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Mobile Health Intervention Reduces Sedentary Time and Physical Inactivity in Patients with Cardiovascular Diseases after Discharge: Systematic Review and Meta-Analysis

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Abstract

Background: Long sedentary time and physical inactivity negatively impact patients with cardiovascular diseases (CVD). Although more and more studies are exploring the effects of mobile health (mHealth), whether an intervention using mHealth reduces sedentary time and physical inactivity is controversial. **Objective:** This systematic review aimed to investigate whether mHealth can reduce sedentary time and physical inactivity in patients with CVD via a comprehensive search and evaluation of relevant articles and review of the effects of mHealth on sedentary time and physical inactivity. **Methods:** We searched articles on three databases PubMed, Web of Science, and CiNii using "mHealth," "CVD," and "clinical trials" as keywords. All studies using mHealth to reduce sedentary time and physical inactivity were included. We assessed risk of bias in the included studies and conducted a meta-analysis using a random effects model. **Results:** After screening 502 articles, we included five randomized controlled trials. In one study, sedentary time was shorter in the intervention group than the control group by 61.5 min/day at 24 weeks. Three studies using physical inactivity as outcome measures were included in a meta-analysis, and the pooled odds ratio was 0.38 (95% confidence interval, 0.22–0.65), favoring the intervention group. All studies showed high risk of performance bias and low risk of selection bias and reporting bias. **Conclusion:** The mHealth intervention may remind patients with CVD of exercise training and help them reduce sedentary time and physical inactivity. Future studies need to show for how long mHealth can reduce sedentary time and clarify the cost-effectiveness of the mHealth intervention.

Keywords: Cardiovascular diseases, meta-analysis, physical inactivity, sedentary time, text messages

Introduction

Physical inactivity is defined as <150 min of activity of moderate intensity per week in adults and <60 min of activity of moderate-to-vigorous intensity daily in adolescents.[1] It is measured subjectively by using questionnaires such as the international physical activity questionnaire (IPAQ) and the global physical activity questionnaire (GPAQ)[2] and objectively by using activity trackers. In the IPAQ/GPAQ, the length and frequency of the respondents participation in weekly physical activity (minutes per week) are recorded in three domains (activity while working, movements, and recreational activities). Vigorous-intensity activity, moderate-intensity activity, and inactivity are assigned metabolic equivalents (METs) of eight METs, four METs, and one MET, respectively. Less than 600 METs minutes per week is regarded as physical inactivity.[3] A review of observational studies and randomized controlled trials (RCTs) suggested that physical inactivity was an independent risk factor for cardiovascular diseases (CVD).[4] Subjectively measured physical activity is often overestimated and less accurate than objectively measured physical activity with wearables.[5,6]

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Sedentary behavior is defined as any waking behavior whose energy expenditure is 1.5 METs or less while in a sitting, reclining, or lying posture.[7] A systematic review and meta-analysis by Biswas *et al*. showed that long sedentary time increased the incidence of CVD and mortality from CVD, cancer mortality, and type 2 diabetes.[8] In a meta-analysis by Jingjie *et al*., the pooled relative risk of CVD incidence was 1.24 in the long sedentary time group compared with the shorter time group.[9]

Long sedentary time and physical inactivity have negative impacts on physical function in patients with CVD. The short physical performance battery (SPPB) is a useful tool to assess physical function in lower limbs, and a SPPB score lower than 10 points is associated with high all-cause mortality.[10] In patients participating in phase I cardiac rehabilitation, the long sedentary time group had a lower score (10.5 ± 2.4 points, $P = 0.001$) on the SPPB than did the shorter time group.[11] Physical inactivity in patients with CVD is one of the components involved in developing physical frailty.[12] Reducing sedentary time and physical inactivity in patients with CVD may maintain their physical function and prevent their readmission to hospital.

A break in sedentary time refers to interrupting sedentary periods with physical activity, and increasing the number of breaks is associated with reduced metabolic risk.[13] In a previous study, sedentary time decreased and the number of breaks increased from baseline to 12 weeks after patients entered cardiac rehabilitation. However, these measures returned to the baseline level from 12 weeks to 6 months later.[14] Although cardiac rehabilitation may be one of the methods of reducing sedentary time, its long-term effects are controversial. We need to examine how to reduce sedentary time and physical activity over the long term.

