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REVIEW ARTICLE

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EFFECTIVENESS OF HEALTHCARE INTERVENTIONS USING OBJECTIVE FEEDBACK ON PHYSICAL ACTIVITY: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Objective: **To determine the effectiveness of healthcare interventions promoting physical activity, which use objective feedback on physical activity delivered using wearable activity monitors as part of the intervention. Intervention groups are compared with control groups receiving usual care or interventions without objective feedback.**

Data sources: **PubMed, EMBASE, MEDLINE and Cochrane Library were searched to identify randomized controlled trials.**

Study selection: **Randomized controlled trials published after 2007 with (former) healthcare patients ≥21 years of age were included if physical activity was measured objectively using a wearable monitor for both feedback and outcome assessment. The main goal of included studies was promoting physical activity. Any concurrent strategies were related only to promoting physical activity.**

Data extraction: **Effect sizes were calculated using a fixed-effects model with standardized mean difference. Information on study characteristics and interventions strategies were extracted from study descriptions.**

Data synthesis: **Fourteen studies met the inclusion criteria (total $n=1,902$), and 2 studies were excluded from meta-analysis. The overall effect size was in favour of the intervention groups (0.34, 95% CI 0.23–0.44, $p<0.01$). Study characteristics and intervention strategies varied widely.**

Conclusion: **Healthcare interventions using feedback on objectively monitored physical activity have a moderately positive effect on levels of physical activity. Further research is needed to determine which strategies are most effective to promote physical activity in healthcare programmes.**

Key words: meta-analysis; physical activity; feedback; wearable electronic devices.

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LAY ABSTRACT

Wearable technology is progressively applied in health care and rehabilitation to provide objective insight into physical activity levels. In addition, feedback on physical activity levels delivered by wearable monitors might be beneficial for optimizing their physical activity. A systematic review and meta-analysis was conducted to evaluate the effectiveness of interventions using feedback on objectively measured physical activity in patient populations. Fourteen studies including 1902 patients were analyzed. Overall, the physical activity levels of the intervention groups receiving objective feedback on physical activity improved, compared to the control groups receiving no objective feedback. Mostly, a variety of other strategies were applied in the interventions next to wearable technology. Together with wearable technology, behavioral change strategies, such as goal-setting and action planning seem to be an important ingredient to promote physical activity in health care and rehabilitation.

Physical inactivity is a worldwide problem. In the long-term, active people have lower risk of disease, such as cerebrovascular stroke and cardiac infarction, and frequent physical activity (PA) is beneficial for health outcomes, such as mental wellbeing, physical fitness and quality of life (1, 2). Short-term effects of PA are also well-established; for example, promoting PA in patients shortly after stroke appears to be beneficial for motor and neurological repair (3, 4).

With increasing evidence from diverse patient populations of the benefits of being physically active, promoting PA is essential in treatment and rehabilitation (5). Unfortunately, promotion of PA in patient populations, such as those with chronic conditions, is challenging, since they are often burdened by several health problems and encounter barriers to physical activity. Therefore, these patients are at greater risk of physical inactivity compared with their healthy peers (6). Medical professionals, especially rehabilitation teams, can play a substantial role in improving PA with regard to patient-specific health behaviours and disease management (5, 6). Knowledge of the most effective way to promote PA in healthcare is needed.

A progressively applied tool to support promotion of PA in healthcare is monitoring activity using wearable technology, such as pedometers and accelerometers (7). These "wearables"' objectively measure PA and, in recent years, their accuracy and validity has increased

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(7–10). Activity monitors can generate various parameters that provide information on PA, e.g. number of steps, walking distance, or energy expenditure. It is possible that providing this objective insight motivates patients to increase their levels of PA (11). In addition, objective insight is not only useful for increasing levels of PA, but it can help patients to regulate their behaviour, e.g. by improving the distribution of activity during the day with regard to the individual's capacity. Van Achterberg et al. (12) support this by stating that self-monitoring contributes to successful behaviour change. Thus, wearable activity monitors facilitate self-management of health behaviour of patients and therefore have the potential to improve patients' functional independence (10).

