. Introduction

Physical activity (PA) plays an important role in maintaining good physical and mental health.[1,2] However, the recommendation of the World Health Organization (WHO) of 150 minutes per week PA[3] is not met by the large number of older people[4] due to lack of interest,[5] lack of time,[6] decrease in work-related PA,[7,8] sedentary behavior,[9] fear of falling, difficulty in commuting to exercise gym or unawareness about the benefits of PA.[10] Lack of PA is a major risk factor for adverse health outcomes across the life course.[11] Among the elderly, it is a risk factor for cognitive decline, depression and disability.[12,13] Conversely, PA reduces the risk of disease[14–18] and all-cause mortality, also among the elderly.[19] Engaging in PA also reduces the risk of falls[20] and cognitive decline[21] in the older population. As a result, specific recommendations for PA in old age have begun to emerge,[22,23] yet most older adults do not meet these recommendations.[22] A systematic review has found increasing age to be a factor for diminished PA.[24] Older people tend to be less physically active than young people, and when they do engage in PA, its intensity is lower.[23]

EHealth and mHealth are technological advancements which could be helpful in promoting PA. The WHO defines eHealth as, "the use of information and communication technologies (ICT) for health" while mHealth as, "the use of mobile wireless technologies for public health".[25] So, eHealth is a broader term related to telemedicine or telehealth (including mHealth) while mHealth is related to the mobile phone.[26] EHealth and mHealth have novel solutions for guiding, training, motivating and reminding a person to engage in PA or exercise. The reminder for PA might be in the form of mobile text messages, pop-up screen reminders of an app, activity monitoring and advice for mobility besides the traditional methods of printed material, prescription, group training for exercise, face to face advice or the word of mouth.[27] MHealth might be the future of healthcare due to the increase in the use of mobile or smartphones and easiness of use.[28] A mobile phone can remind people about the time for an activity, it can provide pop-ups to notice inactivity or boost up for achieving an activity goal. The scope of mHealth ranges from a simple mobile text message to a complex software/app and is useful for goal setting, coaching, monitoring and self-evaluation of exercise or activity. It might act as a tool to encourage people to perform PA which might range from a simple walk to any designated/specific exercise.[29,30] MHealth has some benefits; it is accessible everywhere and a person does not necessarily need a specific time and place to start exercising.[31] Further, it is not necessary to consult a physical trainer in person.[32]

Research findings on the effectiveness of eHealth (including mHealth) for PA in the general population are mixed and reviews report modest effectiveness of such interventions.[33–35] A systematic review has shown that eHealth (including mHealth) may be effective and acceptable to improve PA in people with a mean age of 55 years and above.[36] The narrative review of Jonkman et al. (2018) also found that eHealth interventions measuring PA in the form of pedometers and accelerometers are effective in older people.[37] However, a systematic review is lacking on the effectiveness of mHealth in older people to improve PA despite the growing increase in the use of mobile phones and smartphones.

This systematic review aims to study the effectiveness, usability and acceptability of mHealth for promoting PA in older people above the age of 55. As far as we know, this is the first review on the effectiveness of mHealth interventions on promoting PA in older people.

2. Methods

2.1. Search strategy

An initial and updated literature search was conducted on August 20, 2018 and December 20, 2019 respectively, using the combination of key terms related to mHealth/eHealth, exercise/physical activity and older people in the databases of PubMed, Embase, Web of science and COCHRANE library. The search terms, MeSH and index terms, are attached in Appendix A.

The reference lists of the studies meeting the inclusion criteria and published reviews on eHealth to improve PA in older people were searched to find additional articles.

2.2. Inclusion and exclusion criteria

All study designs were included in this review. Studies were included in the review, if they met all of these three conditions, (1) age of all participants was 55 years or above, (2) mHealth as an intervention for PA, (3) the outcome measure was related to usability, acceptability and/or effectiveness on PA.

Regarding the second criterion, studies with mHealth interventions in the form of mobile phone, smartphone or tablets (text messages, mobile phone or tablet enabled software or apps and smartphones with or without portable activity monitors) targeting PA solely or as part of another treatment (e.g. in diabetic management) were included in this review.

Studies on telephone interventions, video callings, Personal digital assistants (PDAs) and web apps were excluded if it was not clear whether mobile phones/tablets were included in the intervention or not.

Studies not fulfilling any of the above conditions, letters to the editor, conference abstracts and reviews were also excluded.