Mobile health (mHealth) appeared in 2008, and an increasing number of studies are exploring the effects of mHealth,[15] which is defined as medical and public health practice using mobile devices, such as mobile phones, monitoring devices, personal digital assistants, and other wireless devices.[16] Mainly a short message service, mHealth has been used in patients with chronic diseases such as CVD, diabetes mellitus, and lung diseases. mHealth primarily works to provide reminders, and seven of 13 studies for CVD resulted in significant improvements in blood pressure, weight, and lipid profile with mHealth use.[17]

A systematic review and meta-analysis by Akinosun *et al*. showed the effect of digital intervention on sedentary behavior. In their study, the digital intervention included both mHealth and instruction given over the telephone and Internet. The estimated risk ratio of physical inactivity was 0.54 (95% confidence interval [CI] 0.39–0.75, $P < 0.001$).[18]

As mentioned in previous studies, maintaining a non-sedentary lifestyle in patients with CVD over the long term, even after receiving cardiac rehabilitation, is crucial. The use of mHealth applications may serve as reminders for exercise training and help reduce sedentary time or physical inactivity. However, few studies have investigated the specific effects of mHealth interventions on sedentary time or physical inactivity in patients with CVD.

We hypothesized that use of an mHealth intervention in patients with CVD would reduce sedentary time and physical inactivity after discharge compared with not using it.

This systematic review aimed to investigate whether mHealth interventions can reduce sedentary time and physical inactivity in patients with CVD. We conducted a comprehensive search and evaluated relevant articles to review the effects of mHealth on sedentary behavior and physical inactivity.

Methods

Eligibility criteria

The present study was not registered, and no protocol was prepared. The design of the present study was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[19] The present review included only interventional studies. Inclusion criteria for the studies were patients aged 18 or older with CVD, using mHealth to change lifestyle and/or measure physical activity, using sedentary time or physical inactivity as outcome measures, manuscripts written in English and published in 2008–2023, interventional study design, and not an abstract. Exclusion criteria included studies without control groups, observational studies, reviews, meta-analyses, study protocols, and editorials.

Search strategy

We searched studies on three databases: PubMed, Web of Science, and CiNii, using "CVD," "mHealth," and "clinical trials" as keywords. The specific keywords used for each database are listed in the Supplementary Figure 1. The study search was conducted on April 9, 2023. When searching, we used filters to gather only studies published in 2008–2023. The studies selected through searching were stored in the Rayyan systematic review tool, and duplicates were removed.[20] If the manuscripts were unavailable in our institution, we sent E-mails to the authors and/or researchers in other institutions and asked them to provide the full text of the manuscript. Subsequently, we asked two researchers to provide the full text of the article they wrote, and we obtained it as a result.

Selection process

The article selection process consisted of initial screening of the title and abstract and then full-text screening. In the title and abstract screening, two researchers (R.Y. and K.I.) independently read the title and abstract of each study and included the related studies according to the inclusion criteria. In the full-text screening, two researchers (R.Y. and M.K.) independently read the full text of the included studies according to the exclusion criteria. The results of the two researchers were integrated using Rayyan, and the third researcher (Y.K.) assessed any conflicts in the decisions.

Data collection process

We extracted the following information from the included studies: Manuscripts (author, publication year, country, and study design), participants (sample size, diseases, age, and sex), interventions, outcome measures, and the summary of the findings.

Assessment of the risk of bias

Two researchers (R.Y. and M.K.) independently assessed the risk of bias in the included studies according to the Cochrane collaboration risk of bias tool,[21] and the results of the two researchers were integrated. We evaluated each of seven domains: Random sequence generation, allocation concealment, blinding (participants and personnel), blinding (outcome assessment), incomplete outcome data, selective reporting, and other sources of bias as "low risk," "unclear risk," or "high risk."

