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Examining adherence to activity monitoring devices to improve physical activity in adults with cardiovascular disease: A systematic review

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Abstract

Background: Activity monitoring devices are currently being used to facilitate and monitor physical activity. No prior review has examined adherence to the use of activity monitoring devices amongst adults with cardiovascular disease.

Methods: Literature from June 2012 to October 2017 was evaluated to examine the extent of adherence to any activity monitoring device used to collect objective physical activity data. Randomized control trials comparing usual care against the use of an activity monitoring device, in a community intervention for adults from any cardiovascular diagnostic group, were included. A systematic search of databases and clinical trials registers was conducted using Joanna Briggs Institute methodology.

Results: Of 10 eligible studies, two studies reported pedometer use and eight accelerometer use. Six studies addressed the primary outcome. Mean adherence was 59.1% (range 39.6% to 85.7%) at last follow-up. Studies lacked equal representation by gender (28.6% female) and age (range 42 to 82 years).

Conclusion: This review indicates that current research on activity monitoring devices may be overstated due to the variability in adherence. Results showed that physical activity tracking in women and in young adults have been understudied.

Keywords

Adherence, activity monitoring device, accelerometer, pedometers

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Introduction

Rationale

Cardiovascular disease (CVD) remains the leading cause of death and disability globally and is a significant burden on healthcare systems.[1,2] Practitioners have long recognized the importance of physical activity for the maintenance of good health and the prevention of chronic diseases, such as CVD.[3] Returning to activities of daily living and maximizing physical capacity is an important component of the cardiac

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rehabilitation process.[4] Initiation of physical activity, along with the uptake of other risk factor modifications, is highly beneficial to the treatment and ongoing maintenance of CVD.[4,5]

Activity monitoring devices and smartphone applications are a cost-effective alternative to promoting physical activity and such devices, designed to improve physical activity in adults with CVD and other chronic conditions, are currently being tested.[6–9] Additionally, activity monitoring devices have been shown to affect PA behavior change.[10–12] These technologies overcome limitations associated with traditional in-person exercise programs that often have costly resource and labor requirements and are time intensive.[13]

To understand whether interventions using such devices have been effective, we need to identify not only whether behavior change occurred, but the extent to which participants did what was asked of them. This is fundamentally important because inefficient regimen effect can be responsible for an ineffective intervention, and non-significant results.[14] Rate of adherence to the use of activity monitoring devices as specified by the study protocol is a crucial parameter when evaluating programs. However, many studies often report outcomes rather than participant commitment to the intervention,[15] leaving adherence underreported or not reported at all.

A high proportion of the population already carries smartphones and the rate of ownership in developed economies was estimated at above 70% in 2015.[16] Such high uptake of smartphones that can double as physical activity monitors offers significant potential for researchers and clinicians working to promote or measure physical activity. Furthermore, validation studies of the accuracy of commercially available activity tracking technology have been undertaken.[17–19] Functionality of such devices includes accelerometry, step counting (pedometers), visual feedback, activity progression, encouragement, social interaction and Global Positioning System (GPS) tracking, with some more sophisticated platforms incorporating more than one or all types of measurement.[17]

Activity monitoring devices and applications have the potential to make a direct and real-time impact on self-management of physical activity and offer clinicians real-world assessments of their patients' daily activity patterns.[18] Historically, whereas the collection of an individual's activity level data relied on either direct observation or self-report (which can be potentially inaccurate),[20] the latest generation of activity monitoring devices is frequently connected to a central internet platform for remote data sharing, thus enabling the collection of objective data. Although, the inability of such devices to capture physical activity in totality may be under representative of overall physical activity of an individual, for research purposes it is important to determine whether the translation of these types of devices into reliable data collection tools, outside of a controlled environment, is acceptable to participants and will provide reliable and authentic data. Irrespective of the type of device and how it is worn or carried, for valid and useful research data to be collected it must be operating and carried or worn by the participants for the expected duration of the study.

User acceptance and perceived usefulness are known to be associated with a long-term adoption of health mobile applications,[21] and although studies assessing the effectiveness and feasibility of activity monitoring devices as a modality, within a PA intervention, have previously been undertaken, studies have focused on chronic conditions (such as diabetes[6] and COPD[7]), health risk factors,[8,10,13] specific device types or specific populations (e.g. children/youth[22,23]) and not adults with CVD.

A preliminary search of the Joanna Briggs Institute (JBI) Database of Systematic Reviews and Implementation Reports, the Cochrane Central Register of Controlled Trials and PROSPERO International Prospective Register of Systematic Reviews found no systematic review focusing specifically on adherence to the use of activity monitoring devices by adults with CVD. Addressing this gap, this review synthesizes the current literature around adherence in the use of activity devices or applications where study participants, with a confirmed diagnosis of CVD, have generated objective data measuring physical activity (not self-reported in a log or activity diary). Observed changes in physical activity and perceived acceptance of activity monitoring devices, intended to promote changes in physical activity, have also been incorporated into this review.

Objectives

This review examines any adherence to the use of devices or applications used to improve physical activity in adults with CVD. The objectives were to: 1) quantify the extent of adherence (as specified by the study protocol) in the use of activity monitoring devices in the last five years; 2) determine whether the extent of adherence differs by gender, age, length of study, types of device and how the device was worn; 3) determine whether the wearing of an activity tracking device was associated with changes in participants' level of physical activity; and 4) determine the perceived acceptability (satisfaction) of participants using an activity monitoring device or application to change levels of physical activity.