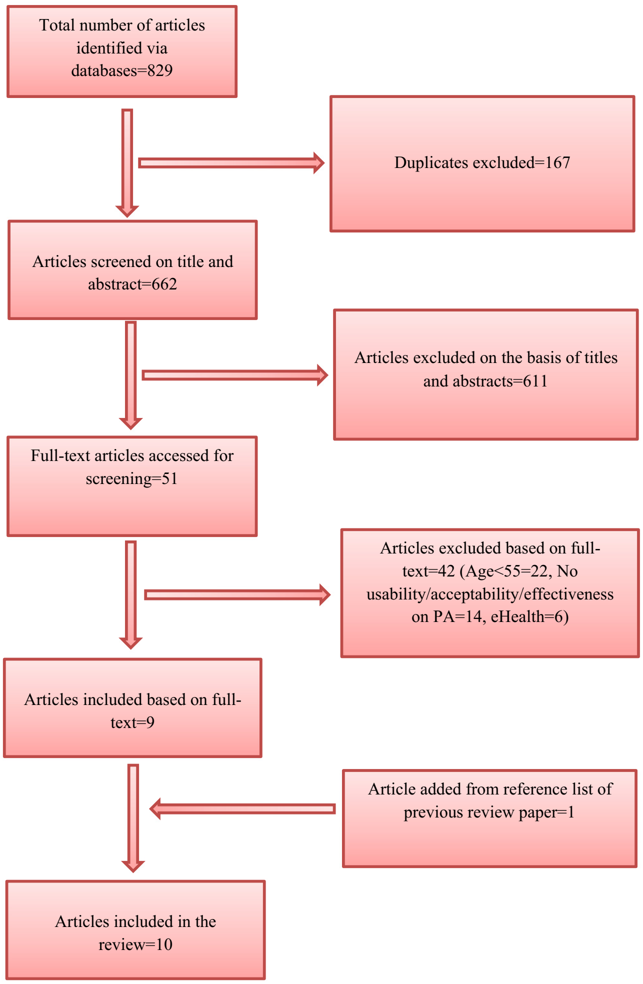

Fig. A. PRISMA flow chart diagram for the selection of studies.

2.3. Selection of studies

As a first step, the titles and abstracts screening of the literature was carried out by two independent authors (first and third author). In the second step, full-text articles of the relevant studies were screened while in the third step, the reference lists of the suitable articles and the review articles on eHealth were searched for additional articles. At each step, any disagreement was discussed until consensus was reached. In the case of non-consensus, the study was discussed with the second author and disagreements were resolved.

2.4. Data extraction

A protocol was developed for data extraction from the articles. The information related to article (year of publication and country of research), participants (male and female ratio and mean age), intervention (name and description of intervention, duration and frequency of reminders for PA), research design, PA measures and results (effectiveness, usability and acceptability of the intervention) was extracted.

2.5. Study quality

The quality of studies was assessed by two authors (first and third author) with Cochrane Collaboration's tool for assessing risk of bias[38] which has six domains: (1) sequence generation for random allocation to conditions; (2) concealment of allocation to conditions; (3) addressing incomplete outcome data; (4) selective outcome reporting; (5) blinding of participants and researchers, and (6) other sources of bias. Domain five was not applicable in this review as participants and researchers were aware of allocation to conditions. Therefore, this domain was not assessed. Each study received a judgement in the form of low risk of bias (+), high risk of bias (–) or unclear risk of bias (?) on respective domains.

The overall risk of bias was rated as low, if the study scored low risk of bias on three or more domains, moderate when it scored low on two domains and high when it scored low on one or no domain. If a domain was not applicable (N.A.), it was considered having a high risk of bias.

When the design of a study was not clear, the corresponding author was contacted through email for the details of the study design.

2.6. Data synthesis

We conducted a systematic review because quantitative data synthesis (meta-analysis) was not possible due to the low number of studies and heterogeneity of the data.

3. Results

3.1. Identified studies

The process of study selection for this review is summarized in Fig. A. The literature search resulted in 662 articles after the removal of 167 duplicate articles, and 611 articles dropped out in

Table A
Summary of risk of bias assessment of included studies.