Meta-analysis

We conducted a meta-analysis using EZR analysis software (Saitama Medical Center, Jichi Medical University, Saitama, Japan). The pooled odds ratio of physical inactivity and 95% CI were calculated. To assess the heterogeneity of the studies, I^2 and P values were calculated. We regarded the heterogeneity as high if $I^2 > 50\%$ and $P < 0.05$.[22] The fixed effects model was used when heterogeneity was low and the random effects model when heterogeneity was high. We assessed publication bias using funnel plots and the Begg's test.[23]

Results

Study selection

The flow diagram of the present study is shown in Figure 1. Through searching in the three databases, 526 articles were found. After removing the duplicate articles, 502 articles were read through in the screening process. Title and abstract screening resulted in the exclusion of 483 articles, and 14 more articles were excluded through full-text screening. Of these 14 articles, 10 were excluded because of their outcome measure, and the other four were excluded because of their study design. Finally, we included five articles in the present review, and three of these five articles were included in a meta-analysis.

Study characteristics

Overview of the included studies

A summary of the included articles is shown in Table 1. We included five studies published in Pakistan,[24] Korea,[25] New Zealand,[26] the United States,[27] and Australia.[28] All studies were RCTs comprising 1,936 participants in total. The age of the participants in the five studies (mean ± standard deviation) was 58.8 ± 10.3 years old. The number of participants varied from 25 to 879 and the female ratio from 14.1% to 24.0%. The participants were all patients with CVD such as coronary heart diseases, postacute coronary syndrome, and heart failure.

Mobile health

All studies used text messages to educate the participants about healthy lifestyles and remind them of exercise training.[24-28] The frequency of the text messages was one message per day,[24] three messages per week,[26] four messages per week,[25,28] and depending on each participant's need and request.[27] Two studies used the interventions shown below in addition to text messages. Maddison *et al*.[26] used a smartphone and chest-worn wearable sensor for the purpose of real-time monitoring and coaching in remote exercise training, reviewing exercise performance data, and goal setting. Duscha *et al*.[27] used the Fitbit activity tracker and the Vida Health app for the purposes of collecting physical activity, exercise prescriptions, and health coaching. The duration of the intervention was from 12 weeks[27] to 6 months, equivalent to 25 weeks.[24-26,28]

Three studies in the present review showed the cost of the intervention. The costs were 2.1 United States Dollars (USD) for the text messaging program and 0.5 USD for the commercial text messenger app,[25] 1,130 New Zealand Dollars (NZD) for a 24-week intervention,[26] and <10 USD for 96 text messages,[28] respectively. In one study,[26] the total cost of treatments was lower in the intervention group than in the control by 4,615 NZD when adding hospital services and medications to the intervention. Although the researchers were supposed to calculate cost-effectiveness through the incremental cost-effectiveness ratio, health-related quality of life did not differ between the groups, and thus an incremental cost-effectiveness ratio could not be calculated.

Sedentary behavior and physical inactivity

Only one study[26] measured sedentary time (minutes per day). The mean difference in sedentary time between the intervention group and control group was −32.8 (−88.0–22.4) min/day at 12 weeks and −61.5 min (−117.8–−5.3) at 24 weeks, favoring the intervention group.

Three studies measured physical inactivity using the IPAQ[24,25] and GPAQ questionnaires.[28] In the study by Manzoor *et al*.,[24] the mean MET minutes were not significantly different between the control and intervention groups at baseline and at 12 weeks ($P = 0.390$) but differed significantly at 24 weeks ($P = 0.007$). At baseline, 22.5% of the participants in the low physical activity category were in the control group and 25.0% were in that category the intervention group. At 24 weeks, 32.6% were in the low physical activity category in the control group and 12.8% were in that category in the intervention group. The relative risk of physical inactivity at 6 months follow-up was 0.75 (95% CI 0.66–0.86, $P < 0.001$) in one study[25] and 0.55 (95% CI 0.47–0.64, $P < 0.001$) in another.[28]

In a study by Duscha *et al*.,[27] "light" activity measured by Fitbit was defined as "low" activity for the purpose of comparing activity level with government guidelines. Low activity minutes did not change between the end of cardiac rehabilitation and 12 weeks after cardiac rehabilitation in

