The Gerontologist
cite as: *Gerontologist*, 2019, Vol. XX, No. XX, 1–17
doi:10.1093/geront/gnz167
Advance Access publication December 23, 2019

Review Article

Interventions Promoting Physical Activity Among Older Adults: A Systematic Review and Meta-Analysis

Guilherme D. Grande, MSc,[1,2] Crystian B. Oliveira, MSc,[2] Priscila K. Morelhão, MSc,[3] Catherine Sherrington, PhD,[4] Anne Tiedemann, PhD,[4] Rafael Z. Pinto, PhD[5] and Marcia R. Franco, PhD[6,*]

[1]Departamento de Medicina Preventiva e Social, Universidade do Oeste Paulista, Presidente Prudente, Brazil. [2]Departamento de Fisioterapia, Faculdade de Ciências e Tecnologia, Universidade Estadual Paulista, Presidente Prudente, Brazil. [3]Departamento de Psicobiologia, Universidade Federal de São Paulo (UNIFESP), Brazil. [4]School of Public Health, University of Sydney, Australia. [5]Departamento de Fisioterapia, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil. [6]Departamento de Fisioterapia, Centro Universitário UNA, Contagem, Minas Gerais, Brazil.

*Address correspondence to: Marcia R. Franco, PhD, Av Maria da Gloria Rocha, 175 Lote 01 Letra B - Bitacula, Contagem, Minas Gerais, CEP 32010-375, Brazil. E-mail: marciarfranco@gmail.com

Received: February 20, 2019; Editorial Decision Date: November 2, 2019

Decision Editor: Patricia C. Heyn, PhD

Abstract

Background and Objectives: Frequent participation in physical activity (PA) has benefits across the lifespan but is particularly important for older adults. PA levels are either measured by objective or self-reported survey methods. Objective PA measurement is used to increase accuracy. This systematic review investigated the effect of physical activity-based interventions on objectively measured PA levels among community-dwelling adults aged 60 years and older.
Research Design and Methods: Literature searches were conducted in five electronic databases and four clinical trial registries. Randomized controlled trials investigating the effect of physical activity–based interventions on objectively measured PA levels (e.g., accelerometers or pedometers) in community-dwelling adults aged 60 years and older compared with no/minimal intervention were considered eligible. Data were pooled using the most conservative estimates reported from each study using the standardized mean difference (SMD). Grading of Recommendations Assessment, Development, and Evaluation (GRADE) was used to evaluate the overall quality of the evidence.
Results: Fourteen published trials and 3 ongoing trials were identified. There were significant effects favoring physical activity–based interventions compared with minimal intervention at short-term (less than or equal to 3 months) (SMD: 0.30, 95% CI: 0.17 to 0.43) and intermediate-term (more than 3 months and less than 12 months; SMD: 0.27, 95% CI: 0.06 to 0.49) follow-ups. The quality of evidence was moderate according to GRADE (downgraded for risk of bias).
Discussion and Implications: Our findings suggest that physical activity–based interventions may increase objectively measured PA levels in community-dwelling older adults. Further studies are still needed to identify the optimal dose, intensity, and mode of delivery of physical activity–based interventions.

Keywords: Objective measure, Pedometer, Accelerometer, Motor activity, Steps, Moderate–vigorous physical activity

The population is rapidly aging worldwide. The older population aged 60 years or older was estimated to be 962 million in 2017 which is more than double the population compared with 1980. Similarly, this number is expected to double again by 2050 reaching nearly 2.1 billion of older adults worldwide (Nations, U., 2007; Nations, U., 2017). The prevalence of physical inactivity also increases substantially with increasing age. According to the World Health

Organization, physical activity (PA) is defined as any bodily movement produced by a contraction of skeletal muscles and that increases energy expenditure. The recommended PA levels for older adults (≥65 years old) are similar to adults (from 18 to 64 years old), that is, 150 min of moderate PA intensity per week, 75 min of vigorous PA intensity per week, or a combination of moderate and vigorous PA intensity plus strength training twice per week (WHO, 2010). Around 45% of people aged over 60 do not meet the recommended PA level (Hallal et al., 2012). For those aged 75 and older, the proportion of people not meeting the recommended PA levels increases to nearly 75% (Australian Institute of Health and Welfare, 2014). The inability to increase PA, despite being willing to do so, is common among community-living older people who have mobility problems and who report negative environmental features in their neighborhood, such as lack of resting places and distances perceived to be too long, noisy traffic, dangerous crossroads, and streets in poor condition. Mobility promotes healthy aging as it relates to the basic human need for physical movement (Rantakokko et al., 2010).