Study and study design	Random sequence generation	Allocation concealment	Incomplete outcome data	Selective reporting	Other bias	Summary risk of bias
Lyons et al., 2017[40] (RCT)	+	+	+	+	?	+
Muller et al., 2016[43] (RCT)	+	+	+	?	?	+
Knight et al., 2014[41] (RCT)	+	+	+	?	?	+
Kim & Glanz, 2013[42] (RCT)	–	–	+	?	?	–
Joosen et al., 2018[46] (Pre-post randomized)	–	–	+	?	?	–
Hong et al., 2015[45] (Pre-post study)	–	–	+	?	?	–
van Het et al., 2014[39] (Pre-post with partial randomization)	–	–	+	?	?	–
Paul et al. (2017)[44] (Mixed method)	–	–	–	?	?	–
Shake et al, 2018[47] (RCT)	+	+	+	?	?	+
Li et al, 2019[48] (Pre-post Test Pilot feasibility study)	–	–	+	?	?	–

+ Low risk of bias, – High risk of bias,? Unclear risk of bias.

Table B
Characteristics of studies, interventions, studied populations and results.

Study	Lyons et al., 2017[40]	Muller et al., 2016[43]	Knight et al., 2014[41]	Kim & Glanz, 2013[42]	Joosen et al., 2018[46]	Hong et al., 2015[45]	van Het et al., 2014[39]	Paul et al, 2017[44]	Shake et al, 2018[47]	Li et al, 2019[48]
Country of Study	USA	Malaysia	Canada (North America)	USA (African American descent)	Belgium	USA	Switzerland	UK	USA	USA
Study Design	RCT (Pilot)	RCT	RCT	RCT (Pilot)	Pre-post randomized	Pre-post	Pre-post (Preclinical exploratory with partial randomization)	Mixed method pilot study	RCT	Pre-post Test Pilot feasibility study
N	40	43	45	36	20	26	44	16	105	8
Control (n)	20	21	N..A.	10	N.A.	N.A.	17	N.A.	45	N.A.
Treatment (n)	20	22	45	26	20	26	27	16	60	8
Female/Male	34/6	32/11	25/20	29/7	8/12	18/8	28/16	8/8	90/15	6/2
Mean Age (Years)	61	63	63	70	81	69 (Median age)	75	71	73	74
Intervention	App & telephonic counseling	Motivational text message	Smartphone & Pedometer	Motivational text message	Smartphone & activity sensors	App	App	App	App	Smartwatch paired with tablet
Control Group	Waiting list control	Exercise booklet	N.A. (only intervention groups)	Walking instruction manual	N.A.	N.A.	Training plan diary	N.A.	Without exercise instruction	N.A.
Frequency of reminders (or use of intervention)	Encouragement to look at the goals and perform PA twice a day	Single Motivational text message a day for 5 days a week	N.A.	Three motivational text messages a day, 3 days a week	Sensors mounted on participants 8am-5 pm for 5 days excluding weekends	One email after two weeks.	Daily Alarm reminder for exercise thrice a day	Daily automatic	App use twice per week for around 1 h	–
Duration (weeks)	12	24 (text messages were used in first 12 weeks)	12	6	10	8–12	12	6	10	4
Studied Parameters	a) Acceptability & effectiveness of the app b) Step count c) Stepping time per day	a) Exercise frequency measured with exercise log b) Secondary Outcome measurements (daily sitting time, Grip Strength, chair-stand test)	Step Count	a) Step Count b) Leisure Time Exercise Questionnaire (LTEQ)	a) Usability of smartphone for Automatic monitoring of PA behavior b) Effects of mHealth system of activity sensors on PA	Effectiveness on goal setting for PA in cancer patients	Effectiveness for Exercise	a) Acceptability and usability of the app b) Step Count	a) Gait speed b) Chair stand and arm curl test for body strength	a) Sedentary time b) PASE (Physical activity scale for the elderly)
Results	a) Acceptability was 4 on the scale of 5 b) Increase of 1090 step count in intervention group in comparison to a decrease of 41 step count in control group after 12 weeks. Effect size was 0.26 (95% CI) c) Increase of 51 min in stepping time per day in the intervention group compared to a decrease of	a) Increased exercise in intervention group compared to control group, when receiving text message in first 12 weeks (with mean difference of 1.21 and P = 0.03) b) No significant difference from 12 to 24 weeks between control and treatment groups on secondary outcomes (P > 0.05)	Increase of 460 step count, not statistically significant ($P = 0.22$) in sedentary group (advised to lower sedentary behavior) while step count insignificantly decreased in exercise (advised for exercise) ($p = 0.84$) and comprehensive (advised to avoid sedentary behavior and do exercise) groups (p = 0.19) after 12 weeks.	a) Increase of 680 step count in intervention group ($P = 0.05$) in comparison to increase of 398 step count ($P = 0.23$) in control group after 6 weeks. b) Improvement of 12 points in intervention group (P = 0.001) in comparison to improvement of 4.6 points (P = 0.01) in control group at LTEQ score after 6 weeks	a) mHealth system practically work to automatically record the activity of a person b) Activity levels increased from week 1, peaked at week 5 and decreased slightly until week 10 on graphical display at automatic PA monitoring	a) Number of participants engaged in regular PA increased by approx.16% ($P = 0.043$). b) Participants completed 50% of the set daily PA goals (jogging, gardening etc.) c) Each participant completed 11 activities/goals	Adherence to Strength-balance exercises for gait was 23% more in the tablet (active Lifestyle app group) than the brochure group. Gait quality was also improved in intervention group	a) Acceptable to users and showed potential to increase physical activity in the interviews b) Mean increase in step count = 14%. , not statistically significant ($p = 0.077$); moderate effect size ($d = 0.56$)	a) The gait speed test (4-meter walk) showed main effect of Time, $F(1,83) = 8.71$, $P < 0.01$, = 0.10, indicating that both groups improved in gait speed b) The exercise group performed better than only health education group in chair stand and arm curl tests. The arm curl test showed both a main effect of Time, $F(1,81) = 11.40$, $P < 0.01$, = 0.12, and a Group × Time interaction, $F(1,81) = 4.78$, $P = 0.03$, = 0.06. Pairwise t-test. The chair stand test showed a main effect of Time, $F(1,77) = 13.18$, $P < 0.01$, = 0.15, and a Group × Time interaction, F	a) Sedentary time decreased both during the intervention (D [mean difference] = –42.3 min, 95% CI[confidence interval] = [–79.4, –5.2], P = 0.03) and at post-intervention (D = –87.4 min, 95%CI = [–133.5,–30.4], P = <0.01).) b) The self-reported physical activity (PASE score) increased at the posttest (D = 96.2, 95% CI = [15.8,176.5], P = 0.025)