Literature reviews have shown that interventions that include objective monitoring of PA are moderately effective in healthy subjects and relatively inactive populations (13–16). However, the methodology of these studies differs considerably. First, the types of populations included varies between reviews and between studies included in reviews. The reviews concentrated, for example, on children, adults (with and without a diagnosis of a specific disease), or, in contrast, on a specific population, such as obese adults with diabetes (13–16). Therefore, these results cannot be transferred directly to healthcare and rehabilitation. Hence, a review that includes patient populations only is needed to support statements of the possible effectiveness of such self-management tools for the promotion of PA in healthcare interventions (16). Another characteristic of studies included in the reviews is that PA monitoring was applied in relatively broadly defined health interventions, which targeted more aspects than PA, e.g. nutrition. Unlike previous reviews, the current review focusses on interventions in which the main goal was promoting PA using wearable monitors. Finally, another methodological issue highlighted by previous reviews is the diversity in intervention strategies applied, which makes comparison complex. In healthcare, in particular, interventions promoting PA using wearable technology are often combined with components of behavioural change techniques (BCT) targeting PA levels, e.g. behavioural counselling with goal-setting, education on the advantages of being active, or identification of barriers to PA (13, 17). These BCT components are often already present in usual care programmes, which makes it even more complex to evaluate objective feedback on PA interventions in healthcare (13). Another example of varying strategies is the method of feedback; interventions differ in showing real-life feedback on a display, text messages or in real-life consultations with therapists. In addition, feedback is provided by multiple types of wearable devices. Both feedback strategy and the presence and type of BCT components may influence the amount of behaviour change. A more detailed insight into the presence of intervention strategies applied in healthcare, together with objective activity monitoring, such as feedback type and BCT components, is needed.

A literature review on the effectiveness of objective feedback on PA in a PA promotion intervention that focuses solely on patient populations would provide valuable knowledge to enable its effective application in healthcare. In addition, the presence of different intervention strategies should be considered.

The aim of this study was to determine the effectiveness of interventions promoting PA in healthcare that use objective feedback about PA via wearable activity monitors. Interventions that use objective feedback about PA are compared either with control groups receiving usual care or with an intervention without objective feedback. Although providing objective feedback can be beneficial for either increasing or regulating PA, this study focuses on the effect of increasing PA levels and includes only those interventions in which the main goal is to promote PA. Furthermore, the influence of intervention strategies is explored by describing the type of feedback and the presence of BCT.

METHODS

Data sources and searches

PubMed, Embase, MEDLINE and the Cochrane Library were searched to identify randomized controlled trials (RCTs) up to August 2017. The key words included in the literature search were: physical activity, feedback and objective device and their synonyms (see Appendix 1 for complete PubMed search strategy). The study design RCT was added to the literature search. Reference lists from the included articles were screened to check and extend the search.

Study selection

Inclusion criteria for RCTs were studies published after 2007 in which: (*i*) the mean age of subjects was >21 years; (*ii*) subjects were (former) patients treated within the healthcare system; (*iii*) PA was used as an outcome measure for the intervention; (*iv*) PA was measured objectively with a wearable monitor; (*v*) feedback on objectively measured PA was part of the intervention; (vi) the main goal of the intervention was promoting PA; (*vii*) concurrent strategies, such as behavioural change techniques, were related primarily to PA; (*viii*) intervention groups received feedback on objectively measured PA as part of the intervention, whereas the control group received an intervention with no feedback on objectively measured PA or usual care.

Exclusion criteria were: (*i*) the full text was not available in English; (*ii*) the document was a conference or oral session abstract, research letter or commentarial note; (*iii*) interventions that combined disciplines, such as nutrition and psychology, which were not primarily related to PA.

Two reviewers (HB and MB) applied the inclusion criteria to the titles and abstracts independently to select potentially relevant studies from the search results. When disagreements occurred, HB and MB resolved them by discussion. If no agreement could be achieved, a third reviewer (JB) was consulted.

Methodological quality assessment

Methodological quality was determined by the risk of bias assessment (18). Risk of bias was scored (low risk, high risk or unclear risk) per item independently by 2 researchers (HB and MB). Random-sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases were items that were reviewed. Judgement of blinding of participants and personnel was considered as low risk when no or incomplete blinding was not likely to influence the outcome, which is expected in studies in which the work of therapists is part of the intervention. When articles were not clear about items, MB and HB discussed the item and decided the score. Any disagreements were resolved by a third researcher (JB). Scores were processed using RevMan 5.3 (Cochrane Community.

Data extraction and synthesis

The following information was extracted from the included articles:

Study characteristics. Population characteristics, intervention and control setting, duration of intervention, PA outcome measure and reported significance of the effect on PA.

Intervention strategies. Wearable monitor used for feedback, feedback parameter, frequency, visualization, therapist/coach contact and BCT components used.