The growing older population brings challenges to the capacity of public health systems and governments in delivering high quality health services as the risk of chronic disease onset and disability rises in older age (Prince et al., 2015). Conservatively estimated, physical inactivity cost healthcare systems international $ (INT$) 53.8 billion worldwide in 2013, of which $31.2 billion was paid by the public sector, US$12.9 billion by the private sector, and $9.7 billion by households. In addition, physical inactivity–related deaths contribute to $13.7 billion in productivity losses, and physical inactivity was responsible for 13.4 million disability-adjusted life-years (DALYs) worldwide (Ding et al., 2016). Compelling evidence shows that PA can provide primary and secondary prevention of chronic disease (Warburton, Nicol, & Bredin, 2006), prolong years of active life (Clark et al., 2012), reduce the risk of early mortality (Löllgen, Bockenhoff, & Knapp, 2009), reduce the risk of falls (Gillespie et al., 2012) and improve functional performance and quality of life among older adults (Sun, Norman, & While, 2013). Despite the wide ranging benefits of regular PA, participation levels particularly among older adults are still low (Matthews et al., 2012; Nelson et al., 2007).

PA levels are commonly measured by self-reported and objective methods, with the self-reported measures including mainly self-reported questionnaires and diaries such as Physical Activity Scale for the Elderly (PASE), Physical Activity Questionnaire for Older Adults, Yale Physical Activity Survey (YPAS), and Incidental and Planned Activity Questionnaire (IPEQ). Although these questionnaires have some evidence of validity and reliability (Delbaere, Hauer, & Lord, 2010; Moore et al., 2008; Silva et al., 2019; Washburn, McAuley, Katula, Mihalko, & Boileau, 1999), their use among the older population is challenging due to changes in cognitive abilities and in recall bias, especially when considering recall over long periods of time (Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012; Shephard & Vuillemin, 2003). In addition, aging and disability modify the metabolic cost of activities, so standard tables and equations used to determine the energy expenditure of common activities that have been developed in younger populations may be inaccurate for use with older adults (Kowalski et al., 2012; Rikli, 2000).

Since self-reported methods have some limitations, objective measures of PA using technology to measure and record in real-time biomechanical and/or physiological consequences of physical activities are commonly used to increase accuracy. Objective measures provide more accurate estimates of energy expenditure and eliminate response biases. These consist of, for example, motion sensing and monitoring devices (accelerometers, pedometers, and heart-rate monitors), physiological markers (cardiorespiratory fitness and biomarkers), and calorimetry (Prince et al., 2008).

Randomized clinical trials (RCTs) and systematic reviews investigating PA-based interventions have identified positive results for prevention of falls (Sherrington et al., 2019), reduction of cognitive decline (Olanrewaju, Kelly, Cowan, Brayne, & Lafortune, 2016), and improvement of balance (Howe, Rochester, Neil, Skelton, & Ballinger, 2011), among others. However, to date, there is limited systematic review evidence of the effect of interventions for increasing objectively measured PA among the older population. Previous systematic reviews (Chase, 2015; Conn, Valentine, & Cooper, 2002; Sun et al., 2013) found a small effect favoring physical activity–based intervention over the control intervention. However, given that these reviews included studies that used objective and self-reported PA measures, there is less clarity about the effect of physical activity–based interventions on objective PA measures alone. In addition, previous reviews have summarized the evidence from different study designs and not RCTs alone. We would argue that, when available, RCTs should be used as this is the most robust research design for assessment of the relative effects of intervention (Chandler et al., 2019). Other methodological flaws in previous systematic reviews include high heterogeneity in the meta-analysis (Chase, 2015), search restriction with regard to the date of publication (Sun et al., 2013), and the lack of assessment of risk of bias and overall quality of evidence (Chase, 2015; Conn et al., 2002; Sun et al., 2013). Therefore, the primary objective of this systematic review was to investigate the effect of physical activity–based interventions on objectively measured PA levels of older adults. Secondly, we also aimed to investigate the effect of physical activity–based interventions on mobility in this population.