Table B (*continued*)

Study	Lyons et al., 2017[40]	Muller et al., 2016[43]	Knight et al., 2014[41]	Kim & Glanz, 2013[42]	Joosen et al., 2018[46]	Hong et al., 2015[45]	van Het et al., 2014[39]	Paul et al, 2017[44]	Shake et al, 2018[47]	Li et al, 2019[48]
	2 min in control group after 12 weeks. Effect size was 0.35 (95% CI)								(1,77) = 4.20, P = 0.04, = 0.05. *t*-test comparisons indicated that the Experimental group improved, while the Control group did not	
Outcome variable Assessment	1. Baseline assessment one week before 2. Midpoint assessment at 6 week 3. Final at 12 week	At 12 and 24 weeks	Each week	Each week	Fitness test at the start, after 1, 3, 5, 7 & 9 week, then after the 10 week	Before and after the intervention	Baseline and after 12 weeks of the intervention	Every week	Within one week before and after intervention	One week before, after 4 weeks of intervention and one week after the intervention
In and between group comparison	In & between intervention and wait-list groups	In & Between SMS receiving and non-receiving groups	In & between groups	In & between SMS receiving and non-receiving groups	Ingroup	Ingroup	In & Between tablet and brochure groups	Ingroup	In & Between only health education & exercise with health education group comparison	Ingroup

the screening process. The major reasons for drop out of articles were the low age of participants, the lack of a mHealth component or the absence of usability/acceptability/effectiveness on PA. Only nine articles met the inclusion criteria and one article was found in the reference list of an eHealth review, so ten articles were included in this review.

3.2. Study quality

The assessment of study quality is presented in Table A. The overall risk of bias was low in four of the studies and high in six of the studies. The risk of bias in the sequence generation and allocation concealment related to selection bias was low in four of the studies and high in six of the studies as the participants were not randomly assigned to the groups in most of the studies. The criterion of incomplete outcome data related to attrition bias scored low in most of the studies as the dropout of participants was low. While the information on selective reporting and the possibilities of other biases were rated unclear in the studies as it was often not reported.

The study design was not clear in two studies and the corresponding authors of the studies did not respond satisfactorily to query and reminders.

3.3. Study and intervention characteristics

The characteristics of the included studies, studied populations, interventions and results are summarized in Table B. The total number of participants in all studies was 383, of which 72% was female. The number of female participants was higher than the number of males in all studies except for one study by Joosen et al. (2018) with 8 female participants (40%). The average age of participants was 70 years, ranging from 61 years (Lyons et al. 2017) to 81 years (Joosen et al. 2018).

