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Review article

Can physical activity measurement alone improve objectively-measured physical activity in primary care?: A systematic review and meta-analysis

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ABSTRACT

There is evidence that simply measuring physical activity alone can increase self-reported physical activity behaviour. The aim of this review was to describe changes in objectively-measured physical activity within control groups in primary care physical activity intervention studies. Five electronic databases (PubMed, MEDLINE, SPORTDiscus, PsychINFO and CINAHL) were searched from inception to February 2019. Physical activity controlled intervention studies objectively measuring physical activity in primary care with adults were included and *meta*-analyses were completed. Thirty studies were eligible and 22 studies were included in the *meta*-analysis. No statistically significant change in steps.day^{-1}, counts.day^{-1} and counts.minute^{-1} were found in the *meta*-analyses within control groups. Moderate-to-vigorous physical activity minutes.day^{-1} significantly decreased (-3.97; 95% CI −6.31 to −1.64; $P < 0.001$). Sub-analyses revealed there was a trend for steps.day^{-1} to increase in participants < 50 years old (504; 95% CI −20 to 1029; $P = 0.06$). Noteworthy increases (≥10%) in objectively-measured physical activity within control groups were found in 17% of studies. Noteworthy increases were reported in studies with younger participants, one-third of the pedometer studies, one-third of studies with participants at risk of chronic disease and in studies with a shorter duration between measurements. No control group improvements were found in participants with chronic disease. Overall, no significant improvements in objectively-measured physical activity were found within control groups in primary care. Further investigation of noteworthy increases in control group physical activity levels is indicated, particularly in certain sub-groups of participants as this may effect physical activity research and interventions in these populations.

1. Introduction

One in two adults in most developed countries are not meeting the public health physical activity guidelines (Hallal et al., 2012). Insufficient physical activity is a major risk factor for chronic disease and death, and in 2013 it was estimated physical inactivity cost health-care systems globally $53.8 billion (international $) (Lee et al., 2012; Ding et al., 2016). Physical activity promotion by health professionals is viewed as a key strategy to increase physical activity levels (World Health Organisation, 2018). However, health professionals report lack of time within consultations as the biggest barrier to physical activity promotion (Huijg et al., 2015; Hébert et al., 2012; Freene et al., 2019). Clearly, there is a need for physical activity interventions that are efficient and effective in healthcare. There is some evidence that brief physical activity interventions and physical activity measurement alone may be effective in increasing physical activity levels in primary care (Orrow et al., 2012; Waters et al., 2012), yet no studies appear to investigate 'measurement as intervention'.

Measurement reactivity, and the mere-measurement effect, have been reported in the physical activity literature (French and Sutton, 2010; Rodrigues et al., 2015). These measurement effects lead to changes in the behavior under investigation. In primary care, systematic reviews and reviews of reviews have found that physical activity interventions have a small to moderate positive effect (Orrow et al., 2012; Sanchez et al., 2015; Goryakin et al., 2018). Considering the possible implications of measurement reactivity, or the mere-measurement

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effect, this may account for some of the small effects, with potential changes in control group physical activity levels. Importantly, a large majority of the studies included in these reviews used self-report measures. In recent years there has been a significant increase in objective physical activity measurement within intervention studies (Silfee et al., 2018). Objective measurement of physical activity (eg: accelerometers, pedometers) is considered a superior method of physical activity measurement compared with self-report measures, with lower levels of variability observed for validity and reliability (Dowd et al., 2018). Despite this, measurement reactivity has been reported in studies using accelerometers (Motl et al., 2012; Baumann et al., 2018) and pedometers (Clemes et al., 2008).

Only one previous review has examined physical activity measurement effects by assessing the frequency of meaningful improvements in physical activity among control group participants in physical activity intervention trials, with no review considering objectively-measured physical activity or completing a *meta*-analysis (Waters et al., 2012). This review found that 28% (n = 8/29) of physical activity intervention studies in primary care reported meaningful improvements in self-reported physical activity among participants who were in the control group (Waters et al., 2012). The authors concluded that control group improvements in self-reported physical activity levels is not uncommon and further investigation of 'measurement as intervention' may inform minimal contact approaches to physical activity promotion. Therefore, the aim of this systematic review and *meta*-analysis of intervention studies is to estimate the effect of control group participation and measurement on objectively-measured physical activity in adults in primary care. Additionally, factors associated with control group changes in objectively-measured physical activity, such as participant and measurement characteristics, will be identified.

2. Methods

The systematic review and *meta*-analysis were guided by the Cochrane Handbook for Systematic Reviews and the PRISMA statement (Moher et al., 2009; Higgins and Green, 2011). The protocol for the review was registered prospectively in PROSPERO (CRD42018104896) on 12 September 2018 and has been described elsewhere (Freene et al., 2019).

2.1. Eligibility criteria

Studies were included if they met the following criteria: (i) randomised controlled trials (RCTs), cluster RCTs and quasi-experimental (controlled) physical activity intervention studies. Control group interventions included no additional contact beyond measurement (true control), an alternative intervention unrelated to physical activity (attention control), usual care only, usual care plus print information addressing physical activity, or usual care plus physical activity tailored advice delivered via personal feedback or verbally (<5 min consultation); (ii) participants were adults (18 years or older); (iii) participants were healthy, at risk of a chronic disease, or had been diagnosed with a chronic disease (eg: type 2 diabetes, coronary heart disease, chronic obstructive pulmonary disease); (iv) the physical activity intervention was completed in a primary care setting (eg: general practice, allied health services, community health and community pharmacy); (v) studies included an objective measurement of physical activity in the control group (eg: accelerometer, pedometer, direct observation, heart rate monitor); and (vi) change in control group objectively-measured physical activity between baseline and post-intervention was reported, or could be calculated.

2.2. Search strategy

One author (NF) searched PubMed; and MEDLINE, SPORTDiscus, PsychINFO, and CINAHL via the Ebsco interface up to February 2019. The electronic databases were searched for the terms (Exercise OR "physical activity" OR "physical fitness" OR "motor activity") AND ("Primary health care" OR "physicians, family" OR "general practi*" OR "primary care" OR "family practi*") AND (Intervention OR "intervention studies") AND (Objective* OR acceleromet* OR "activity monitor" OR "motion sensor" OR pedom* OR "Heart Rate Monitor*" OR "Direct Observation"). No study design or date limits were imposed on the search, and searches were limited to articles published in peer reviewed journals, English language, human participants, and adults, where able.

2.3. Selection process

All articles were imported into Rayyan (Ouzzani et al., 2016), and all duplicates were removed. Using the eligibility criteria, all titles and abstracts were independently screened by NF and SMM. The full texts of the remaining studies were independently reviewed by NF and SMM. Disagreements between authors at all stages were discussed until consensus was reached before moving on to the next stage. The reviewers were not blinded to journal titles or study authors.

2.4. Data extraction

Study characteristics and outcome data were systematically extracted by two independent reviewers into a standardised form (NF, RS). Extracted data were cross-checked for accuracy. If disagreements occurred discussion continued until consensus was reached. Demographic data for the control participants were extracted from eligible studies at the point of randomisation. Mean changes from baseline in the control group objectively-measured physical activity and the SD of the mean change were recorded immediately post-intervention and follow-up, where possible. Where the mean and SD of the change from baseline to endpoint were not reported in the original articles, the following equations were used to calculate them:

$\text{Mean}_{\text{change}} = \text{Mean}_{\text{endpoint}} - \text{Mean}_{\text{baseline}}$;

$$SD_{change} = \sqrt{(SD_{baseline})^2 + (SD_{endpoint})^2 - (2 \times r \times SD_{baseline} \times SD_{endpoint})}$$

here r represents the correlation coefficient. All included studies did not report the correlation of pre and post measurements, or pre and post measurement SDs, therefore the correlation was conservatively set at 0.4 (Follmann et al., 1992; Cohen, 1988). Medians were assumed as means for the purposes of the *meta*-analysis for three studies (Eakin et al., 2014; Altenburg et al., 2014; Davies et al., 2016). SEs were calculated from $\text{SD}_{\text{change}}$, using $\text{SE} = \text{SD}_{\text{change}}/\sqrt{\text{N}_{\text{endpoint}}}$. If $\text{N}_{\text{endpoint}}$ was not reported, $\text{N}_{\text{baseline}}$ was used. SEs were also calculated using $95\%\text{CI}_{\text{change}}$, where SE = (upper limit $95\%\text{CI}_{\text{change}}$ - lower limit $95\%\text{CI}_{\text{change}}$)/3.92. If IQR was reported, SD were calculated using IQR/1.35. Plot Digitizer (version 2.6.8) was used to calculate means and 95% confidence intervals in two studies (Kirk et al., 2003; McMurdo et al., 2010).