Methods

Selection Criteria

Study types

Only RCTs were included. Quasi-randomized clinical trials and other types of studies were excluded. RCTs where participants were randomized to a PA-based intervention group or a control group, that is, no intervention, placebo, or minimal intervention (usual healthcare, advice, waiting list, and self-care guidelines) were considered eligible.

Intervention

Any trial that included an intervention designed to promote PA among older adults was included. Individual- and group-based interventions designed to increase PA levels that included general or therapeutic exercise, educational programs, PA coaching or counseling, cognitive behavioral therapies, and feedback using objective PA measures such as electronic devices (e.g., *Fitbit*) were considered eligible. We included both studies that offered supervised exercise sessions for older adults as part of the trial and studies that aimed to increase independent PA levels.

Participants

Trials that included participants aged 60 years or older living in the community were considered eligible. Studies of interventions designed for populations with specific health conditions such as stroke, Parkinson's disease, multiple sclerosis, labyrinthitis, amputation of upper or lower limbs, cognitive impairment, dementia, osteoporosis, rheumatoid arthritis, osteoarthritis, hip fracture, or Alzheimer's disease were excluded.

Outcomes

The primary outcome was PA levels, measured by objective methods over 3 or more days. In this review, we included trials that used accelerometers, heart-rate monitors, and pedometers to assess PA levels. Other objective measures such as doubly labeled water and direct or indirect calorimetry were considered ineligible because these types of measures do not provide data regarding free-living PA. Self-reported measures of PA (e.g., questionnaires and diaries) were not considered eligible because these measures are prone to bias. The secondary outcome was mobility. Eligible mobility outcomes included, for instance, the Timed Up and Go (TUG) and 6-min walk tests.

Search Strategy

We conducted this systematic review following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). This review was performed following the methods documented in the protocol registered with the PROSPERO database prior to commencement (#CRD42016042006).

The search was conducted in the following electronic databases from the earliest record to August, 2019: Cochrane Central Register of Controlled Trials via Ovid, Medline via Ovid, Embase, Cumulative Index to Nursing and Allied Health Literature via Ebsco, SportDiscus via Ebsco, and Physiotherapy Evidence Database (PEDro). The search strategy combined keywords related to methods to objectively assess physical activity, older adults living in the community, and physical activity and RCTs (see Supplementary Material). We also searched for unpublished or ongoing trials by searching ClinicalTrials.gov, the International Standard Randomized Controlled Trial Number (ISRCTN) register, and the Australian New Zealand Clinical Trials Registry (ANZCTR). This search was aided by the World Health Organization (WHO) International Clinical Trials Registry Platform search portal. In addition, searches in the reference list included studies and previous systematic reviews in the field. The search was not restricted to any single language or date of publication.

Study Selection

Two independent reviewers (G. D. Grande and P. K. Morelhão) evaluated titles and abstracts found in the electronic databases search. When there was any doubt about the inclusion of the study, the full text was retrieved. Thereafter, two independent reviewers (G. D. Grande and P. K. Morelhão) assessed full texts of potentially eligible studies and checked the reference list of the relevant articles, following the inclusion criteria of the review. Any disagreement was resolved by a third reviewer (M. R. Franco).

Data Extraction

Two reviewers (G. D. Grande and P. K. Morelhão) extracted information regarding sample characteristics, interventions, outcomes, time point follow-ups, assessment method, number of monitoring days, and valid measurement day using a standardized data extraction form. Data extracted were means (final values or change score), *SD*s, sample size or mean differences, and 95% confidence intervals (95% CIs). In case of insufficient data, we contacted the authors of the included studies via email requesting information. If the authors did not reply our request, we calculated the missing data using recommendations from the Cochrane Handbook.

Risk of Bias and Quality Assessment

Two independent reviewers rated all studies for risk of bias using the Physiotherapy Evidence Database (PEDro) scale, and disagreements were resolved by a third reviewer.

The PEDro scale consists of a checklist of 10 scored yes/no questions related to the internal and statistical validity of a randomized controlled trial (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). The scores available in the PEDro database were used in this review.