Methods

Protocol and registration

This systematic review was undertaken using a protocol peer reviewed by JBI[24] and registered with PROSPERO (CRD: 42018094781). It follows the preferred reporting items for systematic review and meta-analyses: the PRISMA Statement (Supplementary Material file I online).[25]

Eligibility criteria

Randomized controlled trials (RCTs) that compared, with usual care, an intervention for participants (aged 18 years and over) from any cardiovascular diagnostic group, who used an activity monitoring device in a research study within a community setting were searched. Diagnostic groups included: heart failure; cardiomyopathy conditions; medically managed acute myocardial infarction (ST-segment elevation myocardial infarction, non-ST-segment elevation myocardial infarction) – including or excluding post-myocardial infarction revascularization; medically managed coronary artery disease (e.g. stable angina); revascularization procedures including percutaneous coronary interventions and/or coronary artery bypass graft surgery; post-insertion of implementable defibrillator and permanent pacemaker; repair and replacement of valve device(s); device implant for ventricular assist; and heart transplant. Studies assessing stroke, those including participants less than 18 years of age, or where devices required the physical transcription of data by a participant or researcher (e.g. writing down or entering the daily step count) were excluded.

Usual care included promoting increases in physical activity to participants through printed material, verbal and/or digital form (i.e. audio/video, CD-ROM, website, iPad or other tablet device, computer, basic step counter, computer/internet-based program) and following normal daily physical activity behaviors and routines without directive to achieve increases in physical activity. Studies were included where they evaluated a device (worn or carried) or application to monitor physical activity (i.e. steps, distance travelled, GPS, time active, intensity, duration, rate, acceleration, etc.) in a community context. Ineligible studies included the use of a device or application that monitored activity as the comparator only.

Outcomes

This review considered studies that described physical activity as an outcome measure, although not necessarily considered as one of the outcomes of the RCT. Physical activity is usually defined in terms of intensity, duration and frequency of activity;[26] however, steps, floors climbed and total distance travelled were also considered in this review. Whilst rate of activity can be assessed in determinations of planned physical activity (e.g. fitness classes or runs per week), in the current review overall physical activity accrued in daily living is considered. Perceived acceptability by the participant of using a device or application in interventions intended to promote increases in physical activity is also reported.

Specifically, three outcomes were addressed: one primary and two secondary. The primary outcome was: adherence to the use of activity monitoring device to promote physical activity (adherence to the study protocol can be assessed by self-report, standardized or non-standardized instruments, reported as the feasibility of the intervention, evaluated from the extent of attrition or retention or documented as compliance). Secondary outcomes included: effect of device on physical activity levels (measured as duration, rate and intensity of physical activity, steps, floors climbed, distance travelled) and perceived acceptability (satisfaction) of using an activity monitoring device or application.

Information sources

The search strategy was designed to find both published and unpublished articles in the English language only, due to limited access to translators, and budgetary constraints. Papers published from June 2012 to October 2017 were included, representing a period of increasing availability and acceptance of activity tracking devices incorporation into research protocols.

Search

An electronic search was designed and performed by an experienced research librarian (PN) on 6 October 2017 using the following databases: Medline; CINAHL; PsycINFO; Scopus; Web of Science; Cochrane Central Register of Controlled Trials; ANZ Clinical Trials Registry; Clinicaltrials.gov; and WHO International Clinical Trial Registry Platform. The reference lists of all eligible studies were screened to inform the findings, and in the case of missing or incomplete data, corresponding authors were contacted. A copy of the detailed search strategy can be found in the Supplementary Material file II.

Study selection

Following the search, all citations were collated and uploaded into Endnote and duplicates removed. Titles and abstracts were screened by two independent

reviewers (TSM and CK) for assessment against the inclusion criteria. If consensus could not be reached a third reviewer (RAC) would assess. Full text articles were retrieved and the details of the selected studies were imported into JBI SUMARI[27] and comprehensively assessed against inclusion criteria (TSM and CK). Studies that did not meet these criteria were excluded and reasons entered into the PRISMA flow diagram (Figure 1).

Study protocol definitions

Tracking devices. The key elements of an activity tracking device have been identified as being electronic, wearable, using sensors to track the user's movements and having the ability to provide feedback beyond a basic display.[22] In this review it is defined as a wearable electronic device or smartphone application which records some aspect of movement or location for which the data can be downloaded and analyzed.

Adherence. Adherence is defined as how much a person's behavior (taking medication, following a diet or exercise plan and/or executing lifestyle change) corresponds with the recommendations.[28] Therefore, the measurement of adherence largely depends upon the nature of the study protocol and the recommendations provided. In this context there are no restrictions on how adherence is measured and studies where adherence to a device was assessed by self-report, standardized or non-standardized instruments, reported as the feasibility of the intervention, evaluated from the rate of attrition or retention or documented as compliance are included.

Physical activity interventions. Physical activity can be defined as any movement made by the body, requiring energy expenditure that produces progressive health benefits.[29] This review considers physical activity as part of the more focused definition of exercise as 'a subset of physical activity that is planned, structured,