2.5. Risk of bias assessment

Methodological quality was assessed by two independent reviewers (NF, RS). Any disagreements were resolved by discussion until consensus was reached. The Cochrane Collaboration tool for assessing risk of bias was used for randomised and cluster randomised controlled studies, and the Risk Of Bias in Non-randomised Studies – of Interventions (ROBINS-I) tool was used for quasi-experimental studies (Higgins et al., 2011; Sterne et al., 2016). Risk of bias for each randomised and cluster randomised study were categorised as low, unclear or high risk for each domain of the Cochrane Collaboration tool. Risk of bias for quasi-experimental studies were classified as no information, low, moderate, serious or critical risk.

2.6. Meta-analysis

Meta-analyses were completed for steps.day^{-1}, moderate-to-vigorous physical activity (MVPA) minutes.day^{-1}, counts.day^{-1} and counts.minute^{-1}. For MVPA minutes.day^{-1}, studies that measured MVPA minutes.week^{-1} were converted to MVPA minutes.day^{-1} by dividing by 7 (Eakin et al., 2014; Harris et al., 2015). MVPA hours.day^{-1} were converted to MVPA minutes.day^{-1} by multiplying by 60 (Samdal et al., 2019). Studies that used walking minutes.day^{-1} were also included in the MVPA minutes.day^{-1} *meta*-analyses (McMurdo et al., 2010; Mutrie et al., 2012). A *meta*-analysis with RevMan 5.3 was performed for these measures using a generic inverse variance with random effects model to calculate pooled mean differences with 95% confidence intervals ([35]). Heterogeneity was assessed using the *I* (Lee et al., 2012) statistic and interpreted according to the Cochrane guidelines (Higgins and Green, 2011). Analysis of subgroups were performed for health status, age (<50 years old), measurement device and duration between assessments. Publication bias using a funnel plot was not considered appropriate, as originally proposed, as the aims of the physical activity intervention studies were not focused on changes in physical activity levels in the control group. Sensitivity analyses were completed to compare study designs, studies that used medians as means and studies greater than 10 years old and their effects on outcomes.

2.7. Non-statistical analysis

A narrative synthesis of the study and participant characteristics, methodological quality, control group interventions, and a summary of the types of objective measures used is provided. Studies with noteworthy control group changes (changes in means and medians ≥ 10%) were identified. Comparison of studies with and without noteworthy changes in objectively-measured control group physical activity levels were conducted to explore possible explanatory factors.

3. Results

3.1. Flow of studies through the review

The flow of studies through the review is summarized in Fig. 1. The search identified 2903 unique records, with the full text of 154 records

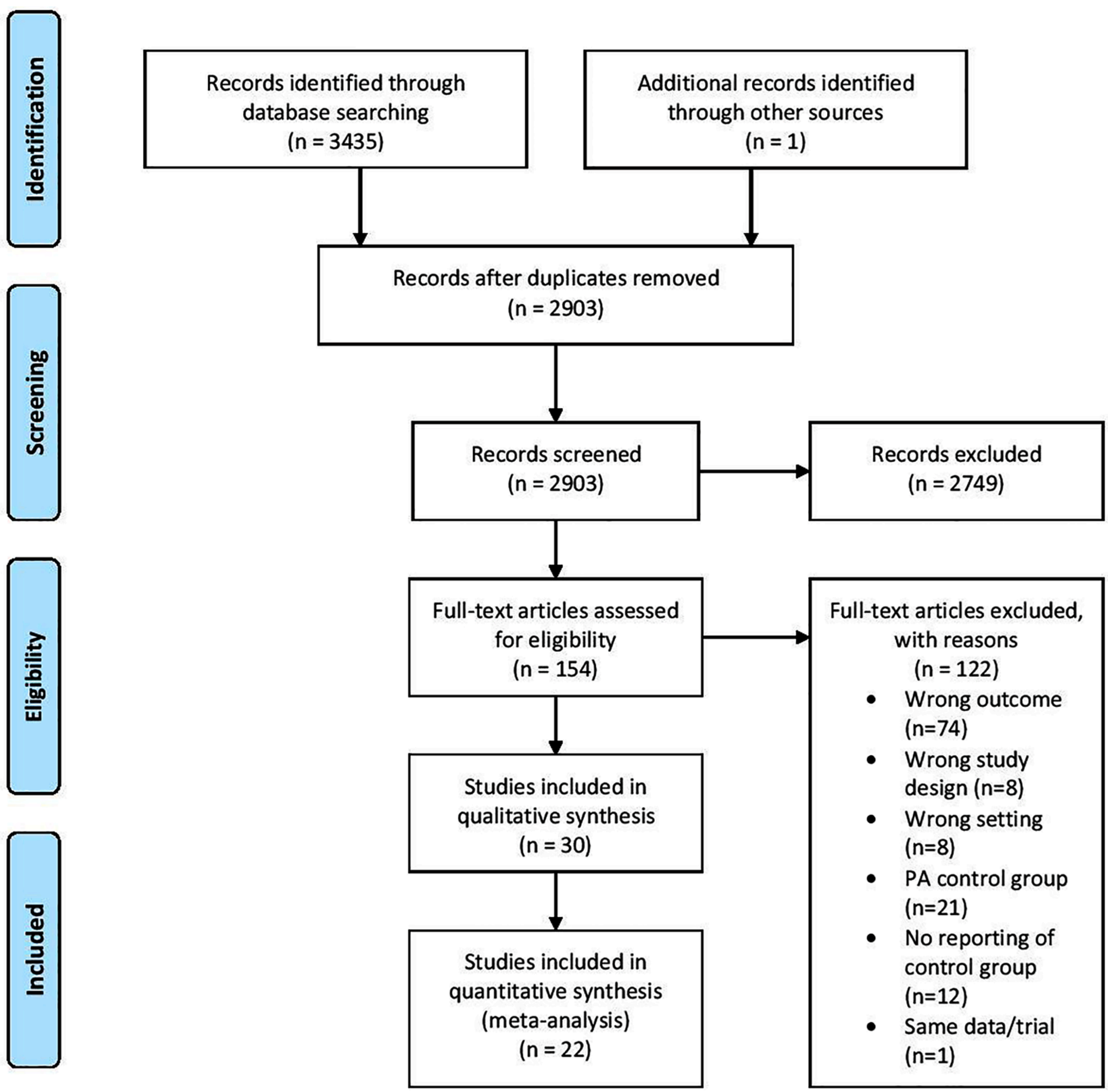

Fig. 1. PRISMA flow diagram demonstrating the flow of studies through the review.

assessed. Thirty records met the inclusion criteria (Eakin et al., 2014; Altenburg et al., 2014; Davies et al., 2016; Kirk et al., 2003; McMurdo et al., 2010; Harris et al., 2015; Samdal et al., 2019; Mutrie et al., 2012; Baba et al., 2017; Calfas et al., 1996; Carr et al., 2008; Devi et al., 2014; Hyman et al., 2007; Kinmonth et al., 2008; McDermott et al., 2018; Melville et al., 2015; Morgan et al., 2014; Pinto et al., 2005; van der Weegen et al., 2015; Vanroy et al., 2017; Wieland et al., 2018; Yates et al., 2017; Dasgupta et al., 2017; De Greef et al., 2011; Fortier et al., 2011; Fuller et al., 2014; Greaves et al., 2015; Bossen et al., 2013; Godino et al., 2016; Harvey-Berino and Rourke, 2003), and 22 studies were included in the *meta*-analysis (McMurdo et al., 2010; Baba et al., 2017; van der Weegen et al., 2015; Eakin et al., 2014; Altenburg et al., 2014; Davies et al., 2016; Harris et al., 2015; Samdal et al., 2019; Mutrie et al., 2012; Carr et al., 2008; Devi et al., 2014; Hyman et al., 2007; McDermott et al., 2018; Melville et al., 2015; Morgan et al., 2014; Wieland et al., 2018; Yates et al., 2017; Dasgupta et al., 2017; De Greef et al., 2011; Fortier et al., 2011; Fuller et al., 2014; Greaves et al., 2015). Eight studies were excluded from the *meta*-analysis as two studies did not provide a measure of variability (Kirk et al., 2003; Calfas et al., 1996), one study used a Biotrainer accelerometer with a different scale of measurement for counts.day^{-1} (Pinto et al., 2005) and five studies used a variety of outcome measures with no more than two studies for each measure (total physical activity minutes.day^{-1} (Bossen et al., 2013); energy expenditure.day^{-1} (Kinmonth et al., 2008; Godino et al., 2016); vector magnitude.hour^{-1} (Harvey-Berino and Rourke, 2003); total physical activity (10 min bout) minutes.day^{-1} [47]).