Effect size calculation. Different types of PA outcome measures were allowed. Nevertheless, all measures were continuous variables, therefore a standardized measure was used to calculate effect size. The standardized mean difference (SMD) was calculated by using the weighted inverse variance approach for fixed-effects meta-analysis models in RevMan 5.3. SMDs of the included studies were combined to calculate an overall summary effect (95% confidence interval (95% CI)), SMDs of 0.2 were considered small, 0.5 moderate and 0.8 large (18). If studies were incomplete in reporting necessary PA measures (mean and standard deviation (SD)) for calculation of the SMD, corresponding authors were emailed to request the missing measures. If SDs were still missing, the calculator in RevMan 5.3 and method of Hozo et al. (19) was used to estimate missing values. A leave-one-out sensitivity analysis was performed by iteratively removing 1 study at a time in order to confirm that the current results were not driven by any single study. Inconsistency (heterogeneity, I^2) was calculated in RevMan 5.3 and was interpreted according to the method of Higgins & Green (18). I^2 was low at 25%, moderate at 50% and high at 75%. In addition, comparable with the method of Kang et al. (20), the contribution of mediating effects was explored by grouping different study characteristics if heterogeneity was significant ($p<0.05$).

RESULTS

Study selection

The literature search yielded 2,322 relevant articles after removing duplicates from the initial search (Fig. 1). After excluding articles published before 31 December 2006 and careful screening of titles and

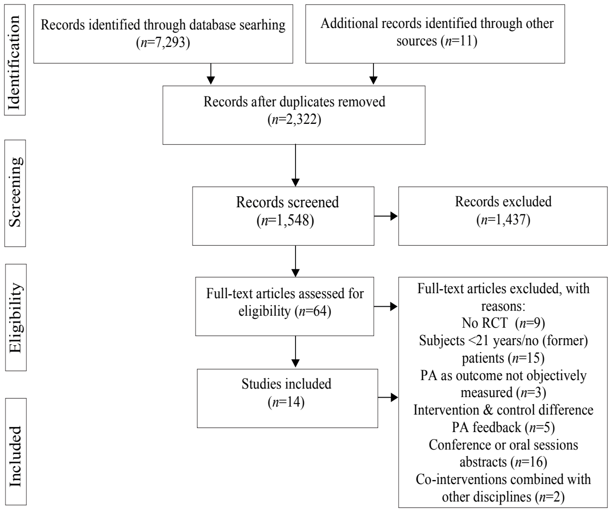

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA): flow diagram of selected studies.

abstracts for inclusion and exclusion criteria, the full text of 64 records were checked. After consulting the third researcher regarding 2 records, all 3 researchers agreed that 14 studies met the inclusion criteria and these were included in the full review. Inclusion and exclusion was modelled using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (21) (Fig. 1).

Methodological quality

Full consensus was reached between researchers MB and HB on risk of bias assessment. Overall, the methodological quality of the included studies was moderate to acceptable (Fig. 2). The most frequent reason for high risk was detection (22–27) and attrition bias (22, 24, 28–30) due to lack of blinding of outcome assessors and high drop-outs, or to being unclear about incomplete outcome data. Blinding of participants and personnel was considered low risk in any study due the clinical intervention setting (Fig. 2). The randomization process was not clearly described in some studies (23, 24, 30–32). In 7 studies, the authors had reasons to report other biases (22, 24, 27, 30–33); for 3 studies the reason was that the RCT was a pilot RCT with a relatively small sample size (30, 31, 33). Kaminsky et al.'s study had the highest methodological risk (30).

Study characteristics

The studies varied with regard to the number and type of participants, duration and intervention characteristics (Table I). The total number of participants in the included studies was 1,902, and the number of participants per study ranged from 16 to 586. Included populations were patients with chronic obstructive

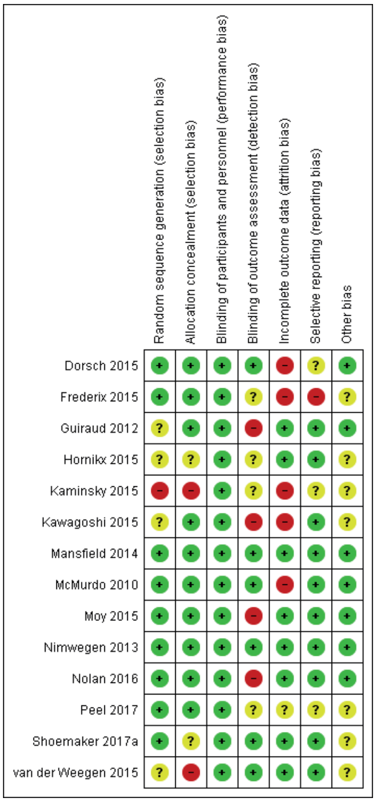

Fig. 2. Risk of bias assessment of included studies ($n=14$).

pulmonary disease (COPD), stroke, various cardiovascular diseases, Parkinson's disease, and geriatric patients. The duration of interventions varied between 20 days (28) and 2 years (34). The duration of 2 interventions was dependent on the length of inpatient rehabilitation (28, 35). In 12 studies, all participants received usual care (UC), and the intervention group received an objective feedback PA intervention in addition to UC (Table I). In the 2 other studies the control group received no care or wait list control (25, 29). Five interventions were performed in an inpatient setting (22, 27, 28, 31, 35) and the other studies were outpatient- or home-based.