Table 1: Summary of the articles

Author (year)/country	Design	Participants (*n*)/age/female ratio	Intervention/duration	Outcome/tool	Summary
Manzoor *et al*. (2021)/Pakistan[24]	RCT	Post-ACS patients (*n* = 160)/52.67 ± 8.4 years/21.2%	CR + individualized counseling + diurnal mobile texting/24 weeks	Low PA/IPAQ	At baseline and 12-week follow-up, PA levels were not significantly different ($P = 0.390$) At 24-week follow-up, the mean MET minutes significantly differed between the intervention and control groups ($P = 0.007$)
Bae *et al*. (2021)/Korea[25]	RCT	Post-PCI patients (*n* = 879)/60.4 ± 10.5 years/16.7%	SMS text messaging/6 months	PI/shortened Korean version of IPAQ	Adjusted relative risk of PI between the control and intervention groups was 0.75 ($P < 0.001$) Per capita cost of the SMS text messaging program was 2.1 USD, and the commercial text messenger app was 0.5 USD
Maddison *et al*. (2019)/New Zealand[26]	RCT	CHD patients (*n* = 162)/61.2 ± 12.6 years/14.1%	Remotely monitored exercise-based CR/24 weeks	Sedentary time/actigraph uniaxial accelerometer	At 24 weeks, a small difference in sedentary time favored remotely monitored exercise-based CR (adjusted mean difference: −61.5 min/day; 95% CI: −117.8–−5.3) Per capita total cost of treatments was lower in the intervention group than in the control by 4,615 NZD. HRQoL did not differ between the groups, and cost-effectiveness could not be calculated
Duscha *et al*. (2018)/United States[27]	RCT	CR participants (*n* = 25)/62.2 ± 8.2 years/24.0%	CR + collection of PA + exercise prescription + health coaching/12 weeks	Low activity minutes/activity tracker	Low activity minutes did not change significantly in the control and intervention groups
Chow *et al*. (2015)/Australia[28]	RCT	CHD patients (*n* = 710)/57.6 ± 9.2 years/18.0%	Usual care + 4 text messages per week/6 months	PI/GPAQ	The relative risk of PI was 0.55 (95% CI: 0.47–0.64) ($P < 0.001$) Per capita cost of 96 text messages was <10 USD

ACS=Acute coronary syndrome, CHD=Coronary heart disease, CR=Cardiac rehabilitation, GPAQ=Global Physical Activity Questionnaire, HRQoL=Health-related quality of life, IPAQ=International Physical Activity Questionnaire, NZD=New Zealand Dollars, PA=Physical activity, PCI=Percutaneous coronary intervention, PI=Physical inactivity, RCT=Randomized controlled trial, SMS=Short message service, USD=United States Dollars, MET=Metabolic equivalent, CI=Confidence interval

either the mHealth intervention group or the usual care group.

Risk of bias in the included studies

The result of the assessment of the risk of bias is shown in Figure 2. All studies had a low risk of bias in random sequence generation and selective reporting, and all had a high risk of bias in blinding (participants and personnel).

Meta-analysis

The forest plot of the meta-analysis is shown in Figure 3. Three studies[24,25,28] used physical inactivity (<600 METs min per week) as an outcome measure, and a meta-analysis was conducted using these studies. We used the random effects model because the heterogeneity was very high ($I^2 = 84\%$, $P < 0.01$). The pooled odds ratio of physical inactivity was 0.38 (95% CI 0.22–0.65), favoring the intervention group. Although the funnel plot appeared to be asymmetrical [Supplementary Figure 1], Begg's test did not show significant publication bias (Kendall's tau = −0.33, $P = 1.00$).

Discussion

Study summary

Five RCTs using mHealth to reduce sedentary time and physical inactivity in patients with CVD were included. All studies used text messages to educate the participants about healthy lifestyles and remind them to perform exercise training.[24-28] One study showed that sedentary time in the intervention group was shorter than that in the control group by 32.8 min/day at 12 weeks and by 61.5 min/day at 24 weeks.[26] The other studies using questionnaires did not show sedentary time clearly.[24,25,28] From our meta-analysis, the pooled odds ratio of physical inactivity in three studies was 0.38, which favored the intervention group [Central Illustration].