3.2. Characteristics of included studies

Of the 30 studies included in the review, 23 were randomised control studies (Eakin et al., 2014; Altenburg et al., 2014; Kirk et al., 2003; McMurdo et al., 2010; Samdal et al., 2019; Mutrie et al., 2012; Morgan et al., 2014; Pinto et al., 2005; Vanroy et al., 2017; Wieland et al., 2018; Carr et al., 2008; Devi et al., 2014; Hyman et al., 2007; Kinmonth et al., 2008; McDermott et al., 2018; Dasgupta et al., 2017; De Greef et al., 2011; Fortier et al., 2011; Fuller et al., 2014; Greaves et al., 2015; Bossen et al., 2013; Godino et al., 2016; Harvey-Berino and Rourke, 2003), five were cluster randomised control trials (Davies et al., 2016; Harris et al., 2015; Melville et al., 2015; van der Weegen et al., 2015; Yates et al., 2017) and two were quasi-experimental trials (Baba et al., 2017; Calfas et al., 1996) (Table 1). The publication dates ranged from 1996 to 2019 in the systematic review and 2007–2019 in the *meta*-analysis, with 77% (n = 23/30) and 91% (n = 20/22) of the studies published in the last 10 years, respectively. Studies were conducted in the UK (Harris et al., 2015; Mutrie et al., 2012; Devi et al., 2014; Kinmonth et al., 2008; Melville et al., 2015; Yates et al., 2017; Greaves et al., 2015; Kirk et al., 2003; McMurdo et al., 2010), USA (Calfas et al., 1996; Carr et al., 2008; Hyman et al., 2007; McDermott et al., 2018; Pinto et al., 2005; Wieland et al., 2018), Canada (Dasgupta et al., 2017; Fortier et al., 2011), Australia (Eakin et al., 2014; Morgan et al., 2014), the Netherlands (Altenburg et al., 2014; van der Weegen et al., 2015; Bossen et al., 2013), Germany (Vanroy et al., 2017; De Greef et al., 2011), Brazil (Baba et al., 2017) and Norway (Samdal et al., 2019). Two studies were conducted in two or more countries (Fuller et al., 2014; Harvey-Berino and Rourke, 2003).

3.3. Quality

The risk of bias for each study type is summarised in Supplementary Fig. 1 (RCTs) and 2 (cluster RCTs), and Supplementary Table 1 (quasi-experimental studies). In the RCTs, approximately 70% of studies reported using random sequence generation for randomisation of participants (n = 16/23) and reported all outcome data (n = 17/23). Concealed allocation (n = 13/23) and blinded outcome assessment (n = 11/23) was performed in approximately half the studies. Owing to the nature of the interventions, blinding of participants and personnel was not possible. The overall risk of bias for cluster RCTs appeared to be lower with over 75% of studies having a low risk for recruitment (n = 5/5), analysis (n = 4/5) and comparison with individual randomised trials (n = 4/5). The risk of bias for the two quasi-experimental studies was higher, with most domains receiving a moderate-to-severe risk rating. Only one of the quasi-experimental studies was included in the *meta*-analyses (Baba et al., 2017).

3.4. Participants

The number of participants involved in the 30 studies was 3000. The mean age of participants was 56.6 (SD 11.8) years old. Approximately half the participants were female (mean proportion of female participants, 55.1% (SD 25.9)) and the mean body mass index was 30.5 (SD 2.8). Ten studies included participants with a chronic disease (n = 683) (Eakin et al., 2014; Altenburg et al., 2014; Kirk et al., 2003; Devi et al., 2014; McDermott et al., 2018; van der Weegen et al., 2015; Vanroy et al., 2017; Dasgupta et al., 2017; De Greef et al., 2011; Bossen et al., 2013). Types of chronic diseases included type 2 diabetes mellitus, chronic obstructive pulmonary disease, knee and/or hip osteoarthritis, stable angina and peripheral arterial disease. Six studies included participants that were at risk of chronic disease (n = 1461) (Davies et al., 2016; Hyman et al., 2007; Kinmonth et al., 2008; Yates et al., 2017; Fuller et al., 2014; Greaves et al., 2015). Participants categorised at risk of chronic disease were those with a body mass index greater than 27 and other risk factors for obesity-related and cardiovascular disease, and diabetes. Fourteen studies included participants that were healthy (n = 795) (McMurdo et al., 2010; Wieland et al., 2018; Fortier et al., 2011; Godino et al., 2016; Samdal et al., 2019; Mutrie et al., 2012; Baba et al., 2017; Calfas et al., 1996; Carr et al., 2008; Melville et al., 2015; Morgan et al., 2014; Pinto et al., 2005).

3.5. Control group interventions

Nine control groups received a true control intervention, with no additional contact beyond measurement (McMurdo et al., 2010; Mutrie et al., 2012; Baba et al., 2017; Carr et al., 2008; Melville et al., 2015; Morgan et al., 2014; Vanroy et al., 2017; Wieland et al., 2018; Bossen et al., 2013) (Table 1). Ten studies used usual care only for their control groups (Eakin et al., 2014; Altenburg et al., 2014; Harris et al., 2015; Samdal et al., 2019; Calfas et al., 1996; Devi et al., 2014; McDermott et al., 2018; van der Weegen et al., 2015; De Greef et al., 2011; Fuller et al., 2014). While five studies used usual care plus written physical activity information (Davies et al., 2016; Kirk et al., 2003; Kinmonth et al., 2008; Yates et al., 2017; Greaves et al., 2015), five studies received usual care plus physical activity tailored advice<5 min (Hyman et al., 2007; Pinto et al., 2005; Dasgupta et al., 2017; Fortier et al., 2011; Godino et al., 2016) and one study used an attention control group (Harvey-Berino and Rourke, 2003).

3.6. Objectively-measured physical activity

The main metric for objectively-measured physical activity was steps.day^{-1} (n = 14 studies) (Altenburg et al., 2014; Davies et al., 2016; Harris et al., 2015; Mutrie et al., 2012; Melville et al., 2015; Morgan et al., 2014; Fuller et al., 2014; Devi et al., 2014; Hyman et al., 2007; Yates et al., 2017; Dasgupta et al., 2017; De Greef et al., 2011), followed by moderate-to-vigorous physical activity minutes.day^{-1} (n = 10 studies) (Eakin et al., 2014; McMurdo et al., 2010; Devi et al., 2014; van der Weegen et al., 2015; Wieland et al., 2018; Yates et al., 2017; Samdal et al., 2019; Mutrie et al., 2012), counts.day^{-1} (n = 4 studies) (McMurdo et al., 2010; Harris et al., 2015; McDermott et al., 2018; Yates et al., 2017) and counts.minute^{-1} (n = 4 studies) (Harris et al., 2015; Baba et al., 2017; Fortier et al., 2011; Greaves et al., 2015). Sixteen other studies used various other metrics, for example, total physical activity minutes.day^{-1} (Bossen et al., 2013), energy expenditure.day^{-1}

Table 1
Characteristics of included studies.