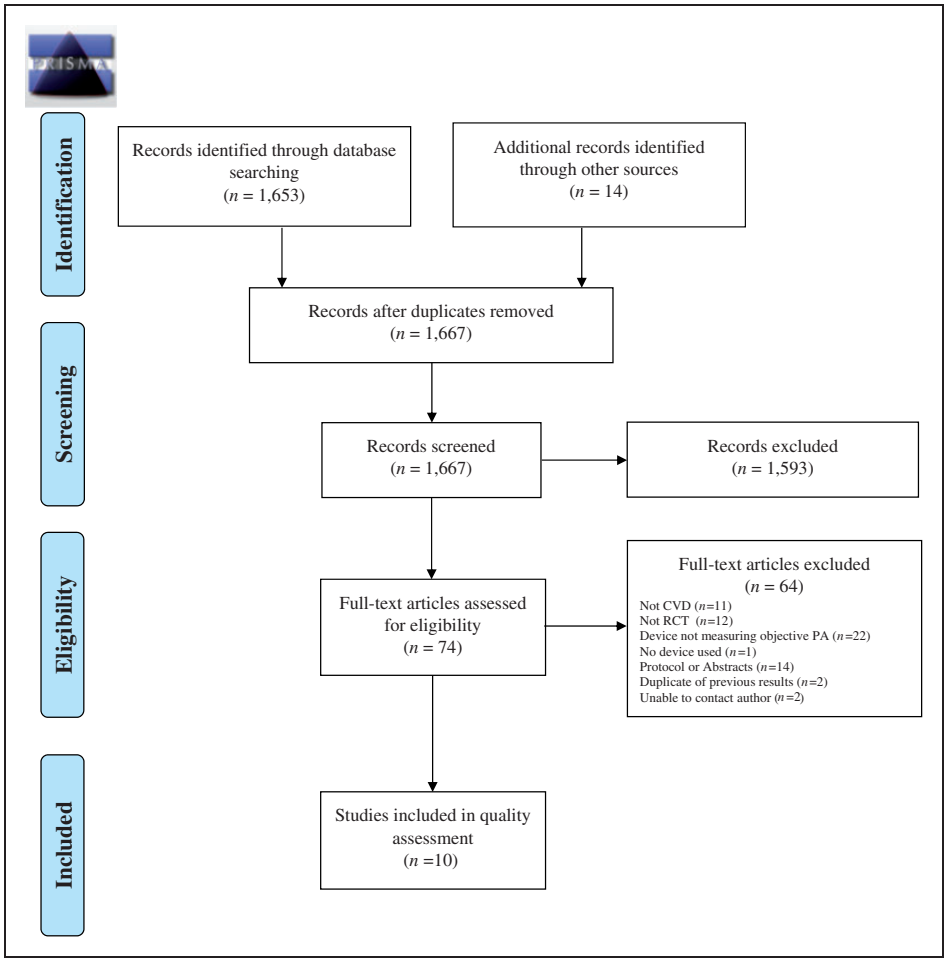

Figure 1. PRISMA flow diagram.
CVD: cardiovascular disease; PA: physical activity; RCT: randomized controlled trial

repetitive, and purposeful in the sense that improvement or maintenance of physical fitness is the objective' (Thompson et al.,[29] p.1). Interventions promoting improvements in physical activity in daily living that used a physical activity device or application, for example, where participants are asked to use and manage an activity monitoring device or application and provide these data (as were determined by the study protocol) to the study were included. Devices that required the physical transcription of data by a participant or researcher (e.g. writing down or entering the daily step count) were excluded.

Data collection process

Study characteristics and outcome data were systematically extracted by one reviewer (TSM) and thoroughly checked for accuracy and completeness by a second reviewer (CK). Contact was made with corresponding authors to determine the inclusion of eight studies as some information was unavailable in the manuscripts. This resulted in an additional three studies being excluded from the review (see Supplementary Material file III for full list of excluded studies).

Data items

Characteristics of eligible studies were extracted (see Table 1). The outcomes previously described were considered to assess inclusion. Overall means and standard deviations (SDs) of age and gender proportion for all participants at the point of randomization are reported. Where demographic data were not available individually by intervention group and control group numbers are provided as overall only. Where intention-to-treat analyses were not undertaken, and some loss to follow up was experienced, results in the primary outcome table are adjusted to include all randomized participants, to assess actual, rather than adherence rates after attrition.

Risk of bias in individual studies

To minimize the risk of bias within studies, methodological quality was assessed by two independent reviewers (TSM and CK) using the JBI standardized critical appraisal instrument for RCTs,[30] and disagreement was resolved by discussion or referral to a third reviewer (RAC). This information was used in assessing the strength of the body of evidence being reviewed.

Summary measures

Summary measures used to address the primary and secondary outcomes were: percentages to determine rate of adherence, mean number of steps per day, mean energy expended and mean number of minutes spent doing physical activity to assess changes in physical activity using objective data, and percentages of user acceptability.

Synthesis of results

As insufficient studies were identified that addressed the same, or similar, research question, a meta-analysis was not performed. A narrative synthesis of the study characteristics, methodological quality, summary of outcome measures and statistical significance is provided.

Risk of bias across studies

A summary of findings providing an assessment of risk of bias across studies was undertaken using GRADEPro GDT software. The GRADE approach for grading the quality of evidence was followed, presenting a narrative synthesis of the evidence based on study limitations (risk of bias) including, indirectness, inconsistency, imprecision and publication bias.

Results

Study selection

The electronic search identified 1653 records and an additional 14 were identified from clinical trials registries. Following de-duplication, the title and abstract of 1667 citations were screened and 74 papers were selected for full text assessment. Sixty-four papers were excluded, of which 46 did not meet our selection criteria, 14 were incomplete studies (abstracts or protocols) and two were duplicates of previous publications. Independent reviewers (CK and TSM) disagreed on three articles and these were sent to the third reviewer (RAC) for adjudication, resulting in the exclusion of one study. An additional two studies were excluded as we were unable to contact the authors. In all, 10 studies were identified for inclusion in this review – the first being published in 2012.