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was used to assess the overall quality of the evidence. The quality of evidence was downgraded from high quality by one level for each of the following criteria: limitation of study design (>25% of participants from studies with 1 or more bias domains were judged as high risk), inconsistent results (wide variance of point estimates across studies, or if the heterogeneity between trials was large [I^2 >50%]), and imprecision (fewer than 300 participants for each outcome); bias in the description (funnel plot demonstrating small effects for the studies) (Atkins et al., 2004; Pinto et al., 2012). The funnel plot we used was a scatterplot of the effect estimates from individual studies against its standard error. The effect estimates from smaller studies should scatter more widely at the bottom, with the spread narrowing among larger studies. Thus, small study effects were investigated by exploring whether smaller trials showed greater effects than larger trials. The presence of small study effects was assessed only for those meta-analyses including more than 10 pair-wise comparisons by visually interpreting funnel plot asymmetry and quantified by using the Egger test (Egger, Smith, Schneider, & Minder, 1997). If the Egger test result was statistically significant (2-tailed p < .100), we downgraded the quality of evidence of all meta-analyses conducted in this review by one level. The indirectness parameter was not evaluated as this review includes a specific population, relevant clinical outcomes, and a specific comparison. The following categories were used: high quality (i.e., the true effect lies close to that of the estimate of the effect), moderate quality (i.e., the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different), low quality (i.e., the true effect may be substantially different from the estimate of the effect), and very low quality (i.e., the true effect is likely to be substantially different from the estimate of the effect). Single RCTs (with under 300 participants) were considered inconsistent and imprecise (i.e., sparse data) and provided "low quality evidence."

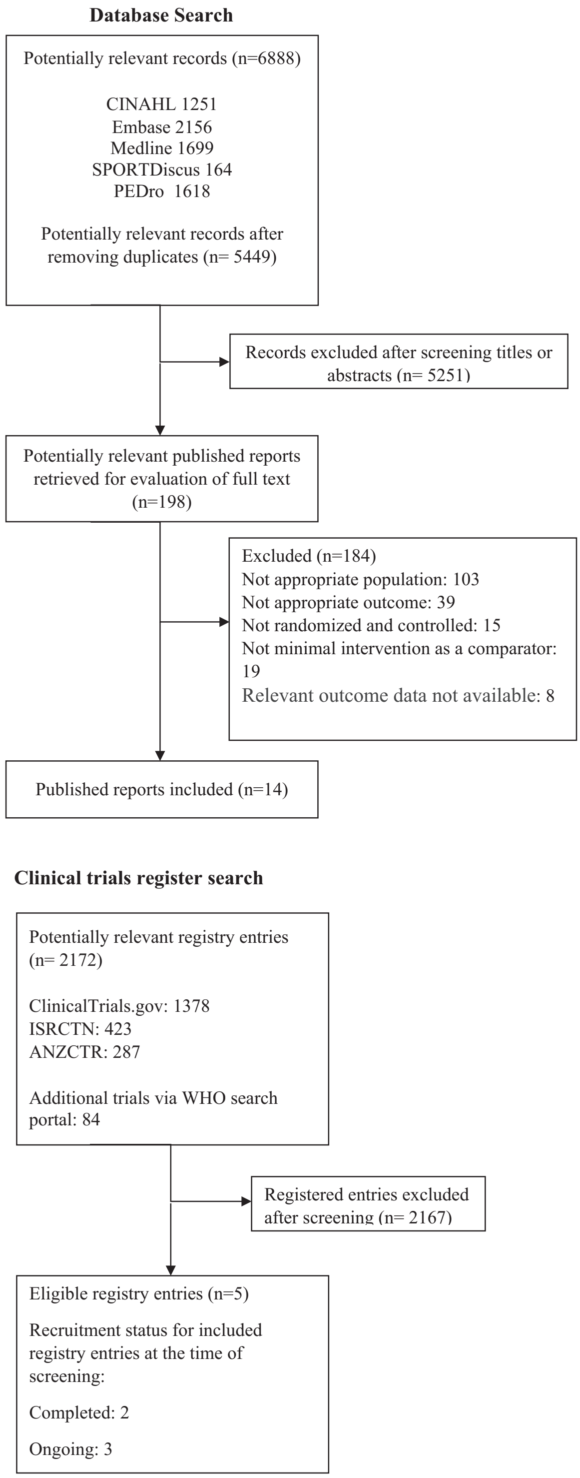

Figure 1. Flow chart of included trials. ISRCTN = International Standard Randomized Controlled Trial Number register; PEDro = Physiotherapy Evidence Database; ANZCTR = Australian New Zealand Clinical Trials Registry; CINAHL = Cumulative Index to Nursing and Allied Health Literature; WHO = World Health Organization.