Author, year, country, design	Control participants	Control Intervention	Device (worn)	Outcome	Mode of administration	Duration between assessments	Number of interim assessments, time between interim assessments	Intensity of physical activity measurements	Control group improvement (≥10%)
Altenburg (2014)[26] Netherlands RCT	n = 24 Age (yr) = 40–80 Gender = NR BMI = NR Health status = chronic disease (COPD)	Usual care	Pedometer	Steps.day^{-1}	Unclear	3-months (follow-up = 15-months)	0	4	End-intervention: No Follow-up: No
Baba (2017)[36] Brazil Quasi-experimental (controlled)	n = 74 Age (yr) = 43.2% (18–49 yrs), 31.1% (50–59 yrs) Gender = 71F, 3 M BMI = NR Health status = healthy	True control	Accelerometer (ActiGraph GT3X)	Counts. min^{-1}	Unclear	6-months (follow-up = 12-months)	0	2	End-intervention: No Follow-up: No
Bossen (2013)[55] Netherlands RCT	n = 40 Age (yr) = 63 (SD 5.4) Gender = 12F, 28 M BMI = 27.5 (SD 4.5) Health status = chronic disease (self-reported knee/hip OA)	True control	Accelerometer (ActiGraph GT3X)	Total physical activity min. day^{-1}	Self-administered	3-months (follow-up = 12-months)	0	3	End-intervention: No Follow-up: No
Calfas (1996)[37] USA Quasi-experimental (controlled)	n = 22 Age (yr) = >18 Gender = NR BMI = NR Health status = healthy	Usual care	Accelerometer (Caltrac)	Counts.hr^{-1}	Self-administered	4–6 weeks	0	2	End-intervention: No
Carr (2008)[38] USA RCT	n = 18 Age (yr) = 49.4 (SEM 1.7) Gender = NR BMI = 30.6 (SEM 0.8) Health status = healthy	True control	Pedometer (Yamax digiwalker)	Steps.day^{-1}	Interviewer-administered	16-weeks	0	2	End-intervention: Yes
Dasgupta (2017)[50] Canada RCT	n = 173 Age (yr) = 59.4 (SD 11.4) Gender = 91F, 82 M BMI = 31.8 (SD 4.5) Health status = chronic disease (type 2 diabetes, hypertension or both)	Usual care plus physical activity tailored advice (<5min)	Pedometer (Yamax digiwalker)	Steps.day^{-1}	Interviewer-administered	14-months	3 Time between unclear	1	End-intervention: No
Davies (2016)[27] UK Cluster RCT	n = 433 Age (yr) = 63.9 (SD 7.9) Gender = 155F, 278 M BMI = 33.1 (SD 5.8) Health status = at risk of chronic disease (pre-diabetes)	Usual care plus physical activity print info	Pedometer (NL-800)	Steps.day^{-1}	Interviewer-administered	36-months	3, 6, 12 and 24-months	3	End-intervention: No
De Greef (2011)[51]	n = 24 Age (yr) = 66	Usual care		Steps.day^{-1}	Interviewer-administered	12-weeks	0	2	

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Table 1 (*continued*)

Author, year, country, design	Control participants	Control Intervention	Device (worn)	Outcome	Mode of administration	Duration between assessments	Number of interim assessments, time between interim assessments	Intensity of physical activity measurements	Control group improvement (≥10%)
Germany RCT	(SD 11.1) Gender = 29.2% F, 70.8% M BMI = 31.5 (SD 5.6) Health status = chronic disease (type 2 diabetes)		Pedometer (Yamax digiwalker)						End-intervention: No
Devi (2014)[39] UK RCT	n = 46 Age (yr) = 66.2 (SD 10.06) Gender = 10F, 38 M BMI = NR Health status = chronic disease (stable angina)	Usual care	Accelerometer (Sensewear Pro 3)	Steps.day^{-1}; moderate physical activity mins.day^{-1}; energy expenditure. day^{-1}	Interviewer-administered	6-weeks (follow-up = 7.5 months)	0	3	End-intervention: No Follow-up: NR
Eakin (2014)[25] Australia RCT	n = 151 Age (yr) = 58.3 (SD 9) Gender = 65F, 86 M BMI = 33.2 (SD 6) Health status = chronic disease (type 2 diabetes)	Usual care	Accelerometer (ActiGraph GT1M)	MVPA min. week^{-1}	Interviewer-administered	18-months (follow-up = 24 months)	1 6-months	2	End-intervention: No Follow-up: No
Fortier (2011)[52] Canada RCT	n = 59 Age (yr) = 47.5 (SD 11) Gender = 41F, 18 M BMI = 30.2 (SD 8.4) Health status = healthy	Usual care plus PA tailored advice (<5min)	Accelerometer (Actical)	Counts. min^{-1}; moderate physical activity mins.day^{-1} (%); vigorous physical activity mins.day^{-1} (%)	Interviewer-administered	13-weeks (follow-up = 25-weeks)	1 6-weeks	3	End-intervention: No Follow-up: No
Fuller (2014)[53] Australia, UK & Germany RCT	n = 376 Age (yr) = 48.2 (SD 12.2) Gender = 388F, 57 M BMI = 31.3 (SD 2.6) Health status = at risk of chronic disease (BMI 27–35 + 1 risk factor for obesity-related disease)	Usual care	Pedometer (Weight Watchers)	Steps.day^{-1}	Interviewer-administered	12-months (follow-up = 24-months)	2 6 and 18-months	2	End-intervention: Yes Follow-up: No
Godino (2016)[56] UK RCT	n = 190 Age (yr) = 48.5 (SD 7) Gender = 92F, 98 M BMI = 26.1 (SD 4.2) Health status = healthy	Usual care plus PA tailored advice (<5min)	Actiheart	Energy expenditure. day^{-1}	Interviewer-administered	8-weeks	0	4	End-intervention: No
Greaves (2015)[54] UK RCT	n = 53 Age (yr) = 63.7 (SD 7.4) Gender = 14F, 39 M BMI = 32.3 (SD	Usual care plus PA print info	Accelerometer (ActiGraph GT3X)	MVPA min. day^{-1}; steps. day^{-1}; counts. min^{-1}	Interviewer-administered	12-months (intervention = 9-months)	1 4-months	2	End-intervention (MVPA min. day^{-1}): Yes End-intervention

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Table 1 (*continued*)

Author, year, country, design	Control participants	Control Intervention	Device (worn)	Outcome	Mode of administration	Duration between assessments	Number of interim assessments, time between interim assessments	Intensity of physical activity measurements	Control group improvement (≥10%)
	3) Health status = at risk chronic disease (BMI 28 + and high cardiovascular risk)								(steps.day^{-1}; counts. min^{-1}): No
Harris (2015)[32] UK Cluster RCT	n = 148 Age (yr) 60–64, n = 69; 65–69, n = 44; 70–75, n = 35 Gender = 79F, 69 M BMI = 27.1 (SD 4.5) Health status = healthy	Usual care	Accelerometer (ActiGraph GT3X)	MVPA min. week^{-1}; MVPA (10 min bout) min.week^{-1}; steps.day^{-1}; counts. day^{-1}; counts. min^{-1}	Interviewer-administered	3-months (follow-up = 12-months)	0	2	End-intervention: No Follow-up: No
Harvey-Berino (2003)[57] USA & Canada RCT	n = 20 Age (yr) = 26.5 (SD NR) Gender = 20F BMI = 29.5 (SD 2.7) Health status = healthy	Attention control	Accelerometer (Tritrac)	Vector magnitude. hour^{-1}	Interviewer-administered	16-weeks	0	3	End-intervention: Yes
Hyman (2007)[40] USA RCT	n = 93 Age (yr) = 52.7 (SD 6.5) Gender = 68F, 25 M BMI = 33.4 (SD 8.2) Health status = at risk of chronic disease (African American, hypertension, smokers)	Usual care plus physical activity tailored advice (<5min)	Pedometer	Steps.day^{-1}	Interviewer-administered	18-months	2 6 and 12-months	2	End-intervention: No
Kinmonth (2008)[41] UK RCT	n = 121 Age (yr) = NR Gender = NR BMI = 27.8 (SD 5.2) Health status = at risk of chronic disease (parental history of diabetes)	Usual care plus physical activity print info	Heart rate monitor	Daily energy expenditure / Resting energy expenditure	Interviewer-administered	12-months	1 6-months	4	End-intervention: No
Kirk (2003)[28] UK RCT	n = 35 Age (yr) = NR Gender = NR BMI = 33.7 (SD 5.7) Health status = chronic disease (type 2 diabetes)	Usual care plus physical activity print info	Accelerometer (Computer Science and Applications)	Counts. week^{-1}	Interviewer-administered	6-months	0	4	End-intervention: No
McDermott (2018)[42] USA RCT	n = 101 Age (yr) = 70.4 (SD 10.1) Gender = 51F, 50 M BMI = 29.9 (SD 5.3) Health status = chronic disease (peripheral arterial disease)	Usual care only	Accelerometer (Actigraph)	Counts. day^{-1}	Interviewer-administered	9-months	2 Every 3-months	3	End-intervention: No