Outcome measures used to calculate the significance of the effect on PA were steps per day, walking time per day, energy expenditure (in kJ or kcal per day or per week), accelerometer counts per day, and time in moderate intensity PA per week. These outcomes were measured using a pedometer or accelerometer (Table I). Steps/day was the most frequently used outcome measure. The significance of the effect on PA was calculated by the authors in 3 different ways: *p*-value of (*i*) difference in mean change between intervention and control group; (*ii*) difference between intervention and control group at follow-up; and (*iii*) difference between baseline and follow-up of the intervention and control group calculated separately (Table I). The study by Frederix et al. (22) did not provide *p*-values of the effect on PA. Eight studies showed a significant positive effect in favour of using feedback from a wearable monitor in the intervention group ($p<0.05$) (23–25, 27, 29, 30, 32, 34).

Intervention strategies

Intervention strategies used in each study are shown in Table I. Table II shows the frequency of intervention strategies used in the included studies. Five studies used a pedometer for feedback (24–26, 29, 30) and the others studies used accelerometers. The most frequently used feedback parameter is steps per day (Table III). Furthermore, frequency of feedback varied between daily and monthly. In 4 studies, patients could choose when to view their PA level (23, 25, 32, 34). In 8 studies, subjects could see their real-time PA on a display (24–26, 29–32, 35). Four studies (22, 25, 30, 34) used no verbal interaction with a coach or therapist in real-life consultations or by telephone to provide feedback.

The following BCT components mentioned in the studies were identified: education (E), goal-setting (GS), barrier identification (BI) and/or problem-solving (PS), action planning (AP) and social support (SS) (Table I). BCT components were used in a wide variety of combinations. Table II shows the frequency of BCT components present in all included studies. Five studies used 3 or more BCT components as concurrent intervention strategies (23, 25, 29, 32, 34). GS was the most-often used BCT component (Table II). GS and E were frequently combined with BI and/or PS. Only 1 study used social support (25).

Effect estimates

Authors were contacted when data on PA to calculate SMD post-intervention were missing (22, 24, 26, 29, 34, 35). SMDs of 11 studies were calculated based on original data, data sent by authors, or a combination of both. In 3 studies, the SD of the outcome measure at follow-up was estimated (29, 31, 33). One of the intervention arms of McMurdo et al. (29) and Shoemaker et al. (33) was excluded from meta-analysis based on inclusion criteria. SMD of Frederix et al. (22) and Peel et al. (27) (respectively SMD=4.64 and 4.73) was more than 3 times as large as SMD of other studies (SMD between –0.09 and 1.17), as shown in Fig. 3. Leave-one-out sensitivity analysis showed that after removing the study of Frederix et al. (and Peel et al.), the overall effect changed to SMD with a smaller confidence interval (SMD=0.34 with 95% CI 0.23–0.44, $z=6.27$, $p<0.01$) and considerable less heterogeneity ($I^2=49\%$) (Fig. 3) compared with the overall effect size when they were

Table I. Overview of study characteristics, intervention strategies and reported effect on physical activity with outcome measure used