Data Synthesis and Analysis

Mean (final value or change), standard deviation, sample size, mean differences (adjusted or not), and 95% confidence intervals were extracted from included studies. Because continuous but heterogeneous PA measures (e.g., minute counts, time spent on PA intensity categories, steps per day, and number of steps) were found, the effects of treatment were calculated using the standardized mean difference (SMD) with 95% CI, with 0.2 representing a small effect, 0.5 a moderate effect, and 0.8 a large effect (Higgins & Green, 2011). Outcome data were extracted and summarized according to the following criteria: short-term (up to 3 months), intermediate (greater than 3 months and less than 12 months), and long-term (12 or more months) follow-ups. As studies often report more than one objective PA measure as an outcome, we opted to conduct two meta-analyses for each follow-up time point: (i) one meta-analysis using the least conservative estimates from each study (i.e., pooling of outcomes showing the large positive treatment effect for the treatment group) and (ii) another meta-analysis using the most conservative estimates from each study (i.e., pooling of outcomes showing small positive or negative treatment effects for the treatment group). If included studies were RCTs with three arms or more (i.e.,

Table 1. Characteristics of Included Studies

Study author, year (ref.)	Sample characteristics	Interventions	I. Assessment method II. Number of monitoring days III. Valid measurement days	Outcome and time points
Conn et al., 2003	*N* = 190 (G1 = 47; G2 = 47; G 3= 47; G4 = 47) Age, years mean (*SD*): G1 = 75.14 (5.89); G2 = 75.18 (7.19); G3 = 73.96 (6.35); G4 = 75.77 (7.41). Country: United States of America	G1—Focusing on motivating participants to exercise plus standard educational information about benefits G2—Brief weekly prompts that consists of alternating telephone calls and mailed materials with exercise-related information G3—Brief weekly prompts plus standard educational information focus on general exercise benefits and appropriate exercise G4—Standard educational information	I. Pedometer (on a belt or waistband) II. 7 days III. Not applicable	-Physical activity level -Stage-of-behavior change. 3-month follow-up
Gothe et al., 2015	*N* = 260 (G1 = 127; G2 = 133) Age, years mean (*SD*): G1 = 70.62 (0.40); G2 = 71.43 (0.43) Country: United States of America	G1—Intervention group received an expertly designed and professionally developed set of exercise DVDs specifically aimed at improving physical function in older adults plus support calls with exercise tips G2—Attentional control received a commercially available DVD that focused on older adults leading a healthy lifestyle plus support calls with generic tips on healthy aging	I. Accelerometer (nondominant hip) II. 7 days III. The interruption period was set to 30 min and participants with a minimum of 3 days with 10 valid hours of wear time	-Accelerometry -MVPA 3- and 6-month follow-up
T. Harris et al., 2018	*N* = 298 (G1 = 150; G2 = 148) Age, years mean (*SD*): G1 and G2: 67 (4.2) Country: United Kingdom .	G1—Pedometer together with accelerometer feedback, including step-count goals, physical activity goals and use of walking planner with instructions given by a nurse G2—Control group received similar educational material but no support offered	I. Accelerometer (on a belt over one hip) II. 7 days III. 5 days with 540 min/day	-Accelerometry -MVPA 3-, 12-, and 48-month follow-up
Lara et al., 2016	*N* = 70 (G1 = 48; G2 = 22) Age, years mean (*SD*): G1:60.9 ± 3.4 G2: 62.0 ± 3.9 Country: United Kingdom	G1—A web-based lifestyle intervention consisting of five modules G2—Control group were instructed, via email, to use nonpersonalized website containing general health information	I. Accelerometer (on the skin at the fifth lumbar vertebra) II. 7 days III. Not applicable	-Steps 2-month follow-up
McMurdo et al., 2010	*N* = 132 (G1 = 60; G2 = 53; G3 = 66) Age, years mean (*SD*): G1: 77.1 (4.9); G2: 77.6 (5.4); G3: 77.0 (4.9). Country: United Kingdom	G1—Pedometer together with a behavior change intervention consisting of a brief education session focusing on beliefs and motivation for walking G2—A behavior change intervention only without the pedometer G3—No intervention	I. RT3 Accelerometer (on the waistband) II. 7 days III. Not applicable	-Accelerometry -Minutes walking -Short Physical Performance Battery (SPPB) 3-month follow-up