Study characteristics

The 10 RCTs included were conducted in nine developed countries: Australia,[31] Belgium,[32] Canada,[33] France,[34] Germany,[35] Norway,[36] Portugal,[37] the United Kingdom[38] and the United States of America (Table 1).[39,40] Studies included a total of 849 (27.7% female) participants ranging in age from 42 to 82 years (mean age range 54 to 70.2 years), who had been previously diagnosed with an eligible cardiac event. The study populations included those with acute coronary

Table 1. Characteristics of included studies.

Study	Country (setting)	Participants	Age in years Mean (SD) [range]	Female *n* (%)	CVD diagnosis	Device (worn)	Intervention	Follow-up (length of study)
Anderson et al. 2015[39]	US	*N* = 38 IG: *n* = 18 CG: *n* = 20 (usual care)	57.0 (10.8) [6.2 –67.8] IG: 56.6 (10.6) CG: 59.4 (12.9)	IG: 3 (17) CG: 8 (40)	CAD (PCTA, stent, CABG, MI, angina)	Pedometer (unknown)	Pedometer worn three months to measure steps/day (during waking hours). Mailed back in reply-paid envelope	Three months
Christle et al. 2017[35]	Germany	*N* = 70 IG: *n* = 35 CG: *n* = 35 (usual care)	70.0 (SD 9.0) [61–79] IG: 70.0 (8.0) CG: 70.0 (9.0)	28 (39) IG: 14 (39) CG: 14 (39)	CD (AHA – Class C moderate/high)	Accelerometer (hip)	Once-weekly individualized combined exercise (10 days)	Six months
Devi et al. 2014[38]	UK; GPs	*N* = 94 IG: *n* = 48 CG: *n* = 46 (usual care)	[56.1–76.3] IG: 66.3 (8.3) CG: 66.2 (10.1)	IG: 14 (29) CG: 10 (22)	CHD	Accelerometer (right upper arm)	Web-based cardiac rehabilitation program 'ActivateYourHeart' delivered via the internet (no face to face) – accelerometer worn two weekdays (12 h/day)	One and six months
Frederix et al. 2015[32]	Belgium	*N* = 139 IG: *n* = 69 CG: *n* = 70 (usual care)	61.0 (9.0) [52–70] IG: 61.0 (9.0) CG: 61.8 (8.0)	25 (18) IG: 10 (14) CG: 15 (21)	CAD or CHF	Accelerometer (pocket)	Six-week Web-based, comprehensive tele-CR (from weeks 6 to 12 of CR) plus usual 12-week center-based CR	One-and-a-half and six months
Guiraud et al. 2012[34]	France; CRP at clinic	*N* = 29 IG: *n* = 19 CG: *n* = 10 (usual care)	57.4 (12.4) [41.9–73.6] IG: 54.5 (12.6) CG: 62.9 (10.7)	5 (17) IG: 2 (11) CG: 3 (30)	CAD, HF	Accelerometer (waistband)	Wore accelerometer for eight weeks; telephone feedback and support (data automatically uploaded to Web portal)	Two months
Houle et al. 2012[33]	Canada	*N* = 65 IG: *n* = 32 CG: *n* = 33 (usual care)	[50–68] IG: 58.0 (8.0) CG: 59.0 (9.0)	14 (21.5) IG: 6 (19) CG: 8 (25)	ACS (unstable angina, STEMI or non-STEMI)	Pedometer (hip)	Pedometer-based program, PA behavior (average steps/day) associated with a diary to record other PA besides walking	Three, six, nine and 12 months
Malmo et al. 2014[36]	Norway	*N* = 51 IG: *n* = 26 CG: *n* = 25 (habitual PA)	[48–71] IG: 56.0 (8.0) CG: 62.0 (9.0)	IG: 6 (23) CG: 3 (22)	AF (non-permanent)	Accelerometer (upper arm)	Device (SenseWear Pro 3) was worn for at least four consecutive days both during the four-week baseline period and the two last weeks of the intervention period	One and five months
Ribeiro et al. 2017[37]	Portugal (outpatient clinic)	*N* = 138 IG: n = 71 CG: *n* = 67 (usual care)	[45–67] IG: 54.0 (9.0) CG: 58.0 (9.0)	IG: 23 (92) CG: 20 (80)	MI	Accelerometer (right hip)	Eight-week aerobic exercise program plus usual medical care and follow-up. Filtered digitized acceleration signals were recorded by accelerometers	Two months

(continued)

Table 1. Continued

Study	Country (setting)	Participants	Age in years Mean (SD) [range]	Female *n* (%)	CVD diagnosis	Device (worn)	Intervention	Follow-up (length of study)
Varnfield et al. 2014[31]	Australia	*N* = 120 IG: *n* = 60 CG: *n* = 60 (usual care)	[46.1–66.3] IG: 55.7 (10.4) CG: 55.5 (9.6)	14 (12) IG: 9 (15) CG: 5 (8)	MI	Accelerometer (smartphone)	Two supervised exercise and 1 h of educational sessions on a weekly basis for six weeks at one of four Health Service District community centers. Smartphone (Nokia N96, Nokia Inc. preinstalled with health diary (Wellness Diary, Nokia Research) and activity monitoring (StepCounter, Nokia Research) used for health and exercise monitoring, and delivery of motivational and educational materials to participants	Six months
Young et al. 2016[40]	US (Nebraska)	*N* = 105 IG: *n* = 54 CG: *n* = 51 (usual care)	70.2 (12.2) [58.0–82.4] IG: 68.7 (11.8) CG: 71.8 (12.6)	70 (67) IG: 29 (53) CG: 38 (75)	HF (Class II-IV)	Accelerometer (waist)	Usual care plus 12 week (PATCH) self-management (SM) training and coaching program delivered by telephone plus in two phases: a one-on-one in-hospital SM training session and post discharge reinforcement sessions (twice a week for weeks 1–2, once a week for weeks 3–6, and every other week for weeks 7–12) delivered by telephone	One, three and six months