	Study characteristics						Intervention strategies					
Ref.	Population	Population (male/female), *n* mean age (SD)	Intervention and control setting	Duration	PA outcome measure	Reported significance of effect	Wearable monitor used for feedback	Parameter	Frequency	Visualization	Therapist/ coach contact	BCT components
Dorsch 2015 (28)	Stroke patients	Intervention: $n=78$ (47/31) 61.8 years (40.3) Control: $n=73$ (45/28) 65.0 years (13.2)	Inpatient RC (UC)	±20 days, during inpatient rehabilitation	Walking time/day	NS (mean change IG vs CG)	Accelerometer (Gulf Coast Data Concepts, Waveland, MS, USA)	Steps/day	3× p/w	n/a	RLC	AP
Frederix 2015 (22)	Coronary artery disease patients	Intervention: $n=40$ (34/6) 58 years (9) Control: $n=40$ (32/8) 63 years (10)	Inpatient RC (UC)	18 weeks	Steps/day	n/a	Triaxial accelerometer (Yorbody Company)	Steps/day	Weekly	WP	n/a	GS
Guiraud 2012 (23)	Non-compliant patients after a cardiac rehabilitation programme	Intervention: n=19 (17/2) 54.5 years (12.6) Control: $n=10$ (7/3) 62.9 years (10.7)	Outpatient cardiac rehabilitation (UC)	8 weeks	EE (kcal/week)	Baseline vs follow-up IG: $p<0.01$* Baseline vs follow-up CG: NS	Accelerometer (MyWelness Key; Technogym SpA, IT, USA)	Time in moderate PA intensity	Every 15 days or login by choice	WP	PC	E + GS + BI + AP
Hornikx 2015 (31)	COPD	Intervention: $n=15$ (9/6) 68 years (6) Control: $n=15$ (8/7) 66 years (7)	Inpatient (hospital) (UC)	4 weeks	Steps/day	Baseline vs follow-up IG: $p<0.05$* Baseline vs follow-up CG: <0.05*	Dynaport MoveMonitor (McRoberts BV, The Hague, The Netherlands)	Steps/day	3 times/week	RT	PC	GS + BI
Kaminsky 2013 (30)	Inactive patients with cardiac diseases	Intervention: $n=10$ (8/2) 53.3 years (8.1) Control: $n=8$ (6/2) 59.4 years (9.9)	Home-based (UC)	8 weeks	Steps/day	Baseline vs follow-up IG: $p<0.05$* Baseline vs follow-up CG: NS	NL-1000 pedometers (New-Lifestyles, Inc. Lee's Summit, MO, USA)	Steps/day	1 starting session	RT	n/a	GS
Kawagoshi 2014 (24)	Elderly with COPD	Intervention: $n=15$ (14/1) 75 years (9) Control: $n=12$ (10/2) 74 years (8)	Home-based rehabilitation (UC)	1 year	Walking time/day	$p=0.04$* (mean change IG vs CG)	Pedometer (Kens Lifecorder EX, Nagoya, Japan)	Steps/day	Monthly	RT	RLC	E + GS
Mansfield 2015 (35)	Stroke	Intervention: $n=29$ (20/9) 64 (19) Control: $n=28$ (16/12) 61.5 years (13)	Inpatient RC (UC)	Based on length of inpatient rehabilitation	Steps/day	NS (mean change IG vs CG)	Accelero-meter (Model X6-2mini, Gulf Data Concepts, LLC, Waveland, MS, USA)	Total walking time, steps/ day, bout durations	Daily	RT	RLC	GS
McMurdo 2010 (29)	Community-dwelling elderly	Intervention: pedometer + BCI: $n=68$ 77.1 years (4.9) (BCI alone group= excluded from meta-analysis) Control: $n=68$ 77.0 years (4.9)	Home-based via primary care	6 months	Accelerometer count	Baseline vs follow-up $p=0.02$* Baseline vs follow-up CG: NS	Pedometer (Omron HJ-113, Healthcare UK Ltd, Milton Keynes, UK)a	Steps/day	First month weekly, last months every 2 weeks	RT	PC	E + GS + BI + AP
Moy 2015 (25)	COPD	Intervention: $n=154$ (146/8) 67.0 years (8.6) Control: $n=84$ (77/7) 66.4 years (9.2)	Home-based	4 months	Steps/day	Baseline vs follow-up IG: $p<0.01$* Baseline vs follow-up CG: NS	Pedometer (Omron HJ-720 ITC Healthcare Ltd, Milton Keynes, UK)	Steps/day	1× p/w or every moment by choice	RT + WP	n/a	E + GS + SS
van Nimwegen 2013 (34)	Patients with Parkinson's disease	Intervention: $n=299$ (194/105) 65.1 years (7.9) Control: $n=287$ (188/99) 65.9 years (7.2)	Home-based via hospital (UC)	2 years	EE (kcal/day)	$p<0.001$* (mean change IG vs CG)	Accelerometer (Directlife, Consumer Lifestyle, Philips, Amsterdam, The Netherlands)	kcal/day	Monthly or login on website by choice	WP	RLC	E + GS + BI
Nolan 2017 (26)	COPD	Intervention: $n=76$ (56/20) 69 years (9) Control: $n=76$ (54/22) 68 years (8)	Outpatient PR (UC)	8 weeks	Time spent expending >3 METs/day	NS (mean change IG vs CG)	Yamax Digi-walker CW700	Steps/day	Every week	RT	RLC	GS + BI
Peel 2016 (27)	Elderly in geriatric rehabilitation	Intervention: $n=128$ (50/78) 81 years (9) Control: $n=127$ (57/70) 82 years (8)	Inpatient geriatric rehabilitation (UC)	4 weeks	Minutes walking/ day non-therapy hours	$p=0.001$* (IG vs CG at follow-up)	ActivPal (PAL technologies Ltd, Glasgow, UK)	Minutes walking/day	Daily and every treatment session	n/a	RLC	GS
Shoemaker 2016 (33)	Patients with heart failure and implantable cardioverter defibrillator	Intervention: $n=6$ 62 years (19) (Exercise/health coaching group is excluded from meta-analysis) Control: $n=4$ 63 years (23)	Home-based (UC)	3 months	Hours of activity/ day	Baseline vs follow-up IG: NS Baseline vs follow-up CG: NS	ActiGraph GT3X triaxial accelerometer	Steps/day	Weekly	MA	RLC	E
Van der Weegen 2015 (32)	Diabetes type 2 and COPD	Intervention: $n=65$ (34/31) 57.5 years (7.0) (SSP group excluded from meta-analysis) Control: $n=68$ (37/31) 59.2 (7.5)	Homebased via GP (UC)	4–6 months	Mean minutes PA/day	$p<0.001$* (mean change IG vs CG)	Personal Activity Monitor AM300 (Pam)	Mean minutes PA/ day	In total 3 sessions or login by choice	RT + WP	RLC + PC	E + GS + BI + AP