Table 1. Continued

Study author, year (ref.)	Sample characteristics	Interventions	I. Assessment method II. Number of monitoring days III. Valid measurement days	Outcome and time points
Mutrie et al., 2012	*N* = 41 (G1 = 20; G2 = 19) Age, years mean (*SD*): G1: 71.6 (6.0); G2: 70.0 (4.3) Country: United Kingdom	G1—A behavior change intervention delivered individually in two 30-min session to each participant by a trained nurse G2—Waiting list	I. Pedometer and ActivPAL (anterior surface of the thigh) II. 7–10 days III. Not applicable	-Step counts 3- and 6-month follow-up
Sims et al., 1999	*N* = 20 (G1 = 10; G2 = 10) Age, years mean (*SD*): G1 and G2: (*SD*): 72.2 (4.26) Country: United Kingdom	G1—Motivational interview with the aim to developed an individualized, In addition, participants received telephone calls at 2 and 6 to discuss goals and barriers to exercise G2—Control group received standard information about exercise benefits	I. Heart-rate monitors (polar) II. 3 days III. 8 hours a day	-Heart-rate 2-month follow-up
Wijsman et al., 2013	*N* = 235 (G1 = 119; G2 = 116) Age, years mean (*SD*): G1: 64.7 (3.0); G2: 64.9 (2.8) Country: Netherlands	G1—A web-based physical activity program based on behavior change theory principles directed at increasing daily physical activity G2—Waiting list	I. Accelerometer (wrist-worn) II. 7 days III. Not applicable	-MVPA 13-week follow-up
Kim & Glanz, 2013	*N* = 45 (G1 = 30; G2 = 15) Age, years mean (*SD*): G1: 69.31 (7.3); G2: 70.55 (7.5) Country: United States	G1—A motivational text messaging using simple one-way direct message, three motivational text messages a day, 3 days a week for 6 weeks G 2—Control group received information on walking.	I. Pedometer (on a belt over one hip) II. Not applicable III. Not applicable	-Steps counts 6-week follow-up
Koizumi et al., 2009	*N* = 68 (G1 = 34; G2 = 34) Age, years mean (*SD*): G1: 66 (4); G2: 67 (4) Country: Japan	G1—Lifestyle physical activity intervention program to encourage participants to accumulate 9000 steps and 30 min of moderate intensity physical activity per day. In addition, participants used accelerometer and received feedback on their physical activity levels G2—Control group wore a blinded accelerometer and was told to continue their normal daily activity patterns during the intervention	I. Accelerometer (waist-level) II. 2 weeks III. Not applicable	-Steps -MVPA -12-min Walk Test 3-month follow-up
Warner et al., 2016	*N* = 271 (G1: 90; G2: 27; G3: 80; G4: 74) Mean age in years (*SD*): 70.34 (4.89) Country: Germany	G1—Behavior change intervention targeting positive views-on-aging and based on self-regulatory techniques G2—Same behavior change intervention but with the views-on- aging component replaced by an additional planning task. G3—Same Behavior change intervention but targeting volunteering instead of physical activity (i.e., without the views-on-aging component or additional planning sheet) G4—No intervention	I. Accelerometer (left-wrist) II. 10 days III. Not applicable	-MVPA 3-month follow-up

Table 1. Continued

Study author, year (ref.)	Sample characteristics	Interventions	I. Assessment method II. Number of monitoring days III. Valid measurement days	Outcome and time points
Mackey et al., 2019	N = 48 (G1: 24; G2: 24) Mean age in years (*SD*): 71.9 (6.6) Country: Canada	G1—Group motivational meetings: three monthly 60-min group motivational meetings led by an activity coach G2—Waiting list.	I. Accelerometer II. 3 days III. 8 hr a day	-Steps -MVPA -SPPB 3-month follow-up
Muellmann et al., 2019	N = 529 (G1: 195; G2: 172; G3: 162) Mean age in years (*SD*): 69.7 (3.3) Country: Germany	G1—Participants received access to a web-based PA diary to track their PA behavior over the 10-week intervention period G2—Participants additionally received a Fitbit Zip to objectively track PA; data of the Fitbit were synchronized with the website. The website provided weekly feedback on whether PA goals were reached G3—No intervention	I. Accelerometer II. 3 days III. 8 hr a day	-MVPA
Oliveira et al., 2019	N = 131 (G1: 64; G2: 67) Mean age in years (*SD*): G1: 69.7 (3.3); G2: 72 (7) Country: Australia	G1—Participants received a 2-hour home visit by a trained physiotherapist, including: a face-to-face health coaching session; setting two mobility-related goals; receiving and setting up a pedometer; undergoing a fall risk assessment (Quickscreen); tailored advice; and a fall prevention advice brochure Staying Active and on Your Feet G2—The control group received the same fall prevention brochure as the experimental group and was advised to continue their usual activities with no restriction placed on physical activity	I. Accelerometer II. Not applicable III. Not applicable	-Counts/min