ACS: acute coronary syndrome; AF: atrial fibrillation; AHA: American Heart Association; CABG: coronary artery bypass graft; CAD: coronary artery disease; CG: control group; CD: cardiac disease; CR: cardiac rehabilitation; CRP; cardiac rehabilitation maintenance program; CVD: cardiovascular disease; HF: heart failure; IG: intervention group; GP: General Practitioner; MI: myocardial infarction; PA: physical activity; PCTA: percutaneous transluminal coronary angioplasty; STEMI: ST-elevation myocardial infarction; UK: United Kingdom; US: United States

syndrome,[31–34,37–39] heart failure[32,34,40] and coronary heart disease.[34,35] All RCTs included the wearing or carrying of a device that objectively measured physical activity; 10 using an accelerometer and two a pedometer. Follow-up times ranged from one to 12 months.

Risk of bias within studies

All 10 studies included had notable methodological weaknesses. Randomization to control or intervention group was adequately concealed in only five studies,[31,33,37,38,40] blinding of the outcome assessors was found for four,[32,35,36,40] intention to treat analysis was undertaken in only three,[33,34,36] and participant blinding was not used in the any of the RCTs. Overall, only two studies[33,36] reached a quality score greater than 65% (Table 2).

Results of individual studies

Table 3 shows the six studies[31,34,35,37,38,40] that addressed our primary outcome (adherence) involving 556 participants (33.1% female). Mean adherence was 59.1% (39.6% to 85.7%) at last follow-up. In three studies[31,38,40] adherence rates were presented for two follow-up points. Two studies[31,40] reported the rate of adherence as decreasing with time (76.4% and 39.0% to 58.3% and 27.0% respectively) and in the other[38] the adherence rate remained constant (39.6%); however, these data should be interpreted with caution due to the methodological limitations of studies.

Where devices were worn/carried by both intervention group and control group and physical activity data were collected objectively. Intervention group participants showed a greater adherence in four of the studies.[31,35,37,40] Varnfield and colleagues[31] found a significant difference in adherence rates between intervention and control groups ($p < 0.05$) concluding that the use of a smartphone as part of their care assessment platform (intervention group) was more effective in keeping participants in rehabilitation (80% compared with 47% in the control group) and as effective in improving health outcomes.[31]

Table 4 shows the studies that addressed our secondary outcomes: objective measurement of physical activity and user acceptability of the device. Nine RCTs involving 798 participants (27.6% female) collected objectively measured physical activity. The majority of these RCTs[31–33,35,38–40] used steps per day from baseline to follow-up as an outcome measure. Change in steps per day was significantly different ($p < 0.05$) between intervention and control groups in four of these studies,[33,35,38,39] two reported non-significant results[32,40] and in one study[31] significance was not reported. The one study reporting changes in steps using a pedometer reported an increase of 1973.9 steps per day as compared with the RCTs reporting physical activity using accelerometers where steps per day increased from 497[38] to 1586[35] in the intervention groups. Two studies[34,37] reported physical activity as energy expended at different intensity levels and again significant differences between intervention and control groups were reported. As data were objectively collected directly from the device in each of the included studies, the data collected for intervention group and control group were for days worn (not passive days).

Two studies[31,32] addressing this review's last outcome involving 259 participants (15.1% female) reported very high acceptability of using a device (97% and 85% respectively). Frederix and co-authors[32] reported a 95% acceptance to their tele-rehabilitation program with 44% saying they were very satisfied and 51% satisfied. Varnfield and colleagues[31] used an accelerometer in a smartphone purely as a motivational tool and reported that 85% of participants found the step counter to be motivational in reaching their cardiac rehabilitation goals.[31]

Risk of bias across studies

The certainty of evidence for the three outcomes was generated using GRADEPro GDT software (Table 5). Certainty was moderate for the primary (adherence) and first secondary outcome (physical activity levels), due to methodological heterogeneity of studies and no intention-to-treat analyses, which may have impacted the adherence to the device and the mean number of steps/level of physical activity reported. Evidence for the acceptability outcome was provided by qualitative self-report feedback and the certainty of evidence has been downgraded to very low accordingly.

Discussion

Summary of evidence

No reviews have previously examined adherence to the use of activity monitoring devices amongst participants with a confirmed diagnosis of CVD. This systematic review has examined the extent of adherence to any activity monitoring device used to collect objective physical activity data between 2012 and 2017. Of the 1667 citations reviewed, 10 RCTs were eligible for inclusion, suggesting that this area has not been well researched. Six studies addressed the primary outcome (adherence) involving 556 participants (33.1% female). Overall, adherence across these six studies was 59.1% at last follow-up; ranging from 39.6% to 85.7% at six months.

Table 2. Risk of bias within studies.