Of the ten studies, six were related to PA or exercise in community living healthy elderly,[39–44] one to increase PA in older cancer patients[45] one to improve PA in healthy residents (chosen by a physiotherapist) of a care home,[46] one to senior centres[47] and one to the participants visiting a geriatric clinic.[48]

All of the ten studies investigated the effectiveness of mHealth and three studies examined features of acceptability and usability as well.[39,40,44–46] Tablet or mobile-enabled app interventions were investigated in five of the studies.[39,40,44,45,47] Simple motivational text message interventions were used in two of the studies.[42,43] A smartphone with pedometer intervention was used in one study.[41] A smartwatch paired with a tablet was used in one study.[48] While a mHealth system intervention (consisting of a smartphone with wireless activity sensor mounted on the body for automatic continuous monitoring of PA) was used in one study conducted at a care home.[46] The duration of use of the intervention was 12 weeks in five of the studies,[39–41,43,45] 10 weeks in two studies,[46,47] 6 weeks[42,44] in two studies and 4 weeks[48] in one study. Post-intervention measurements were taken immediately or within one week after the end of the intervention period and there were no follow-ups.

Five of the studies were conducted in the USA, of which four included general older Americans[40,45,47,48] and one included older immigrants of African descent.[42] The other five studies were conducted in Canada -North America,[41] Belgium,[46] Switzerland,[39] Malaysia[43] and UK.[44]

Of the ten included studies, five studies were RCTs,[40–43,47] one was a pre-post randomized study,[46] two had a pre-post study design,[45,48] one was mixed-method study[44] and one had a preclinical exploratory design with pre-post measurements and a control group.[39] There was no control group in three of the studies,[45,46,48] one study compared three groups (sedentary, exercise and comprehensive groups) based on different advice for activity,[41] the participants were divided into four groups in one study for focal group discussion[44] while there was an exercise/training booklet control group in three studies,[39,42,43] a waiting list control group in one study[40] and a control group without specific exercise instruction in one study.[47]

3.4. Usability and acceptance of interventions

Usability and acceptance of interventions were examined in three studies.[39,40,44–46] Lyons et al. (2017) found that the Jawbone Up app was usable in general older people and the acceptance rate was 80%, the app was considered user-friendly, convenient and comfortable in use by the participants. The participants also intended to continue use of the app in future.

Joosen et al. (2018) found that a smartphone-based solution is usable for monitoring PA in a care home. This system can monitor PA and present the level of PA in graphical form which can be translated into a fitness score. Furthermore, 58% of the participants consider the mHealth system beneficial to stay motivated for PA due to active monitoring. However, 74% of the participants asked for more encouragement to stay active in future.

Paul et al. (2017) reported on the acceptability and usability of the STARFISH app. In the pilot study, older people in focal group discussions gave positive comments on the acceptability and usability of the app for staying physically active. Many participants in the study found that the app was easy to understand and simple to use. The participants expressed that the app encouraged them to perform PA.

3.5. Effectiveness of interventions

Overall, eight out of ten studies found that mHealth interventions were effective on PA or exercise in older people irrespective of the kind of mHealth intervention (whether it was app-based, text message-based or mounted sensor-based for activity monitoring). In the studies of Knight et al. (2014) and Paul et al. (2017), the increase in step count for PA was not statistically significant. Further, the study of Joosen et al. (2018) reported the transient effect (increase in PA) of the mHealth system until the mid-period of the application of the intervention, when a motivation to use new technology was there. While the study of Muller et al. (2016) reported that PA behavior diminished when the intervention was stopped.

Between group comparisons, next to ingroup comparisons, were made in six of the studies.[39–43,47] The between group comparisons have shown that the participants in the intervention groups improved more on PA in comparison to the control groups. Ingroup comparisons were made in all studies and participant improved on PA measures compared to baseline. Further details can be found in Table B.

3.6. Motivational reminders

One of the studies in our review reported a decrease in PA level after withdrawal of motivational reminders.[49] It is difficult to say whether a single daily reminder is more effective than a reminder which is two or three times a day for optimal PA. In the studies, interventions were diverse which make a proper comparison difficult. The study on self-measured PA reported the efficacy of five different motivational text messages five times a week.[43] similarly a study with three text messages (in the morning, afternoon and evening) three days a week also reported effectiveness on step count.[42] Furthermore, fortnightly email was found to be effective to improve PA in cancer patients.[45] Similarly, interventions with daily reminders for exercises reported better results than no-reminder control groups.[39]

3.7. Effectiveness in relation to form of mHealth

Comparison of the effectiveness of mHealth in relation to simple and complex form of mHealth on objective measurement of step count was inconclusive. A simple motivational text message intervention in the study of Kim and Glanz (2013) resulted in an increase of approximately 680 step counts in 6 weeks. Though, a complex mHealth intervention in the study of Lyons et al. (2017) resulted in an increase of approximately 1100 step counts in 12 weeks. Due to the difference between studies in the intervention period and population characteristics, it is difficult to say whether the simplicity or complexity of mHealth interventions have an effect on PA or not. It is noticeable that none of the studies in our review compared a text message intervention with an app intervention to improve PA in older people.