*Significant effect on increase in PA in intervention group $p<0.05$, n/a: not applicable; PA: physical activity; EE: energy expenditure; IG: intervention group; CG: control group; RC: rehabilitation centre; GP: general practice; PR: pulmonary rehabilitation, (UC): both intervention and control group received usual care; NS: not significant.. visualization: real-time display (RT)/web-based portal (WP)/mobile application (MA); Therapist or coach contact: real-life consultation (RLC)/phone call (PC)/text message or e-mail (TE).

Table II. Overview of frequency of specific intervention strategies used in the included studies

Intervention strategies	Frequency in the 14 included studies
Type of feedback monitor	
Pedometer	5
Accelerometer	9
Feedback parameter	
Steps/day	9
Energy expenditure (kcal/day)	2
Duration of (MV)PA/day	3
Feedback frequency*	
Daily	2
≥ Once per week	7
< Once per week	5
Login by choice	4
Feedback visualization*	
n/a	2
Web portal or mobile application	6
Real-life display	8
Therapist/coach contact*	
Real-life consultation	8
Phone call	4
None	3
BCT components*	
Education	7
Goal-setting	12
Barrier identification	6
Action planning	4
Social support	1

*Multiple studies used a combination of multiple components.
n/a: not applicable; MV: moderate to vigorous; PA: physical activity; BCT: behavioural change techniques.

included (SMD=0.64 with 95% CI 0.52–0.73, $z=11.97$, $p<0.01$) and heterogeneity ($I^2=97\%$). Therefore, the SMD of Frederix et al. (and Peel et al.) were excluded from the meta-analysis and weight was reduced to 0% (Fig. 3). Heterogeneity was moderate but significant ($I^2=49\%$, $p=0.03$, Fig. 3), which supported the exploration of the contribution of different study characteristics to the overall SMD. Pooled mean SMD per study characteristic is shown in Table III. Outpatient- and home-based interventions had a larger effect (SMD=0.37) on PA than inpatient interventions (SMD=0.17). The shortest intervention durations (<10 weeks) had the largest effect (SMD=0.70). In populations with cardiac diseases objective feedback PA interventions had the largest effect (SMD=0.70) on PA compared with other patient populations (SMD=0.19–0.35).

Table III. Pooled standardized mean differences per group of study characteristics

Study characteristics	N (total $n=14$ studies)	Pooled mean SMD [95% CI]
Setting		
Inpatient	5	0.17 [−0.08, 0.43][a,b]
Outpatient-/home-based	9	0.37 [0.26, 0.49]
Duration		
Dependent on rehabilitation length	2	0.19 [−0.08, 0.46]
<10 weeks	4	0.70 [0.20, 1.20][b]
10–20 weeks	3	0.30 [−0.06, 0.66][a]
>20 weeks	5	0.35 [0.23, 0.48]
Population		
Stroke	2	0.19 [−0.08, 0.46]
Cardiac	4	0.75 [0.16, 1.33][a]
Geriatric	2	0.35 [0.01, 0.69][b]
Parkinson's disease	1	0.45 [0.28, 0.62]
COPD	5	0.23 [0.05, 0.41]

[a]Analysed without Frederix 2015 (22) based on leave-one-out sensitivity analysis
[b]Analysed without Peel 2016 (27) based on leave-one-out sensitivity analysis
CI: confidence interval; SMD: standardized mean difference; COPD: chronic obstructive pulmonary disease.

DISCUSSION

To our knowledge, this is the first review to focus on interventions aiming at promoting PA that include feedback based on objective measurements of PA in healthcare settings. Overall, meta-analysis showed a moderately positive effect on PA, with the weight of evidence being in favour of the interventions using objective feedback on PA. Study characteristics varied widely across included studies. Pooled analysis of characteristics provided more insight into the effectiveness of setting, intervention duration, and target population. In addition, there was high variability in intervention strategies.