Comparison with previous studies

A previous review[18] included 25 studies, of which four studies published from 2009 to 2017 used physical inactivity as an outcome measure. In contrast, the present review included five

Key question

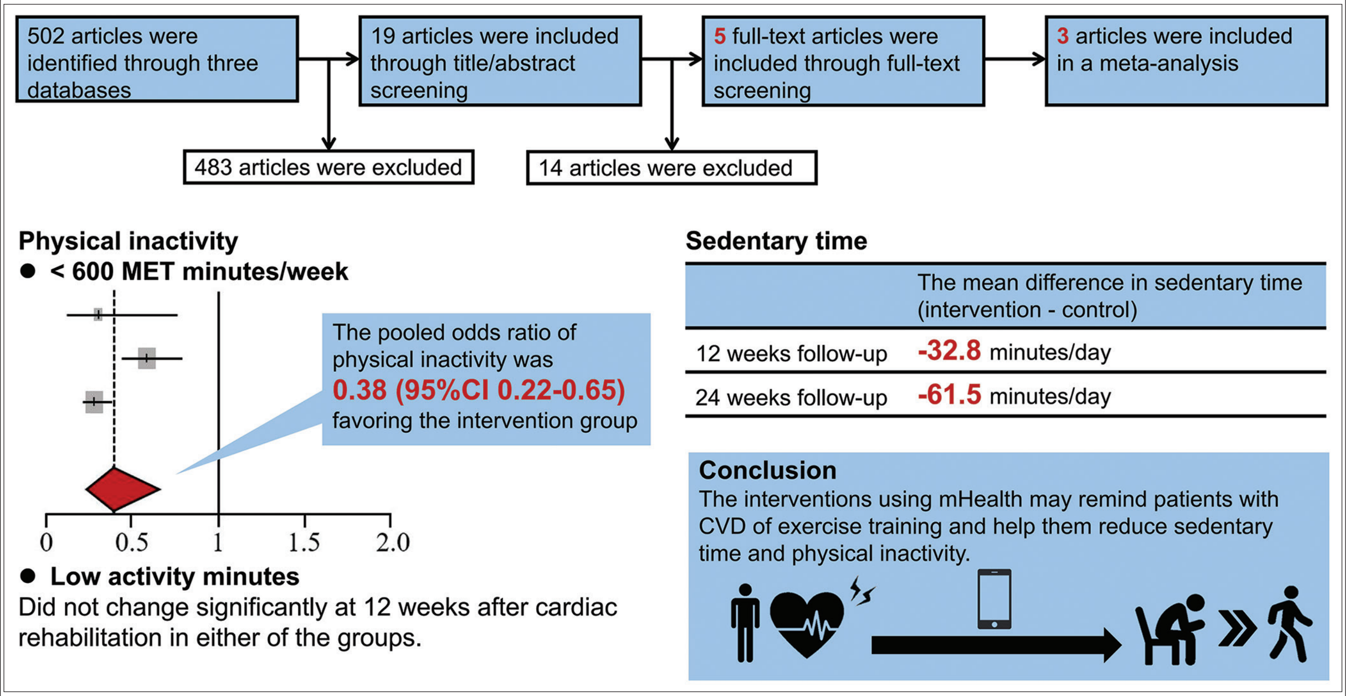
Can the use of mHealth intervention in patients with CVD reduce sedentary time and physical inactivity after discharge?

Key finding

In one study, the mean difference in sedentary time between the intervention group and the control was 61.5 minutes per day at 24 weeks follow-up. Three studies used physical inactivity as outcome measures and the pooled odds ratio of physical inactivity was 0.38.

Message for readers

Interventions using mHealth may remind patients with CVD to perform exercise training and help them reduce their sedentary time and physical inactivity to maintain a non-sedentary life. Future studies need to use accelerometers to measure inactivity and to show how long mHealth can reduce sedentary time.



Central Illustration: The effect of mHealth intervention on sedentary time and physical inactivity in patients with cardiovascular disease. CVD=Cardiovascular diseases, MET=Metabolic equivalent, CI=Confidence interval

studies published from 2015 to 2021. One study, conducted by Chow *et al*.,[28] was included in both reviews. Participants were patients with CVD in both the previous[18] and the present review. Contrary to the effect on patients with CVD, mHealth intervention did not significantly reduce sedentary time in healthy children and adolescents aged 21 or younger.[29] In the previous review,[18] the mean age of the participants was 60.0 ± 2.7 years old, and the female ratio was 24.7%. Similarly, in the present review, the mean age was 58.8 ± 10.3 years old, and the female ratio ranged from 14.1% to 24.0%.