4. Discussion

The results of the current review indicate that mHealth may be acceptable and may be an effective tool to increase PA or exercise in older people. Both simple and complex mHealth interventions may be effective. The interventions may be effective in comparison to no intervention or a non-mHealth intervention and the intervention period lasted for a short period of 1.5–3 months. However, not all studies had a randomized controlled design, some studies conducted pre- and postintervention measurements without a control group.

This review is different than the review on the effectiveness of eHealth by Muellmann et al. (2018) as it is specifically focused on mHealth and all participants are 55 years old or above in the included studies. Muellmann et al. (2018) reported the effectiveness of eHealth interventions for a short term and was inconclusive about the efficiency of eHealth in the long period of time. The findings of this review on mHealth are consistent with the findings of Muellmann et al. (2018) on eHealth.

4.1. Motivational support

Motivational support is considered as an important aspect of mHealth interventions to improve PA.[49] Motivational reminders may be important in interventions, but the optimal frequency of these reminders is not clear yet. If WHO guidelines are followed, the recommended PA is at least 150 min a week (accumulative) that can be like 30 min a day and five times a week in healthy older people while older adults with poor mobility should exercise for at least three days a week.[3] A reminder on three or five days a week seems an appropriate choice, but the frequency of reminders also depends on the personality type (sedentary or active), personal need and preference of the person using it. Future research could investigate the optimal frequency of reminders for an optimal PA in different older people.

4.2. Simple and complex forms of mHealth

It would be interesting to investigate differences in effectiveness between simple and complex forms of mHealth in the future. In the future, apps could be more prevalent in advanced regions like Europe, the USA and China where more people own a smartphone while text messages are a good solution in developing countries in Asia and Africa where mobile phones are more common than smartphones and text messages are not expensive. It may be investigated in future research whether a motivational text message may have the same effect as an app or a complex system of mHealth (with mounted sensor) in older people.

4.3. Optimal step count

Step count is the objective method of measurement of PA and the average step count in healthy older people may range from 2000 to 9000 and pedometer-based interventions could cause an increase of 775 step count.[50] The recommended (increase in) daily step count for good physical health in older people is not specifically operationalized yet. In fact, the increase in step count is operationalized for some physiological conditions. For example, an increase of 600 or more daily step count is related to a low risk of hospital admission in older patients of Chronic Obstructive Pulmonary Disease (COPD).[51] More research is needed to determine the recommended (increase in) step count for older people.

4.4. WHO on PA in bouts of 10 min

The WHO recommends aerobic PA in bouts of at least 10 min.[3] However, the included studies in this review did not explicitly use the bouts of 10 min. This might be related to the fact that the activity performed in bouts of less than 10 min could be equally effective, as the recommendation of PA in bouts of 10 or more minutes is supported by limited data.[52,53] Further, intensive exercises of short duration do not give so much health benefits, when there are long periods of sedentary behavior.[54] In the future, the WHO may further investigate/elaborate its recommendation on PA for older people regarding the bouts of 10 min.

4.5. mHealth and population groups

An effective PA intervention for the general population might need some adaptations to stay effective in the subgroups of that population.[55] In older people, the effectiveness of the same mHealth interventions may vary in different subgroups based on age, educational status, digital literacy, ethnicity and cultural perspectives. So, older people may not be treated as a single group. In the future, it might be interesting to compare an intervention in different groups of older people.

4.6. Future of mHealth

The future of mHealth interventions for PA in older people looks promising. mHealth interventions have several benefits in comparison to traditional interventions. These benefits are related to low costs, the flexibility of time and place to work with the interventions, and the sustainability of mHealth interventions. Traditional interventions with coaching professionals are usually expensive and require a dedicated time and place. Further, a large number of older people that need PA interventions makes mHealth really promising.