These results complement those of previous studies in finding that using objective feedback of PA via wearable monitors increases levels of PA. Previous meta-analyses (13, 15, 16, 20) also showed positive effects on PA in favour of the intervention groups. In contrast, the overall effect size of the current study (0.34) was lower than effect sizes of the other meta-analyses (>0.50) (13, 15, 16). This may be explained by the type of populations included in the current

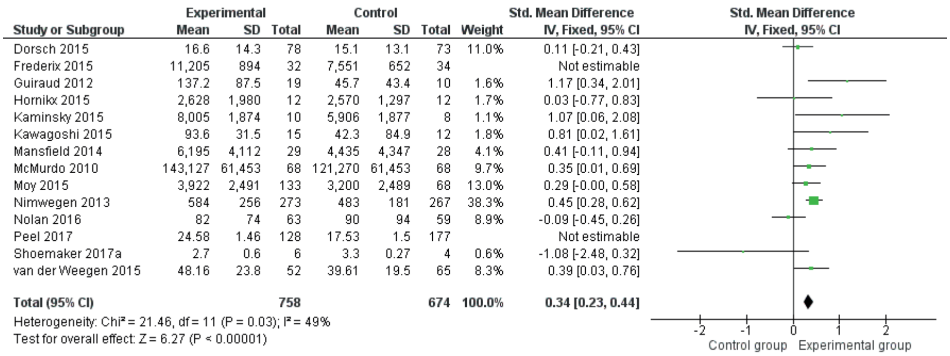

Fig. 3. Forest plots for physical activity outcome measures, overall estimate of the intervention effect.

study. The study focused on patients of healthcare institutions, who were mostly patients with (chronic) neurological or cardiovascular diseases. These patients may experience more barriers to increasing their PA compared with healthy individuals (6). In addition, participants in the current study were slightly older (mostly around 65 years of age) compared with other studies. It is possible that older individuals increase their PA less because they experience difficulty using new technologies, such as activity monitors, to increase PA. Nevertheless, the overall positive results suggest that using wearable technology is also a promising tool to promote PA in healthcare settings.

Similar to other reviews (14, 16), large heterogeneity was found in the study characteristics. However, after excluding 2 studies based on leave-one-out sensitivity analyses, heterogeneity was acceptable. Mediating effects of study characteristics (setting, duration and population) were explored by calculation of pooled SMDs of grouped characteristics (Table III). Regarding intervention setting, the effect sizes of studies were smaller in an inpatient setting compared with home-based interventions, suggesting that the difference between the intervention and control groups is smaller when both groups are situated in an inpatient setting, as stated by Dorsch et al. (28), who found comparable results. It can be assumed that both the intervention and control groups in inpatient populations were more dedicated to a strict treatment schedule. Thus, the chance that behaviour of both the control and intervention groups was similar was higher compared with an outpatient- or home-based setting. In other words, a free-living environment allows more voluntary physical behaviour. This statement may also explain the difference in magnitude of the overall effect in the current study (0.34) in comparison with, for example, the overall effect in the meta-analysis by Kang et al. (20) amongst mostly healthy and younger free-living populations (0.68).

Analysis of intervention duration in the current study agreed with the study of Goode et al. (17), since shorter intervention durations showed larger effects on PA compared with longer-lasting interventions. SMD calculation in the current study was based on post-intervention measurements. Adherence to use of wearables for a longer time in daily life may be more difficult, and thus the chance of relapsing to previous behaviour is higher. Future studies should include more follow-up measurements to examine the sustainability of behaviour change due to these interventions.

The frequency of applying different intervention strategies was explored in this study and the results emphasize the importance of combining objective PA feedback with BCT strategies (Table II). All interventions included in this review were combined with multiple BCT components (Tables I and II), assuming that researchers find BCT a substantial element for designing RCTs for promotion of PA in healthcare. In addition, Nolan et al. (26) explained the lack of improvement in PA by the low levels of added behavioural counselling. Nevertheless, BCT is an umbrella construct, and the BCT components in the studies included in the current review varied considerably. Not all studies described the content of the BCT sufficiently in the intervention and control groups, hence BCT could only be assessed approximately. Therefore, only careful suggestions for effect directions could be drawn regarding specific BCT components. Goal-setting, education and barrier identification are factors that are probably important, since they were often present in interventions with a relatively large positive effect size. Nevertheless, in 12 of the 14 included studies, the control group received usual care, and it can be assumed that, in most cases, BCT was also present in usual care. As Hakala et al. (16) have suggested previously; the effect size is influenced by the load of the control treatment. With respect to the current study, this could mean that the magnitude of the effect is relatively small because of the amount of BCT that is already present in usual care, and thereby also in control groups.