In terms of the contents of the intervention, the previous review[18] included intervention over the telephone and the Internet in addition to mHealth, whereas the present review included only studies using mHealth. In another similar review,[30] behavioral change techniques suggested by smartphone apps to improve physical activity and/or sedentary behavior were examined in patients with CVD. These techniques were categorized based on the behavior change technique taxonomy (v1),[31] and "habit reversal" was the most frequently used to improve sedentary behavior. However, the effect on sedentary behavior could not be analyzed because of an inadequate number of studies.

In terms of the duration of the intervention in the presently reviewed studies, the follow-up period ranged from 12 weeks[27] to 6 months.[24-26,28] A 6-month follow-up was conducted most frequently,[24-26,28] and all of these studies showed a positive effect on sedentary time or physical inactivity. In a review by Pfaeffli Dale *et al*.,[32] two of seven RCTs used physical activity as an outcome measure and showed a positive effect at both the 3- and 6-month follow-ups, respectively. In addition, Al-Arkee *et al*. examined the effect of intervention using mHealth on patients with CVD in their review,[33] although their outcome measure was medication adherence. The duration of the intervention did not have a statistically significant impact on medication

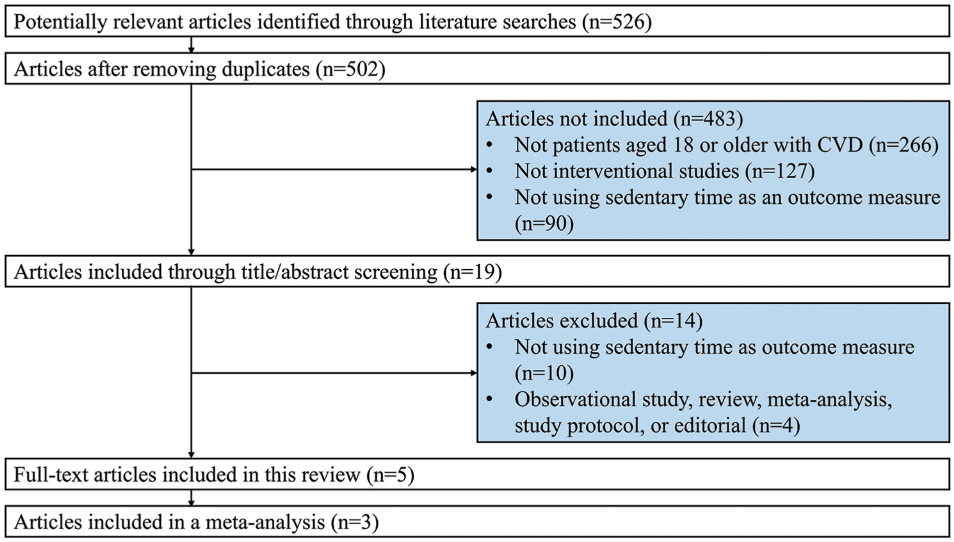


Figure 1: Flow diagram of the present study

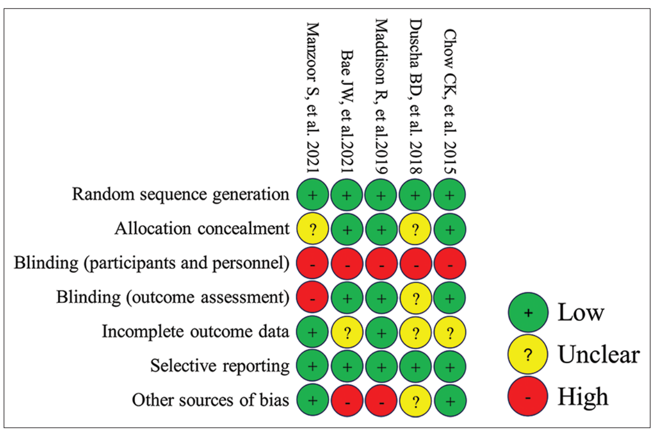


Figure 2: Assessment of the risk of bias of the included studies

adherence according to their meta-regression analysis, possibly because the heterogeneity in the included studies was high. These results indicate that the effective duration of intervention using mHealth may be around 6 months. However, future studies need to analyze the impact of intervention duration on sedentary time or physical activity through subgroup analyses.