4.7. Limitations

This review has certain limitations and its findings cannot be generalized due to reasons like small number of participants, heterogeneity of studied populations, absence of proper comparison between simple and complex forms of mHealth, short duration of interventions, no follow-up measurements, the inclusion of both RCTs and pre-post studies, low quality of some of the studies, inclusion of studies in which PA was just a part of an intervention for primary care or component for automatic monitoring and feedback, and the use of self-reported measures of PA in some of the studies.

In addition, studies were missing information on the participants' education, digital skills and motivation to use mHealth. It might be that the results mainly account for a selective group of older people who are innovators or early adopters with good digital skills and motivation to adapt to change and use mHealth.

4.8. Recommendations for future research

We recommend future research on the comparison of simple mHealth solutions with complex mHealth interventions. We recommend evaluation of the effectiveness of text message' reminders delivered on a mobile phone compared to an app' reminder. We suggest an investigation of the frequency of optimal reminders for PA. Only few studies were conducted on usability and acceptability of mHealth and more research is needed on it. Further research is recommended for evaluation of usability, acceptability and effectiveness of mHealth in older people in relation to digital literacy, physical health, socioeconomic status and follow-up of long duration.

5. Conclusion

To conclude, the results of this review suggest that mHealth may be effective to improve PA and show an increase in exercise behavior in older people. Motivational reminders may be an important aspect of a good PA intervention. In the future, mHealth may add to or replace traditional methods of improving PA and it is necessary to tailor interventions with the needs of older people. Researchers could explore mHealth features which are precise, relevant, simple to use and still effective for maintaining and promoting good physical health. A large number of older people are in need of effective PA interventions and mHealth might be an economical and effective solution for their good physical health and independence in activities of daily life.

Conflict of interest

Authors do not have any conflict of interest to declare.

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Appendix A. Search strategy

A literature search was conducted in the databases of PubMed, Embase, Web of science and COCHRANE library.

The search in PubMed generated 245 articles with the following Mesh terms,

((‘‘Exercise"[mesh] OR ‘‘Exercise"[ti] OR ‘‘physical activity ‘‘[ti] OR ‘‘Physical Exertion"[mesh] OR ‘‘Physical Fitness"[mesh] OR ‘‘Sports"[mesh] OR ‘‘Physical Exertion"[ti] OR ‘‘Physical Fitness" [ti] OR ‘‘Sports"[ti] OR ‘‘sport"[ti] OR ‘‘physical care"[ti] OR ‘‘Physical Education and Training"[mesh] OR ‘‘Physical Education"[ti] OR ‘‘physical training"[ti]OR ‘‘Healthy Lifestyle"[mesh]) AND (‘‘mhealth"[ti] OR ‘‘m-health"[ti] OR ‘‘mobile health"[ti] OR ‘‘wearable technology"[ti] OR ‘‘wearable technologies"[ti] OR ‘‘Smartphone"[ti] OR "Smartphones"[ti] OR iphon*[ti] OR "mobile apps" [ti] OR "mobile apps"[ti] OR "app"[ti] OR "apps"[ti] OR webapp* [ti] OR "ehealth"[ti] OR "e-health"[ti] OR "Telemedicine"[majr]) AND ("Aged"[mesh] OR "elderly"[tw] OR "elder"[tw] OR "elders" [tw] OR geriatr*[tw] OR "Homes for the Aged"[mesh] OR "Health Services for the Aged"[mesh] OR "Senior Centers"[mesh] OR older adult*[tw] OR old adult*[tw] OR older person*[tw] OR old person*[tw] OR older patient*[tw] OR old patient*[tw] OR "older women"[tw] OR "old women"[tw] OR "older men"[tw] OR "old men"[tw] OR old adult*[tw] OR older adult*[tw] OR "Older individual"[tw] OR "Older individuals"[tw] OR "old people"[tw] OR "older people"[tw] OR "Oldest Old"[tw] OR "Nonagenarians"[tw] OR "Nonagenarian"[tw] OR "Octogenarians"[tw] OR "Octogenarian"[tw] OR "Centenarians"[tw] OR "Centenarian"[tw] OR "septuagenarian"[tw] OR "septuagenarians"[tw] OR "Aging"[mesh] OR "aging"[tw] OR "ageing"[tw])).