JBI RCT critical appraisal tool	Anderson et al. 2015[39] *n* (%)	Christle et al. 2017[35] *n* (%)	Devi et al. 2014[38] *n* (%)	Frederix et al. 2015[32] *n* (%)	Guiraud et al. 2012[34] *n* (%)	Houle et al. 2012[33] *n* (%)	Malmo et al. 2014[36] *n* (%)	Ribeiro et al. 2017[37] *n* (%)	Varnfield et al. 2014[31] *n* (%)	Young et al. 2016[40] *n* (%)	Overall *n* (%)
1. Was true randomization used for assignment of participants to treatment groups?	U	Y	Y	Y[a]	U	Y[a]	Y[a]	Y	Y	Y	8 (80.0)
2. Was allocation to treatment groups concealed?	U	N	Y	N	U	Y[a]	N	Y	Y	Y	5 (50.0)
3. Were treatment groups similar at baseline?	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	9 (90.0)
4. Were participants blind to treatment assignment?	U	N[a]	N	N	U	N[a]	N	N	N	N	0 (0.0)
5. Were those delivering treatment blind to treatment assignment?	N	Y	N	N	U	N	N	N	N	N	1 (10.0)
6. Were outcome assessors blind to treatment assignment?	N	Y	N	Y[a]	U	N	Y[a]	N	N	Y	4 (40.0)
7. Were treatments groups treated identically other than the intervention of interest?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10 (100.0)
8. Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Y	N	Y	Y	Y	N	Y	Y	N	Y	7 (70.0)
9. Were participants analyzed in the groups to which they were randomized?	N	N	N	N	Y	Y	Y	N	N	N	3 (30.0)
10. Were outcomes measured in the same way for treatment groups?	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9 (90.0)
11. Were outcomes measured in a reliable way?	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	9 (90.0)
12. Was appropriate statistical analysis used?	N	N	N	N	N	Y	Y	N	N	N	2 (20.0)
13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	9 (90.0)
	5 (38.5)	8 (61.5)	8 (61.5)	8 (61.5)	7 (53.8)	9 (69.2)	10 (76.9)	8 (61.5)	5 (38.5)	8 (61.5)	

[a]Information obtained from primary research author.

JBI: Joanna Briggs Institute; N: no; RCT: randomized controlled trial; U: unable to contact author on this matter; Y: yes

Table 3. Summary of primary outcome: adherence to using the device.

Study	Adherence to device	Results (n = number of participants analyzed)	Adherence rate at follow-up %
Guiraud et al. 2012[34]	Accelerometer procedure and use of Web portal	Overall 100% adherence to device for both IG and CG at two months CG 36.8% of the IG achieved target for moderate-intensity PA at two months	**100.0**
Christle et al. 2017[35]	Wore accelerometer on hip for 10 days (minimum 10 h/day)	IG ($n = 30$) 84% adherence at six months CG ($n = 30$) 77% adherence at six months Non-completion: $n = 1$ (IG) developed muscle pain resulting in a discontinuation of exercise $n = 7$ (2 IG, 5 CG) discontinued due to reasons unrelated to clinical status or the intervention $n = 2$ (IG) were not included in the analyses due to incomplete data	**85.7**
Varnfield et al. 2014[31]	Used accelerometer (smartphone) to record ≥ 30 min of moderate activity on most days of the week	IG ($n = 26$) ↑ than CG – adherence to program (94%)* at four weeks ↑ than CG – completion of program (80%)* at six months Non-completion: logistical (2%); change in health (9%); difficultly in using IT tools (7%); lack of motivation (2%); improved health (2%) and other (5%) CG ($n = 46$) ↓ than IG – adherence to program (68%)* at four weeks ↓ than IG – completion of program (46%)* at six months Non-completion (>70%): logistical (25%); completing life demands (14%); change in health (14%); change in criteria (2%); study design (10%); lack of motivation (4%); privacy (2%); and other (2%)	**58.3**
Ribeiro et al. 2017[37]	Wore accelerometer seven consecutive days; measured PA ≥ 8 h/day	IG ($n = 71$) 45.1% (32) at eight weeks Non-completion: 2.8% (2) did not adhere to protocol (<80% exercise sessions) 54.9 (39) no seven-day and/or 8 h/day PA record CG ($n = 67$) 43.3% (29) at eight weeks Non-completion: 6.0% (4) lost to follow-up 56.7% (38) no seven-day and/or 8 h/day PA record	**44.2**
Devi et al. 2014[38]	Wore accelerometer two weekdays (12 hours/day) – IG only	IG (n = 48) 39.6% (19) completed the intervention (six months) 60.4% (29) did not progress past stage 3 (one month) average three log-ins/week per participant – over program mean = 18.68 (SD 13.13, range 1–51)	**39.6**
Young et al. 2016[40]	Wore accelerometer on waist daily	IG ($n = 51$) 45.1% (23) reported 7 days/week at three months 54.9% (28) reported 0–6 days/week exercise at three months 38.0% (19) reported 7 days/week at six months	**27.0**

(continued)

Table 3. Continued

Study	Adherence to device	Results (n = number of participants analyzed)	Adherence rate at follow-up %
		62.0% (31) reported 0–6 days/week exercise at six months CG ($n = 49$) 34.0% (16) reported 7 days/week at three months 66.0% (31) reported 0–6 days/week exercise at three months 17.4% (8) reported 7 days/week at six months 82.6% (38) reported 0–6 days/week exercise at six months	

CG: control group; IG: intervention group; PA: physical activity; ↓lower/decrease; ↑higher/increase
*$p < 0.05$

The primary outcome for this review was adherence to a device used to objectively measure physical activity, distinct from physical activity assessed by self-report.[41,42] However, studies that included the objective measurement of physical activity and also examined adherence to the study protocol were included. Adherence could be assessed by self-report, standardized or non-standardized instruments, reported as the feasibility of the intervention, evaluated from the extent of attrition (i.e. abandonment of wearing the tracking device) or retention, or documented as compliance. In two studies,[31,38] adherence was defined only as adherence to the protocol. In these studies, it was not possible to ascertain whether those not completing, or adhering to, the protocol, had adhered to using the device. A systematic review, conducted to establish measures available to assess self-reported adherence to home-based rehabilitation programs, found a gap in the literature for well-developed measures available to capture adherence.[14] Rather than simply recording numbers of those completing an intervention, it is suggested that a well validated and reliable self-report measure may provide extra support to clinicians in determining whether their prescribed exercise regime is effective, needs adjusting or the patient needs further support. Varnfield and colleagues[31] found a significant difference ($p < 0.05$) in adherence to their cardiac rehabilitation program, between intervention group and control group, and concluded that the use of a smartphone in conjunction with a home-based cardiac rehabilitation program overcame some key barriers, such as, work and family demands, poor motivation, dislike of group classes and the lack of personalized exercise regimens.