The present review showed a low risk of selection bias and reporting bias and a high risk of performance bias. A recent systematic review that evaluated the effect of mHealth interventions on patients with heart failure similarly showed a low risk of reporting bias and a high risk of performance bias.[34] In intervention studies, participants can easily know whether they belong to the intervention group or not, and this could have yielded a high risk of bias in blinding of participants in both the previous and present study.

A previous review[18] conducted a meta-analysis that assessed the relative risk of physical inactivity, and the pooled relative risk was 0.54 (95% CI 0.39–0.75, $P < 0.001$). Similarly, the meta-analysis in the present review revealed a pooled odds ratio of 0.38 (95% CI 0.22–0.65, $P < 0.001$).

Possible explanations and implications

All studies included in the present review used text messages for education and reminders. In most of the studies, it took 24 weeks to complete the interventions and sedentary time and physical inactivity decreased even at the 24-week follow-up. Text messaging and 24-week follow-up intervention may be effective in keeping patients with CVD non-sedentary.

By using mHealth, patients and therapists do not need to meet face-to-face. In rural areas where personnel and facilities are insufficient, mHealth may help more patients receive health coaching, goal setting, and exercise prescriptions.

The female participation rate among the included study participants was approximately 20%. Generally, women have a low rate of participation in cardiac rehabilitation,[35] possibly due to household responsibilities such as housework and childcare, which may leave them with less time to attend rehabilitation programs. mHealth intervention may improve the gender difference in cardiac rehabilitation participation rates. Increasing the opportunity to use the mHealth intervention may save participants time in visiting the facilities and enable them to participate in cardiac rehabilitation at home.

Although several studies in the present review showed the financial cost of the intervention, cost-effectiveness was not calculated. One study showed lower costs in the intervention group,[26] indicating that an intervention using mHealth may be cost-effective.

Most studies on mHealth include only participants who have their own mobile phones. We need to take measures allowing patients who cannot use mobile phones to also access the interventions. In addition, the mean age of participants included in the present review was about 58 years old, and studies that include older participants are lacking. A recent review showed that older patients with CVD have barriers to using mHealth such as vision loss and lack of knowledge and have difficulty in receiving

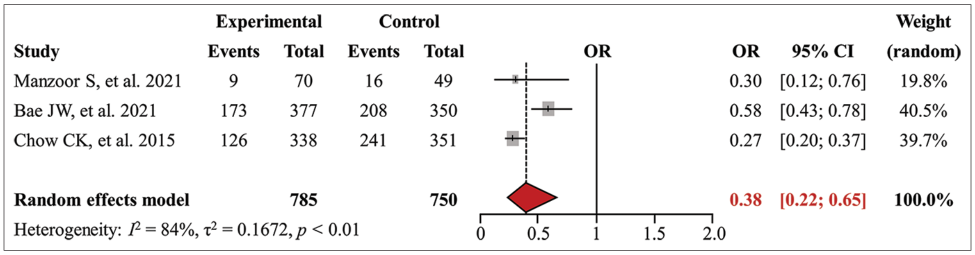


Figure 3: Results of the meta-analysis of physical inactivity. OR=Odds ratio, CI=Confidence interval

cardiac rehabilitation through mHealth.[36] To overcome these barriers, technology such as personal voice assistants has been developed. Additional advancements in technology could enable these older patients to easily receive mHealth interventions.

Strengths of this study

To our knowledge, this is the first systematic review of the effects of mHealth on sedentary behavior and physical inactivity in patients with CVD. We investigated ways to reduce sedentary time and physical activity in patients with CVD, especially focusing on mHealth. As a result, we showed that mHealth might be useful in reducing sedentary time and physical inactivity in these patients.