Note: G = group; N = Number of participants; *SD* = standard deviation; MVPA = Moderate and vigorous physical activity.

Table 2. Risk of Bias Scores of Included Studies*

Study author, year (ref.)	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropout rate	Intent-to-treat analysis	Between group difference reported	Point estimate and variability reported	Total PEDro* Score†
Oliveira et al., 2019	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Wijsman et al., 2013	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
McMurdo et al., 2010	Y	Y	N	N	N	Y	Y	Y	Y	Y	7
Mutrie et al., 2012	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Mackey et al., 2019	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Muellmann et al., 2019	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Conn et al., 2003	Y	N	Y	N	N	N	Y	N	Y	Y	5
Kim & Glanz, 2013	Y	N	Y	N	N	N	N	Y	Y	Y	5
Koizumi et al., 2009	Y	N	Y	N	N	N	Y	N	Y	Y	5
Lara et al., 2016	Y	N	Y	N	N	Y	Y	N	N	Y	5
Gothe et al., 2015	Y	N	Y	N	N	N	N	N	Y	Y	4
Sims et al., 1999	Y	N	Y	N	N	N	N	N	Y	Y	4
Harris et al., 2018	Y	N	N	N	N	N	N	N	Y	Y	3
Warner et al., 2016	Y	N	Y	N	N	N	N	N	N	Y	3

Note: *PEDro = Physiotherapy Evidence Database; Y = yes; N = no.
†Score reflects the number of affirmative responses. Total PEDro score range 0–10, with scores close to 10 indicating low risk of bias.

studies investigating the efficacy of more than one PA-based intervention compared with a control group), we followed the Cochrane handbook (Higgins & Green, 2011) and opted to split the sample from the control group in the number of PA-based interventions investigated to allow inclusion of each pair-wise comparison separately in the meta-analysis. In case of insufficient data, we contacted the authors of the included studies via email to request the missing data. If this method failed, we estimated the missing data using recommendations from the Cochrane Handbook.

As a secondary analysis if there were enough trials reporting data on the same outcome and time points, we also calculated pooled effects as a mean difference (MD) for that outcome.

The heterogeneity of the studies was evaluated with the I^2 statistic and by inspection of the forest plots. Pooled effects were calculated using Comprehensive Meta-Analysis software, version 2.2.04 (Biostat), using random-effects models. We obtained the pooled effects using random-effects model which accounts the heterogeneity between the estimates of included studies. However, when the heterogeneity was higher than 50%, we combined the estimates to obtain a meta-analysis but also downgraded one level of the overall quality of evidence for inconsistency (Higgins & Green, 2011).

Results

The initial electronic database search identified 5,449 potentially eligible articles. After screening of titles and abstracts, 198 potentially eligible articles were considered for inclusion and full-text articles were retrieved. Of these,