Bravata and colleagues[43] found that across 26 studies (eight RCTs and 18 observational studies), having a step goal was an important predictor of increased physical activity. Lau and colleagues[44] found consistent evidence supporting the improvement of psychosocial variables (e.g. self-efficacy[45]) through information and communications technology (ICT) interventions; however, the evidence for the change in behavioral variables, such as physical activity level, was less consistent. Barriers are likely to exist and differ at each of the levels of behavior change.[46] According to a study investigating the use of activity monitoring devices for the self-management of chronic conditions,[47] there are three key critical components to the long-term adherence to activity monitoring devices: formation of habit; social motivation; and goal reinforcement feedback. Additionally, usability is named as a key factor in the meaningful use of activity monitoring devices.[48]

Guiraud et al.[34] analyzed a group of participants who had previously been non-compliant to physical activity and participation in a cardiac rehabilitation program. They were subsequently randomized into activity monitoring device and non-device wearing groups to assess adherence to the device. This evaluation is important in that it provides evidence for those who may be able to adhere to a program of exercise or protocol but who are unable to adhere to the use of an activity monitoring device, and vice versa. In other settings, studies have shown that using pedometers to observe levels of physical activity can be useful to indicate adherence to activity programs.[49] Further research is needed to uncover whether adherence to a protocol may be a confounder in assessing adherence to the device.

While pedometers are becoming an item of everyday wear in the general population,[50] the use of accelerometers for research purposes has also seen a dramatic increase in use more recently[51,52] due to their size, ease of use and non-invasiveness. They are commonly used as an objective method for assessing physical activity in field-based research.[42] Compared with pedometers, accelerometers provide an increase in the accuracy of data,[53] are superior to self-report[54] and have the ability to integrate prompts and cues, reward mechanisms and self-monitoring of behavioral

Table 4. Summary of secondary outcomes: effectiveness and satisfaction.

Study	Objective PA measured by *accelerometer*	Result	*p* value
Christle et al. 2017[35]	Change in steps/day from baseline	IG ↑ steps/day (+1586) at six months CG ↓ steps/day (–838) at six months	<0.01
Devi et al. 2014[38]	Change in steps/day from baseline	IG ↑ steps/day (+497) at six weeks CG ↓ steps/day (–861) at six weeks	<0.02
Frederix et al. 2015[32]	Change in steps/day from baseline	IG ↑ steps/day (+351) at six weeks IG ↑ steps/day (+785) at six months CG ↑ steps/day at six months	NS
Young et al. 2016[40]	Change in steps/day from baseline	IG ↑ steps/day at three and six months ↑ kcal/kg per day at three and six months ↑ daily minutes of moderate/vigorous activity at three and six months	NS
Guiraud et al. 2012[34]	Energy expended, time doing moderate intensity PA PA and time spent at different intensity levels (mean minutes)	IG ↑ total energy expended at two months ↑ energy expended at moderate intensity at two months ↑ time spent at moderate intensity PA at two months	0.004 0.013 0.002
Ribeiro et al. 2017[37]	Minutes PA/day: sedentary PA; light PA; moderate-to-vigorous PA; total PA (counts/min)	IG ↑ moderate-to-vigorous PA (min/day) at two months CG unchanged moderate-to-vigorous PA (min/day) at two months	0.030 0.024
Varnfield et al. 2014[31]	Step number, duration and intensity	IG ↑ in walking speed at 1.5 months ↑ steps per day at 1.5 months	NR
Study	**Objective PA measured by *pedometer***		
Anderson et al. 2015[39]	Change in steps/day from baseline	IG ↑ steps/day (+1973.9) at three months CG ↓ steps per day (–1369) at three months	0.010
Houle et al. 2012[33]	>7500 steps/day at each time point	IG ↑ % at six, nine and 12 months ($p = 0.01$; 0.03; 0.04) Interaction effect (group by time) in PA level was different between groups from baseline to six-month follow-up ($p = 0.033$)	0.033
Study	**User acceptability**	**Result**	
Frederix et al. 2015[32]	Qualitative – offline feedback forms	97% acceptability in using motion sensor (easy to read and easy to use) 95% (65/69) acceptability in tele rehabilitation program: very satisfied (44%, 30/69); satisfied (51%, 35/69).	
Varnfield et al. 2014[31]	Acceptability to step counter	>85% found step counter to be motivational in reaching CR goals	

CG: control group; CR: cardiac rehabilitation; IG: intervention group; NR: not reported; NS: non-significant; PA: physical activity; ↓lower/decrease; ↑higher/increase

outcomes.[55] In this current review, two studies reported on pedometer use and eight on accelerometers. The following devices were identified: accelerometers (ActiGraph,[37,40] Aipermon 440,[35] Sensewear Pro3,[36,38] tri axial Yorbody[32] and single axis accelerometer[34]); and the Yamax Digiwalker[33] and tri-axis technology (3D)[39] pedometers; however, Anderson[39] describes his pedometers as having tri-axis technology and measuring vertical acceleration, indicating technology closer to an accelerometer. One study used systems integrated with online platforms and a tablet device but did not state the brand of accelerometer.[40]

Another review on the use of wearable devices to promote physical activity[13] warns that there have

Table 5. GRADE summary of findings.