The study design of this systematic review was based on the PRISMA statement, and we assessed the quality of each of the included studies in detail. We also conducted a meta-analysis including only RCTs.

Limitations

This study has several limitations. One purpose of the present review was to investigate via a meta-analysis the length of time for which mHealth can reduce sedentary time. However, only one study used sedentary time as an outcome, and we could not conduct a meta-analysis for this outcome. Future studies should use accelerometers and show the length of time that mHealth use can reduce sedentary time in patients with CVD. Second, we conducted a meta-analysis using only three studies of physical inactivity instead of sedentary time. Therefore, their heterogeneity was very high, and the effect might be overestimated or underestimated. Third, to investigate the effect of mHealth, most of the studies excluded participants who did not own or could not use mobile phones. This might have resulted in selection bias. Fourth, physical inactivity was subjectively measured in the included studies. Subjectively measured physical activity may lead to overestimation and be less accurate compared to objectively measured physical activity. Finally, the screenings resulted in only five articles for analysis, none of which was from Europe, Africa, or South America. This may be because few studies used sedentary behavior as an outcome measure.

Conclusion

Interventions using mHealth may remind patients with CVD to perform exercise training and help them reduce their sedentary time and physical inactivity to maintain a non-sedentary lifestyle. Few studies have measured sedentary time objectively with the use of accelerometers. Future studies will need to use accelerometers to measure inactivity and show how long mHealth can reduce sedentary time in patients with CVD. In addition, future studies need to clarify cost-effectiveness of the intervention using mHealth.

Author contributions

All authors developed the concept and the design of the study. Ryo Yoshihara conducted a literature search, statistical analysis, and manuscript preparation. Masahiro Kitamura, Kodai Ishihara, Yuji Kanejima, and Kazuhiro P. Izawa edited and reviewed the manuscript. All authors have given the final approval for the current version to be published.

Ethical statement

Ethical statement is not applicable for this article.

Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Financial support and sponsorship

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Conflicts of interest

Dr. Kazuhiro P. Izawa is an editorial board member of *Heart and Mind*. The article was subject to the journal's standard procedures, with peer review handled independently of Dr. Kazuhiro P. Izawa and the research groups. There are no conflicts of interest.

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Supplemental Materials

The keywords used in each database

PubMed	
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#3	(Multicenter Study [Publication Type]) OR (Comparative Study [Publication Type]) OR (Clinical Trial [Publication Type]) OR (Controlled Clinical Trial [Publication Type]) OR (Randomized Controlled Trial [Publication Type]) OR (Prospective Studies [MeSH Terms]) OR (Follow-Up Studies [MeSH Terms]) OR (Randomized Controlled Trials as Topic [MeSH Terms]) OR (Clinical Trials as Topic [MeSH Terms])
#4	#1 AND #2 AND #3

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#2	TI=(Mobile health) OR TI=(mHealth)
#3	#1 AND #2

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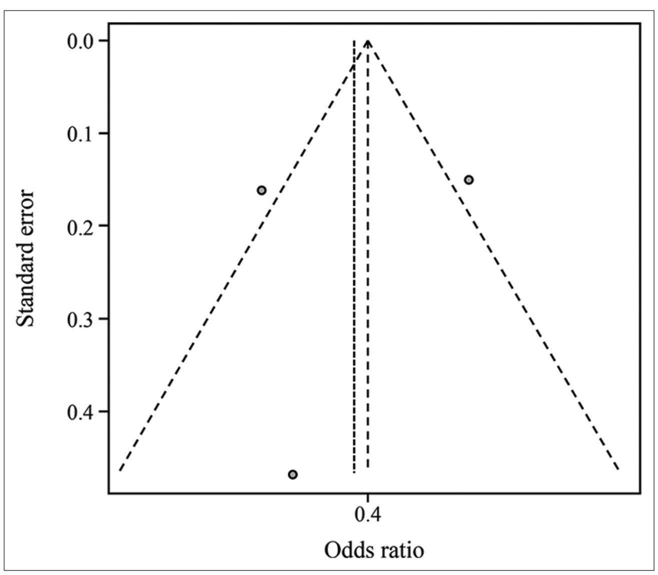

Supplementary Figure 1: Funnel plot