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Table 1 (*continued*)

Author, year, country, design	Control participants	Control Intervention	Device (worn)	Outcome	Mode of administration	Duration between assessments	Number of interim assessments, time between interim assessments	Intensity of physical activity measurements	Control group improvement (≥10%)
McMurdo (2010)[29] UK RCT	n = 68 Age (yr) = 77 (SD 4.9) Gender = 68F BMI = NR Health status = healthy	True control	Accelerometer (RT3 Accelerometry Research Tracker)	Counts. day^{-1}; Walking $mins.day^{-1}$	Unclear	6-months	0	1	End-intervention: No
Melville (2015)[43] UK Cluster RCT	n = 48 Age (yr) = 47.7 (SD 12.3) Gender = 20F, 28 M BMI = 32.6 (SD 7.4) Health status = healthy	True control	Accelerometer (Actigraph GT3X)	MVPA mins. day^{-1} (%); total physical activity $mins.day^{-1}$ (%); steps. day^{-1}	Interviewer-administered	12-weeks (follow-up = 24-weeks)	0	3	End-intervention: No Follow-up: NR
Morgan (2014)[44] Australia RCT	n = 45 Age (yr) = 40.9 (SD 5.6) Gender = 45 M BMI = 32.3 (SD 3.9) Health status = healthy	True control	Pedometer (Yamax sw200)	$Steps.day^{-1}$	Interviewer-administered	14-weeks (intervention = 7-weeks)	0	2	End-intervention: Yes
Mutrie (2012)[34] UK RCT	n = 21 Age (yr) = 70 (SD 4.3) Gender = 15F, 6 M BMI = NR Health status = healthy	True control	Pedometer (NL-1000); Accelerometer (activPAL)	$Steps.day^{-1}$; walking time $mins.day^{-1}$	Interviewer-administered	12-weeks	0	2	End-intervention: No
Pinto (2005)[45] USA RCT	n = 48 Age (yr) = 68.3 (SD 7.6) Gender = 30F, 18 M BMI = 28.2 (SD 4.5) Health status = healthy	Usual care plus physical activity tailored advice (<5min)	Accelerometer (Biotrainer)	Counts. day^{-1}	Self-administered	6-months	1 3-months	3	End-intervention: No
Samdal (2019)[33] Norway RCT	n = 61 Age (yr) = 49.4 (SD 13.5) Gender = 46F, 15 M BMI = 34.1 (SD 5.4) Health status = healthy	Usual care	Accelerometer (Sensewear Pro 3)	MVPA hrs. day^{-1}	Interviewer-administered	6-months	0	2	End-intervention: No
van der Weegen (2015)[46] Netherlands Cluster RCT	n = 68 Age (yr) = 59.2 (SD 7.5) Gender = F, M BMI = 28.2 (SD 4.3) Health status = chronic disease (type 2 diabetes or COPD)	Usual care	Accelerometer (Personal activity monitor)	MVPA mins. day^{-1}	Self-administered	6-months (follow-up = 9-months)	0	2	End-intervention: No Follow-up: No
Vanroy (2017)[47] Germany RCT	n = 21 Age (yr) = 59.4 (SD 8.2) Gender = 11F, 10 M BMI = NR Health status = chronic disease (type 2 diabetes)	True control	Accelerometer (Sensewear)	Total physical activity (10 min bout) $mins.day^{-1}$	Interviewer-administered	6-weeks (follow-up = 6-months)	0	4	End-intervention: No Follow-up: No

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Table 1 (*continued*)

Author, year, country, design	Control participants	Control Intervention	Device (worn)	Outcome	Mode of administration	Duration between assessments	Number of interim assessments, time between interim assessments	Intensity of physical activity measurements	Control group improvement (≥10%)
Wieland (2018)[48] USA RCT	n = 34 Age (yr) = 38.9 (SD 11.7) Gender = 23F, 11 M BMI = 23.8 (SD 5.4) Health status = healthy	True control	Accelerometer (Kinetic activity monitor)	MVPA mins. day^{-1}	Interviewer-administered	12-months	1 6-months	2	End-intervention: No
Yates (2017)[49] UK Cluster RCT	n = 385 Age (yr) = 63.7 (SD 8.1) Gender = 148F, 237 M BMI = 32.4 (SD 5.3) Health status = at risk chronic disease (high type 2 diabetes risk score)	Usual care plus PA print info	Accelerometer (Actigraph GT3X)	MVPA mins. day^{-1}; steps. day^{-1}; steps. day^{-1} (≥500 counts. min^{-1}); counts.day^{-1}	Interviewer-administered	36-months	0	3	End-intervention: No

SD, standard deviation; RCT, randomised control trial; COPD, chronic obstructive pulmonary disease; NR, not reported; OA, osteoarthritis; MVPA, moderate-to-vigorous physical activity

(Kinmonth et al., 2008; Godino et al., 2016), and vector magnitude. hour^{-1} (Harvey-Berino and Rourke, 2003) (Supplementary Table 1).

Accelerometers were used in 19 studies to measure physical activity (Eakin et al., 2014; Kirk et al., 2003; McMurdo et al., 2010; Harris et al., 2015; Samdal et al., 2019; Baba et al., 2017; Calfas et al., 1996; Devi et al., 2014; McDermott et al., 2018; Melville et al., 2015; Fortier et al., 2011; Greaves et al., 2015; Bossen et al., 2013; van der Weegen et al., 2015; Vanroy et al., 2017; Wieland et al., 2018; Yates et al., 2017), pedometers were used in nine studies (Altenburg et al., 2014; Davies et al., 2016; Mutrie et al., 2012; Carr et al., 2008; Hyman et al., 2007; Morgan et al., 2014; Dasgupta et al., 2017; De Greef et al., 2011; Fuller et al., 2014) and two studies used other devices (Kinmonth et al., 2008; Godino et al., 2016). The measurement device was administered by an interviewer in 77% (n = 23/30) of the included studies. The median duration between physical activity measurements (baseline to end-intervention) was 24 weeks (IQR 12, 52), varying between 4 and 6 weeks and 36 months. The median intensity of physical activity measurements was 2 (IQR 2, 3), with the main type of additional physical activity measurement being a physical activity questionnaire (subjective measure) and measurement of other constructs related to physical activity, for example, a self-efficacy questionnaire. Eleven studies included follow-up data, with follow-up assessments varying between 6 and 24 months post baseline measures (Supplementary Table 1).

3.7. Improvement in physical activity within control groups

Seventeen percent of studies increased their physical activity levels 10% or more in the control group (n = 5/30) at the end of the intervention period (Carr et al., 2008; Morgan et al., 2014; Fuller et al., 2014; Greaves et al., 2015; Harvey-Berino and Rourke, 2003) (Table 2). All studies were RCTs and the majority of control groups in these studies had<55 participants, although one study with a noteworthy control group improvement had 376 participants (Fuller et al., 2014). There were no 10% or more improvements in control group physical activity levels from baseline to follow-up, therefore, there was no *meta*-analysis completed for this. The risk of bias appeared to be slightly higher in studies reporting a noteworthy change in objectively-measured physical, with 60% (n = 3/5) of studies reporting no blinding of outcome assessments (Carr et al., 2008; Morgan et al., 2014; Fuller et al., 2014; Greaves et al., 2015; Harvey-Berino and Rourke, 2003). Noteworthy increases were reported in studies with younger participants, one third of the pedometer studies, one third of studies with participants at risk of chronic disease, one fifth of the studies using steps.day^{-1}, one fifth of studies with healthy participants and in studies with a shorter duration between measurements (Table 2). Number of interim physical activity assessments, intensity of physical activity measurement, sex and body mass index did not appear to be possible explanatory factors for control group improvements in physical activity. Of the ten studies that included chronic disease participants, none included control group improvements in physical activity.