Study limitations

First, due to the heterogeneity in intervention strategies and treatments of control groups, the specific effect of the objective PA feedback component could not be determined.

Furthermore, the SMDs of PA were calculated based on post-intervention measurements assuming that the RCTs in this meta-analysis included an acceptable randomization procedure. However, baseline comparison of PA was often not taken into account in randomization procedures. Therefore, intervention and control groups may have differed in baseline PA, which might have influenced the results. Future studies should compare the intervention and control group based on mean changes between pre- and post-measurements. Another methodological limitation in the current meta-analysis concerns comparison of the intervention effects based on SMD. In the included studies, the SMDs were calculated using diverse PA outcome measures and generated by different methods of data-processing using various devices. These methodological differences between studies in accelerometer data-processing limit comparability (36). Using a standardized version of the effect size, such as the SMD, only partly resolves the problem of comparing different PA outcomes measured using different devices.

In some studies the PA outcome parameter differed from the PA feedback parameter (23, 24, 26, 28, 33). For example, Dorsch et al. (28) used the number of steps as feedback parameter and the walking time as outcome measure. Attempting to attain a goal based on a certain number of steps per day (amount of PA) is a different approach to measuring walking time (PA duration). This can lead to a mismatch between target parameters of PA promotion during the intervention and evaluation of PA.

Publication bias might have influenced the current results to some extent. Since congress abstracts, commentary articles and languages other than English were excluded, some studies with negative results regarding PA might have been missed. The methodological quality of the included studies was moderate; none of the studies scored "low risk" on all bias items. However, small sample sizes of a considerable proportion of the included studies, procedures of blinding of assessors, and incomplete data reporting limits the quality of evidence regarding intervention effects. Therefore, these results should be interpreted with caution.

Despite these limitations, this review provides useful indications for the use of wearable technology in rehabilitation programmes. One of the indications is that, next to BCT, human interaction is recognized as an important feature, since contact with a coach or therapist in real life consultations or by phone calls was present in a large proportion of the included studies. Adopting innovative technologies, such as wearable monitoring, in rehabilitation therefore requires tight tuning with therapy programmes. Blended interventions may offer a solution; innovative technological advancements, such as integrated goal-setting, automatic feedback functions, and real-time tele-consulting, can make human interaction and other BCT components more feasible, and less expensive, partly by reduction of the therapists' workload (37). In addition, a systematic review by Geraedts et al. showed that remote contact seems an acceptable-to-good alternative for real-life contact in PA interventions. A further advantage, according to Chiauzzi et al. (39), is that PA self-tracking has the potential to lead to positive patient engagement in healthcare interventions. Furthermore, patients are now becoming increasingly familiar with self-tracking technology (39, 40). Overall, application of wearable technology has the potential to contribute to health behaviour and self-management of patients, which may contribute to a more efficiently organized and financially attractive healthcare system. Further research is needed to determine the most effective intervention strategies, with regard to the amount and type of therapist contact and BCT components for specific patient populations. Literature studies with less heterogeneity in terms of study characteristics, intervention strategies and methodology are required.

Conclusion

Overall, healthcare interventions that provide objective feedback about PA, delivered by wearable monitors, compared with other strategies promoting PA showed a moderately positive effect on PA. Study characteristics and intervention strategies varied widely. Future research should focus on determining which intervention strategies are most effective in promoting PA in healthcare programmes.

The authors have no conflicts of interests to declare.

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Appendix 1. PubMed search strategy

#1: "motor activity" [Mesh:NoExp] OR "motor activity" OR "physical activity" OR exercise [Mesh:NoExp] OR exercise OR "exercise intensity" OR activity OR training OR swimming [Mesh:NoExp] OR swimming OR running [Mesh:NoExp] OR running OR walking [Mesh:NoExp] OR walking OR sedentary OR "physical behaviour" OR movement OR stepcount* OR "step count*"

#2: feedback [Mesh:NoExp] OR "feedback, Psychological" [Mesh:NoExp] OR "feedback, Physiological" [Mesh:NoExp] OR feedback OR motivat*

#3: accelerometry [Mesh:NoExp] OR accelero* OR pedomet* OR "cell phones"[Mesh:NoExp] OR "cell phones" OR smartphone OR telephone OR "mobile phone" OR monitor* OR microcomputer OR ambulatory OR ambulant OR device OR equipment OR sensor OR gps OR tracking OR stepcount* OR "step count*"

#4: "Randomized Controlled Trial" [Publication Type] OR "Randomized Controlled Trials as Topic"[Mesh] OR "randomized controlled trial" OR RCT