The search in Embase generated 176 articles with the following search terms,

((exp "Exercise"/ OR "Exercise".ti OR "physical activity".ti OR exp "Physical Exertion"/ OR exp "Fitness"/ OR exp "Sport"/ OR "Physical Exertion".ti OR "Physical Fitness".ti OR "Sports".ti OR "sport".ti OR "physical care".ti OR "Physical Education"/ OR "Physical Education".ti OR "physical training".ti OR "Healthy Lifestyle"/) AND ("mhealth".ti OR "m-health".ti OR "mobile health".ti OR "wearable technology".ti OR "wearable technologies".ti OR "Smartphone".ti OR "Smartphones".ti OR iphon*.ti OR "mobile apps".ti OR "mobile apps".ti OR "app".ti OR "apps".ti OR webapp*.ti OR "ehealth".ti OR "e-health".ti OR exp *"Telemedicine"/) AND (exp "Aged"/ OR "elderly".mp OR "elder".mp OR "elders".mp OR geriatr*.mp OR "Homes for the Aged".mp OR "Health Services for the Aged".mp OR "Senior Centers".mp OR older adult*.mp OR old adult*.mp OR older person*.mp OR old person*.mp OR older patient*.mp OR old patient*.mp OR "older women".mp OR "old women".mp OR "older men".mp OR "old men".mp OR old adult*.mp OR older adult*.mp OR "Older individual".mp OR "Older individuals".mp OR "old people".mp OR "older people".mp OR "Oldest Old".mp OR "Nonagenarians".mp OR "Nonagenarian".mp OR "Octogenarians".mp OR "Octogenarian".mp OR "Centenarians".mp OR "Centenarian".mp OR "septuagenarian".mp OR "septuagenarians".mp OR "aging".mp OR "ageing".mp)) AND exp "Humans"/.

The search in Web of science generated 183 articles with the following search terms,

(ts=("Exercise" OR "Exercise" OR "physical activity" OR "Physical Exertion" OR "Fitness" OR "Sport" OR "Physical Exertion" OR "Physical Fitness" OR "Sports" OR "sport" OR "physical care" OR "Physical Education" OR "Physical Education" OR "physical training" OR "Healthy Lifestyle") AND ti=("mhealth" OR "m-health" OR "mobile health" OR "wearable technology" OR "wearable technologies" OR "Smartphone" OR "Smartphones" OR iphon* OR "mobile apps" OR "mobile apps" OR "app" OR "apps" OR webapp* OR "ehealth" OR "e-health" OR "Telemedicine") AND ts=("elderly" OR "elder" OR "elders" OR geriatr* OR "Homes for the Aged" OR "Health Services for the Aged" OR "Senior Centers" OR older adult* OR old adult* OR older person* OR old person* OR older patient* OR old patient* OR "older women" OR "old women" OR "older men" OR "old men" OR old adult* OR older adult* OR "Older individual" OR "Older individuals" OR "old people" OR "older people" OR "Oldest Old" OR "Nonagenarians" OR "Nonagenarian" OR "Octogenarians" OR "Octogenarian" OR "Centenarians" OR "Centenarian" OR "septuagenarian" OR "septuagenarians" OR "aging" OR "ageing")) NOT ti=(veterinary OR rabbit OR rabbits OR animal OR animals OR mouse OR mice OR rodent OR rodents OR rat OR rats OR pig OR pigs OR porcine OR horse* OR equine OR cow OR cows OR bovine OR goat OR goats OR sheep OR ovine OR canine OR dog OR dogs OR feline OR cat OR cats)

And the search in Cochrane Library resulted in 225 articles with the following search terms,

(("Exercise" OR "Exercise" OR "physical activity" OR "Physical Exertion" OR "Fitness" OR "Sport" OR "Physical Exertion" OR "Physical Fitness" OR "Sports" OR "sport" OR "physical care" OR "Physical Education" OR "Physical Education" OR "physical training" OR "Healthy Lifestyle") AND ("mhealth" OR "m-health" OR "mobile health" OR "wearable technology" OR "wearable technologies" OR "Smartphone" OR "Smartphones" OR iphon* OR "mobile apps" OR "mobile apps" OR "app" OR "apps" OR webapp* OR "ehealth" OR "e-health" OR "Telemedicine") AND ("elderly" OR "elder" OR "elders" OR geriatr* OR "Homes for the Aged" OR "Health Services for the Aged" OR "Senior Centers" OR older adult* OR old adult* OR older person* OR old person* OR older patient* OR old patient* OR "older women" OR "old women" OR "older men" OR "old men" OR old adult* OR older adult* OR "Older individual" OR "Older individuals" OR "old people" OR "older people" OR "Oldest Old" OR "Nonagenarians" OR "Nonagenarian" OR "Octogenarians" OR "Octogenarian" OR "Centenarians" OR "Centenarian" OR "septuagenarian" OR "septuagenarians" OR "aging" OR "ageing")):ti,ab,kw

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