3.8. Steps.day^{-1}

Steps.day^{-1} was measured in 14 studies (10 RCTs (Altenburg et al., 2014; Mutrie et al., 2012; Morgan et al., 2014; Dasgupta et al., 2017; De Greef et al., 2011; Fuller et al., 2014; Devi et al., 2014; Hyman et al., 2007); four cluster RCTs 27,32,43,49), totaling 1915 participants. One study used both an accelerometer and pedometer to measure steps. day^{-1}, providing results in different directions (Mutrie et al., 2012). Steps.day^{-1} did not significantly improve within control groups with a pooled mean difference of 66 steps less than baseline (95% CI −423 to 291; P = 0.72; Fig. 2A), and high heterogeneity ($I^2 = 82\%$; $\chi^2 = 77.24$; P < 0.0001). This result did not change when two studies that only provided medians were removed (Altenburg et al., 2014; Davies et al., 2016), nor when two studies that were conducted greater than 10 years ago were removed from the analyses to account for improvements in the accuracy of devices over time (Carr et al., 2008; Hyman et al., 2007). Three studies reported a noteworthy change (Carr et al., 2008; Morgan et al., 2014; Fuller et al., 2014). Sub-analyses revealed in studies that included participants<50 years old (n = 4; 487 participants) (Carr et al., 2008; Melville et al., 2015; Morgan et al., 2014; Fuller et al., 2014) there was an increase in steps.day^{-1} within control groups (pooled mean difference = 504 steps.day^{-1}; 95% CI −20.39 to 1028.63; P = 0.06; Fig. 2B). In studies that used pedometers to measure steps.day^{-1} (n = 9, 1207 participants) (Altenburg et al., 2014; Davies et al., 2016; Mutrie et al., 2012; Carr et al., 2008; Hyman et al., 2007; Morgan et al., 2014;

Table 2
Differences between studies with and without a noteworthy (≥10%) control group improvement in objectively-measured physical activity.

Characteristic*	Control group improvement (≥10%)(n = 5)	No control group improvement(n = 25)
Device used for objective measurement of physical activity		
Pedometer	3 (60)	6 (24)
Accelerometer	2 (40)	17 (68)
Other	0 (0)	2 (8)
Measurement device administered by an interviewer	5 (100)	18 (72)
Physical activity measurement outcome		
Steps.day^{-1}	3 (60)	11 (44)
MVPA minutes.day^{-1}	1 (20)	9 (36)
Counts.day^{-1}	0 (0)	5 (20)
Counts.minute^{-1}	0 (0)	4 (16)
Other	1 (20)	15 (60)
Duration between baseline and end-intervention measurement (weeks), median (IQR)	16 (15–52)	24 (12–52)
Number of interim assessments, median (IQR)	0 (0–1.5)	0 (0–1)
Intensity of physical activity measurements, median (IQR)	2 (2–2.5)	3 (2–3)
Additional types of physical activity measurements		
Objective measure	0 (0)	1 (4)
Subjective measure	1 (20)	12 (48)
Objective measure of fitness	1 (20)	6 (24)
Other constructs related to physical activity	1 (20)	12 (48)
Measurement of other health behaviors	3 (60)	7 (28)
Characteristics of study participants		
Proportion of female participants (%), mean (SD)	53 (48)	56 (21)
Age (yrs), mean (SD)	45.7 (13.6)	59.4 (9.8)
BMI (kg/m^2), mean (SD)	31.2 (1.2)	30.3 (3.1)
Health status		
Healthy	3 (60)	11 (44)
At risk of chronic disease	2 (40)	4 (16)
Diagnosed with chronic disease	0 (0)	10 (40)
Control intervention		
True control	2 (40)	7 (28)
Attention control	1 (20)	0 (0)
Usual care only	1 (20)	9 (36)
Usual care plus written physical activity information	1 (20)	4 (16)
Usual care plus physical activity tailored advice (<5 min)	0 (0)	5 (20)

*Number (%), unless otherwise stated. MVPA, moderate-to-vigorous physical activity; BMI, body mass index.

Dasgupta et al., 2017; De Greef et al., 2011; Fuller et al., 2014) there was also a trend for steps.day^{-1} to increase (pooled mean difference = 196 steps.day^{-1}; 95% CI −334.79 to 726.36; P = 0.47; Supplementary Fig. 3). In studies that included healthy participants (n = 5; 259 participants) (Harris et al., 2015; Mutrie et al., 2012; Carr et al., 2008; Melville et al., 2015; Morgan et al., 2014), there was a very small, positive increase in steps.day^{-1} that was not significant (pooled mean difference = 39 steps.day^{-1}; 95% CI −400.86 to 479.13; P = 0.86; Supplementary Fig. 4). Five studies included 1340 participants who were at risk of chronic disease and measured steps.day^{-1} (Davies et al., 2016; Hyman et al., 2007; Yates et al., 2017; Fuller et al., 2014; Greaves et al., 2015). The pooled mean difference in these participants was a decrease of 234 steps.day^{-1} (95% CI −932.44 to 465; P = 0.51; Supplementary Fig. 5). In studies of shorter duration between measurements (<6 months), eight studies measured steps.day^{-1} including 377 participants (Altenburg et al., 2014; Harris et al., 2015; Mutrie et al., 2012; Carr et al., 2008; Devi et al., 2014; Melville et al., 2015; Morgan et al., 2014; De Greef et al., 2011). The pooled mean difference was a very small increase of 20 steps.day^{-1} in the control groups (95% CI −358.95 to 398.52; P = 0.92; Supplementary Figure 6). Sensitivity analysis found that there was a difference in direction of the pooled mean difference when comparing cluster RCTs and RCTs. The pooled mean difference for cluster RCTs (n = 4) was a significant decrease in steps.day^{-1} (-716.72; 95% CI −975.52 to −457.93; P < 0.00001; I^2 = 35%). While for RCTs (n = 10), there was an increase in steps.day^{-1} (208.18; 95% CI −98.15 to 514.52; P = 0.18; I^2 = 49%).

3.9. Moderate-to-vigorous physical activity minutes.day^{-1}

Ten studies measured MVPA minutes.day^{-1}, including 1035 participants (Eakin et al., 2014; McMurdo et al., 2010; Devi et al., 2014; van der Weegen et al., 2015; Wieland et al., 2018; Yates et al., 2017; Samdal et al., 2019; Mutrie et al., 2012). There was a significant decrease in MVPA minutes.day^{-1} within control groups from baseline to end-intervention, with a pooled mean difference of −3.97 min (95% CI −6.31 to −1.64; P = 0.0009; Fig. 3). This result did not change when one study that only provided medians was removed from the analysis (Eakin et al., 2014). One study reported a noteworthy change (Greaves et al., 2015). In studies that included healthy participants (n = 5; 332 participants) (McMurdo et al., 2010; Samdal et al., 2019; Mutrie et al., 2012) there was also a significant decrease in MVPA minutes.day^{-1} (pooled mean difference = -4.75 min; 95% CI −7.74 to −1.75; P = 0.002; Supplementary Figure 7). There were only two studies where the mean age of participants was<50 years old (Samdal et al., 2019; Wieland et al., 2018). There were three studies where the duration between measurements was<6 months. In the sensitivity analysis, including RCTs only (n = 7), there was a non-significant decrease in MVPA minutes.day^{-1} (mean difference = -3.1; 95% CI −6.86 to 0.66; P = 0.11; I^2 = 49%).

3.10. Counts.day^{-1}

Counts.day^{-1} was measured in four studies (McMurdo et al., 2010; Harris et al., 2015; McDermott et al., 2018; Yates et al., 2017), with a total of 702 participants included in the *meta*-analysis. One study used a bio-trainer to measure counts.day^{-1} using a different scale to the other measures and was therefore not included (Pinto et al., 2005). There was no significant change in control group counts.day^{-1} from baseline to end-intervention, with a pooled mean difference of −14,000 counts (95% CI −34,950 to 7,200; P = 0.20; Fig. 4). No studies reported noteworthy changes. There was only one study where the duration between measurements was<6 months, and no studies where the mean age of participants was<50 years old. Half of the studies were conducted in healthy participants (n = 2/4).