Extent of adherence to the use of an activity monitoring device to collect objective physical activity data; including effect of device on physical activity and acceptance of device.

Patient or population: adults (aged 18 years and over) with cardiovascular disease
Setting: community
Intervention: use of an activity monitoring device to collect objective physical activity data
Comparison: usual care

Outcomes	Impact	No of participants (studies)	Certainty of the evidence (GRADE)
P1: rate of adherence to activity monitoring device to promote PA assessed with: rate of adherence (percentage). Follow-up: mean six months.	Mean adherence 59.1% (range 39.6–85.7). There was heterogeneity of setting, intervention, type of device, where device worn and means of collection of data across six studies.	493 (six RCTs)	⊕⊕⊕◯ Moderate[a]
S1: effect of device on PA levels assessed with: steps per day/ level of activity/energy expended. Follow-up: mean six months.	Increase in steps/day was significantly different between intervention and controls ($p < 0.05$) in four of the six studies where this was reported. One study did not report significance and the last two studies reported a significant difference in energy expended/time spent doing PA.	798 (nine RCTs)	⊕⊕⊕◯ Moderate[b]
S2: perceived acceptability (satisfaction) of using an activity monitoring device or application to promote increases in PA assessed with: qualitative feedback. Follow-up: mean six months.	Two studies reported the participant's acceptability and satisfaction towards the device. These data were self-report collected using feedback forms. Acceptability to device was reported for more than 85% of participants.	259 (two RCTs)	⊕◯◯◯ Very low[a,c]

GRADE Working Group grades of evidence:
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect;
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different;
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect;
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

[a]Methodological heterogeneity of studies.
[b]No intention-to-treat analysis may have impacted on mean number of steps/level of PA reported.
[c]These data are qualitative, collected from feedback forms.
PA: physical activity; RCT: randomized controlled trial

been few studies evaluating their efficacy in promoting physical activity and research is needed to determine effectiveness, especially in marginalized communities, and with children and adolescents. It was not possible to ascertain any meaningful differences between countries, communities or settings in this review due to the small number of studies conducted in developed countries all with similar health practices and technologies. Furthermore, there is no representation in this review from developing countries or marginalized populations. Participants in the eligible RCTs ranged in age from 42 to 82 years. Lau and colleagues[44] also concluded that very few systematic reviews have documented the effects of ICT-based interventions on physical activity behavior in children and adolescents specifically. In one of the few studies found to include participants aged less than 40 years[56] a marked attrition (50% at two weeks and 75% at four weeks, and only three participants were reported adhering for the full six weeks) to wearing an activity tracker was shown in a sample ($n = 30$) of undergraduate students aged 20 to 24 years. A variety of reasons for non-adherence were

reported ranging from 'the device was uncomfortable to wear' to 'I forgot to put it on in the morning'. One participant in the study complained that 'physical activity trackers should be inconspicuous' while another remarked on the frustration in having 'to remember to take it out of my pocket and put it on the new clothes I am wearing' when changing her clothes or taking a shower (Shih et al.,[56] p.7).

The low mean adherence rate found in this review (59.1%) may be a consequence of the age of the participants and raises the question of what technology is most suitable for this age group, and the possibility that accelerometry is more suited to a young demographic. In addition, the lack of younger participants found in this review could be a reflection of lower prevalence of CVD in these age groups; however, of 849 participants just 28.6% ($n = 243$) were female. It is known that women are under-represented in cardiac research.[57] Gender differences in the adoption of physical activity trackers have been understudied and are rarely reported,[56] and this review has found a lack of empirical research in this area. Research is warranted to understand the gender differences in this area.[58]

The effectiveness and validity of using activity monitoring devices to record and collect objective physical activity data has been shown;[43] however, now emerging are ethical considerations around the use of accelerometry. To stimulate discussion in the literature, Fuller and colleagues[59] propose four areas needing to be addressed: informed consent; privacy and confidentiality; mitigation of risk; and the additional considerations of marginalized (vulnerable) populations. Data may give a detailed account of a participant's movements and activities during a set period, much of which may not be relevant to the research. Data privacy and access of data to third parties is a major concern to the public at this time.[59]

Limitations

Ten eligible studies each had some methodological weaknesses therefore weakening the results of this review. Randomization to study groups was adequately concealed in only five studies, intention to treat analysis was undertaken in only three and assessment of outcome was blinded in six (Table 2). In addition, there was a high heterogeneity between studies and for each of the variables addressed in our second objective. Therefore, the authors were unable to undertake an overall meta-analysis.

Conclusions

This review highlights the lack of evidence for the adherence to the use of activity monitoring devices. Review outcomes suggest that the evidence is not equally presented across age and gender, nor does it address the specific needs of using this technology in marginalized communities. As research addressing the use of activity monitoring devices evolves and the objectively collected physical activity data is further validated, challenges remain to ascertain the effectiveness of using activity monitoring devices as we move from subjective (self-report) to objective data. In addition, there are ethical issues that will need to be addressed surrounding consent to, and risk from, using such devices and consideration of privacy, confidentiality and clinical outcomes.

Author contribution

TSM, CK and RAC contributed to the conception of the work. PN contributed to the acquisition, analysis, or interpretation of data for the work. TSM and CK drafted the manuscript. All authors critically revised the manuscript and gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

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