3.11. Counts.minute^{-1}

Four studies used counts.minute^{-1} to measure physical activity (Harris et al., 2015; Baba et al., 2017; Fortier et al., 2011; Greaves et al., 2015), including 334 participants. There was no significant difference in control group counts.minute^{-1} from baseline to end-intervention, with a mean difference of −4 counts (95% CI −21.12 to 12.62; P = 0.62; Fig. 5). No studies reported noteworthy changes. Seventy-five percent of studies included healthy participants (n = 3/4), half of the studies had an assessment duration<6 months, and one study had a mean age<50 years old.

4. Discussion

This is the first systematic review and *meta*-analysis to examine changes in objectively-measured physical activity in control groups

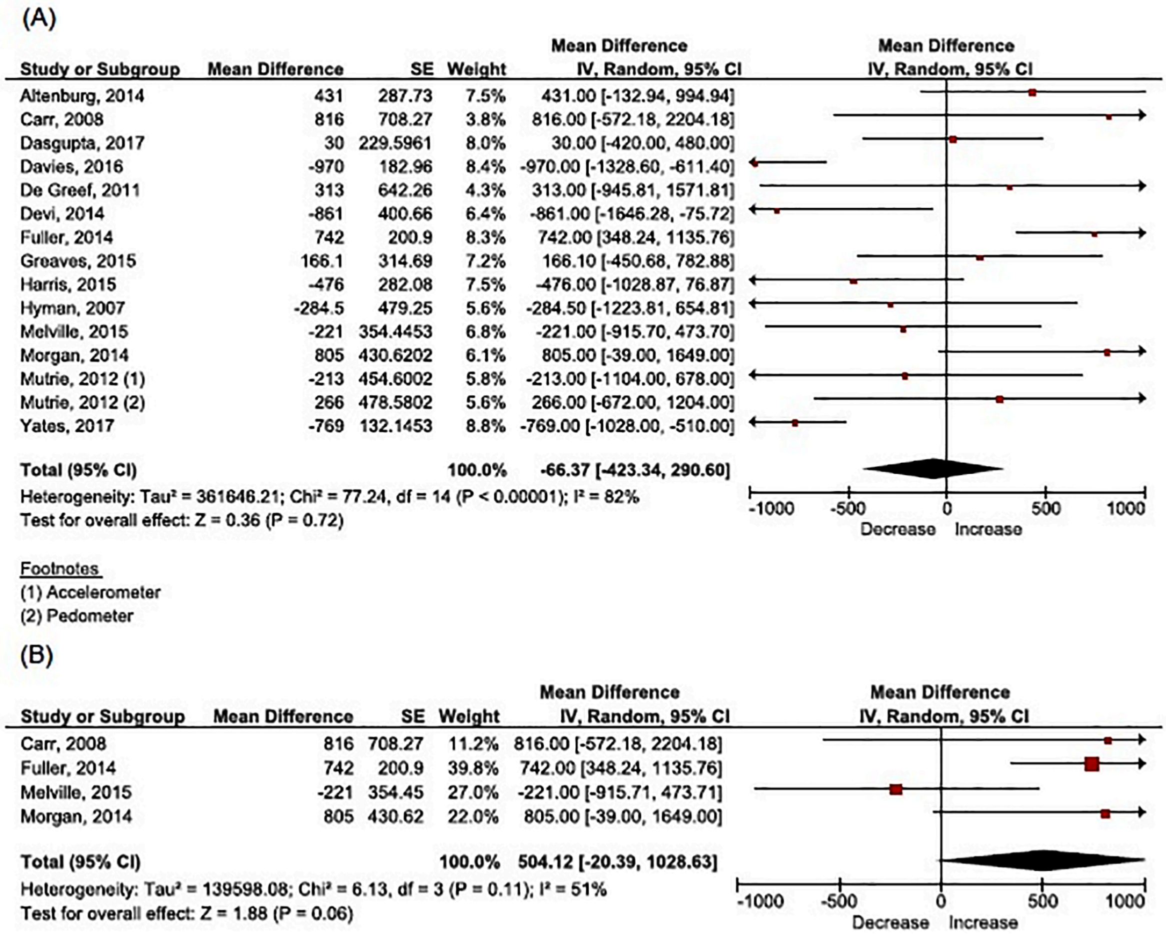

Fig. 2. Mean differences and 95% confidence intervals within control groups for objectively-measured (A) steps.day^{-1}, and (B) steps.day^{-1} (<50 years old).

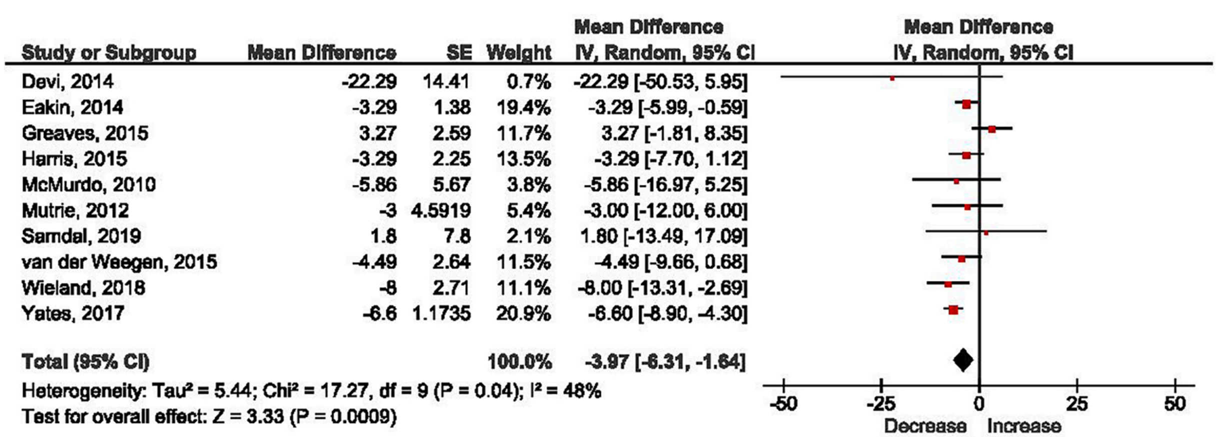

Fig. 3. Mean differences and 95% confidence intervals within control groups for objectively-measured moderate-to-vigorous physical activity minutes.day^{-1}.

within physical activity intervention trials in primary care. Meta-analyses demonstrated that steps.day^{-1}, counts.day^{-1} and counts.minute^{-1} did not significantly change in control groups, while moderate-to-vigorous physical activity minutes.day^{-1} significantly decreased. Despite this, almost 20% of studies reviewed reported a noteworthy improvement (≥10%) in objectively-measured physical activity among control group participants. Improvements were found in studies with younger participants and in studies with shorter duration between measurements. One third of pedometer studies reported noteworthy improvements. Objectively-measured physical activity did not improve for any control group participants with chronic disease, although improvements were reported in participants that were healthy or had risk factors for chronic disease. Meta-analysis revealed that in control group participants<50 years old there was a trend to increase their steps.day^{-1} with measurement alone.

According to the *meta*-analyses, measurement reactivity, or the mere-measurement effect, is not present in objectively-measured physical activity in primary care. Although, the measurement effect has been

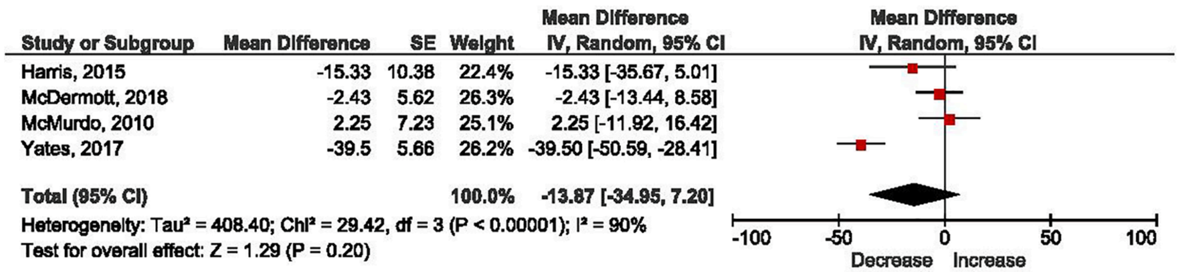

Fig. 4. Mean differences and 95% confidence intervals within control groups for objectively-measured counts.day^{-1} (,000).

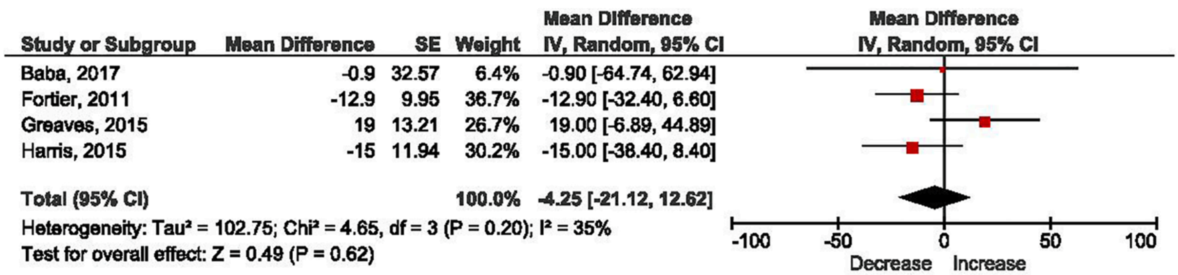

Fig. 5. Mean differences and 95% confidence intervals within control groups for objectively-measured counts.minute^{-1}.

reported where objective measurement of physical activity has been used, with participants increasing their physical activity levels in the light intensity range, with little change in MVPA (Motl et al., 2012; Baumann et al., 2018; Clemes et al., 2008). The mechanism of action behind measurement reactivity and the mere-measurement effect is unclear, with a range of possible underlying mechanisms including the behaviour change techniques of 'prompts/cues' and 'credible source' (Michie et al., 2014). There may be reasons other than measurement reactivity for control group improvements in physical activity. This could include self-monitoring (Michie et al., 2014). Objective measurement of physical activity within control groups is an outcome measure, rather than an intervention. Typically displays are not visible on devices such as accelerometers, although they may be visible in studies using pedometers, and self-monitoring may contribute to increases in objectively-measured physical activity (Bravata et al., 2007). Other reasons for control group improvements in physical activity could include the recruitment of motivated participants, social-desirability bias and a higher intensity of contact compared to usual care in a clinical setting (Waters et al., 2012). The advantage of using objectively-measured physical activity is the minimisation of self-report or social-desirability bias. This may explain why Waters (2012) found that almost 30% of studies reported control group improvements in physical activity intervention studies conducted in primary care using self-reported physical activity levels, whereas we found almost 20% (Waters et al., 2012). Regardless of this, control group improvements in physical activity levels, whether measured by self-report or objectively, were found in a considerable proportion of studies in primary care, and this is worthy of further investigation and consideration when conducting physical activity studies within this setting. Particularly in a proportion of the population who may be more motivated to change their physical activity levels with minimal input, such as younger adults without chronic disease.

In contrast to Waters (2012), studies with a shorter intervention duration (compared with longer intervention duration) were more likely to result in improvements in objectively-measured physical activity (Waters et al., 2012). Waters (2012) discussed that their finding may be confounded by longer duration intervention studies being significantly more likely to have interim assessments between baseline and end-intervention measures. The number of interim assessments appeared to impact on participants physical activity levels, which may support our findings that a shorter duration between assessments were more likely to result in noteworthy improvements in physical activity. Additionally, no noteworthy changes were found at follow-up assessments, indicating that interim assessments or more frequent measurement may be important. A recent pilot RCT investigating the effects of frequency of physical measurement with very brief advice from a health professional in healthy participants within a primary care setting, found that a higher frequency of measurement may result in an increase in objectively-measured MVPA ($P = 0.084$, Cohen's $d = 0.58$) (Freene et al., 2019). Although, this review found there was no difference in the number of interim assessments between studies with and without noteworthy improvements.

The type of control intervention delivered did not appear to have an effect on control group improvements in physical activity, with all control group interventions, ranging from true control to usual care plus written physical activity information, finding improvements in physical activity in at least one study. It has been argued that true control group interventions should be employed more frequently to allow researchers to more easily interpret the change in control group physical activity levels driven possibly by the measurement effect, although this does not seem to be consistent in this setting (Waters et al., 2012). Interestingly, there were no improvements in physical activity in usual care plus physical activity tailored advice<5 min control groups. As discussed by Waters (2012), given the limited description of study protocols, the difference between interview-administered measurement devices and<5 min of tailored physical activity advice may be minimal (Waters et al., 2012). Most studies in this review used an interviewer to provide the measurement device ($n = 23/30$), with all studies with noteworthy improvements using this method of administration.

Similar to Waters (2012), this review found that a higher proportion of studies with participants at risk of chronic disease had noteworthy improvements in physical activity compared to studies with healthy and chronic disease participants (Waters et al., 2012). Participants at risk of chronic disease may be more motivated to increase their physical activity levels without the need for comprehensive interventions. Whereas, no noteworthy changes in physical activity were found in studies with chronic disease participants. This may indicate that interventions required for behavior change in this population may need to be more complex with potentially more barriers to physical activity participation. This is supported by a *meta*-analysis of patient education interventions to increase physical activity among chronically ill adults, finding that studies with behavior change strategies (eg: goal setting, feedback, contracting, consequences) to increase physical activity reported larger effect sizes compared to studies that did not use any behavioral strategies (Conn et al., 2008).

Our results may also explain why smaller non-significant differences are found in physical activity intervention studies in primary care which involve younger, healthier participants, with a trend for these participants in the control group to also increase their physical activity levels. A recent systematic review found no effect for physical activity interventions in primary care in young and middle-aged adults' without clinical conditions (Murray et al., 2017). They concluded that primary care may not be the most appropriate setting for promoting physical activity in healthy populations but may have a significant role in clinical populations. This is concerning, and it is important for researchers to acknowledge when planning a physical activity intervention study in primary care that younger and healthier participants may increase their physical activity levels within control groups. This will affect their results and may also indicate that minimal resources are required to stimulate improvements in physical activity levels in this group. Clinically this may indicate that frequent measurement of physical activity alone may be a low-cost and time-efficient approach that is effective in a proportion of younger, healthier participants in primary care to increase physical activity levels. Further research is indicated, including the long-term sustainability of increases in physical activity using this approach.

4.1. Strengths and limitations

This review was conducted in accordance with the PRISMA guidelines and followed a pre-specified protocol registered on PROSPERO. A major strength of this review is the use of a 10% improvement in physical activity levels from baseline, reinforcing the public health physical activity guidelines message that anything is better than nothing ([63]). Although, it is acknowledged that there is currently no consensus on what is a clinically meaningful difference in objectively-measured physical activity and the results may differ using a different definition of a noteworthy improvement. Furthermore, the 10% meaningful increase in physical activity measures is more than the reported measurement error for pedometers (<5%), where one third of the studies using this device found noteworthy improvements (Schneider et al., 2003; Crouter et al., 2003; Vincent and Sidman, 2003). Sub-analyses were also conducted to evaluate potential explanatory factors for changes in control group physical activity levels, and sensitivity analyses was conducted to compare study designs, the use of medians as means and studies conducted in the last 10 years, and their impact on the results.

Despite these strengths, there are some limitations. Meta-analyses were only conducted for four objective measures of physical activity due to the limited number of studies using other objective measures for physical activity. Only the primary care setting was considered within this review, with some focus on general practice and family physicians (medical practitioners), therefore findings cannot be generalised to other settings. There were also a small numbers of studies for sub-analyses, preventing further exploration using *meta*-analyses, and a number of studies had small sample sizes (<100 participants; n = 20/30). The cut-off for participants' age was also based on the mean age of participants and some participants will have been older than the cut-off years. Additionally, high statistical heterogeneity was present in steps.day^{-1}, steps.day^{-1} (pedometers), steps.day^{-1} (at risk of chronic disease) and counts.day^{-1} *meta*-analyses, while other *meta*-analyses had low to moderate heterogeneity with *I* (Lee et al., 2012) values ranging from 0% to 92% for the pooled mean differences.

5. Conclusions

No significant improvements in objectively-measured physical activity were found in control groups in primary care. Nevertheless, there is evidence of some improvement in physical activity levels within control groups. This may indicate that physical activity measurement alone in a proportion of younger participants without chronic disease may be enough to increase objectively-measured physical activity levels in primary care, although further investigation of sub-groups of participants, including the minimal use of pedometers, is needed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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