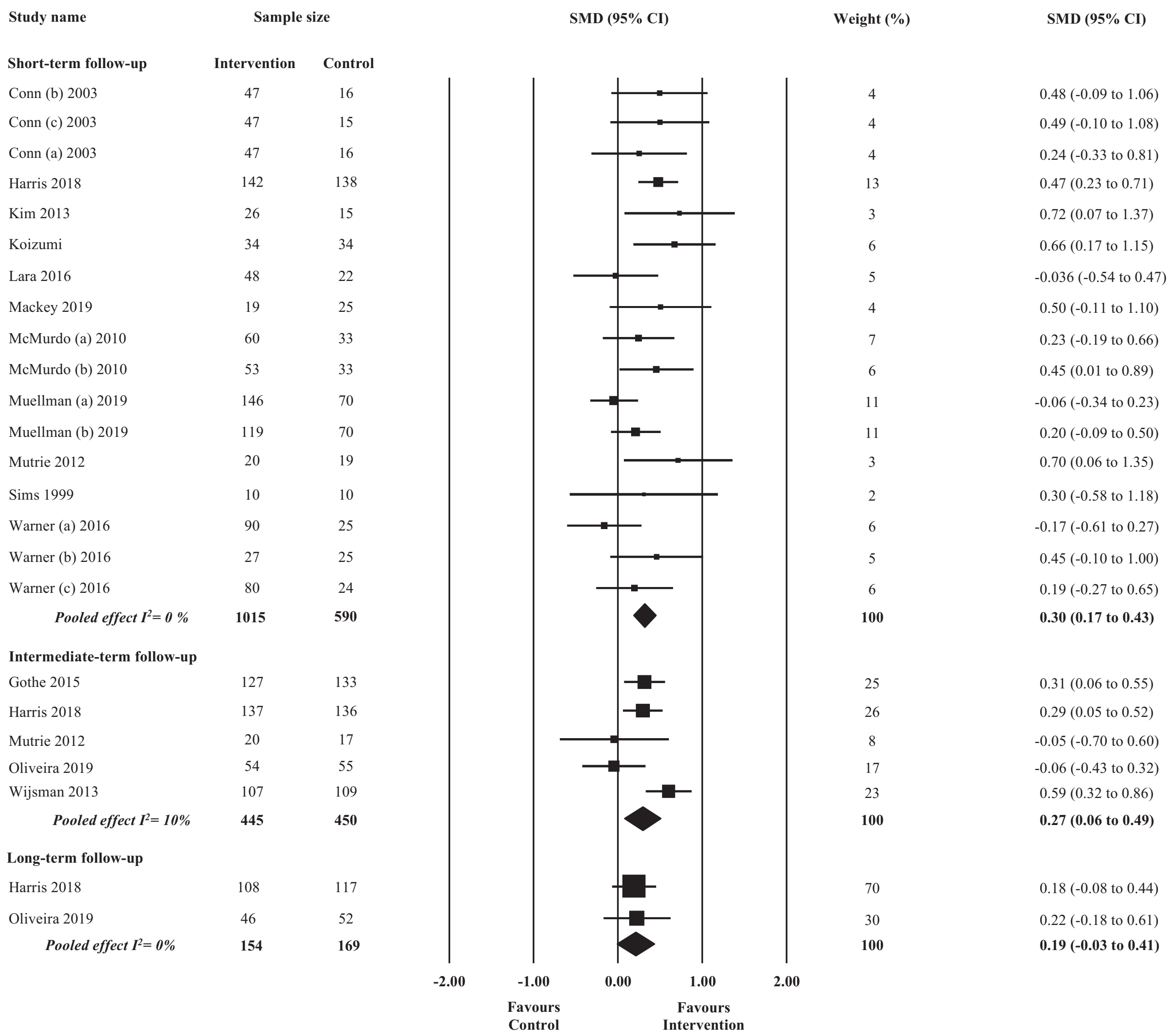

Figure 2. Meta-analyses of studies reporting objective physical activity measures using the most conservative estimate from each included study. SMD = Standardized Mean difference; CI = 95% confidence interval.

Table 3. Evidence Table for Outcome Measures

	Quality assessment				No. of participants			
No. of studies	Risk of bias	Inconsistency	Imprecision	Publication bias	Intervention group	Control group	Effect (95% CI)	Quality
Physical Activity Level								
Short-term follow-up								
11 trials	Serious risk of bias*	No Serious Inconsistency†	No serious Imprecision‡	Undetected§	1015	590	SMD = 0.30 (0.17 to 0.43)	□ + + □ Moderate
Intermediate follow-up								
5 trials	Serious risk of bias*	No Serious Inconsistency†	No serious Imprecision‡	Not assessed‖	445	450	SMD = 0.27 (0.06 to 0.49)	□ + + Moderate
Long-term follow-up								
2 trials	Serious risk of bias*	No Serious Inconsistency†	No serious Imprecision‡	Not assessed‖	154	169	SMD= 0.19 (-0.03 to 0.41)	□ + + Moderate
*Physical Activity *Level (MVPA)*								
Short-term follow-up								
3 trials	Serious risk of bias*	No serious Inconsistency†	No serious Imprecision‡	Not assessed‖	496	248	MD = 5.19 (-0.61 to 10.99)	□ + + Moderate
Intermediate follow-up								
2 trials	Serious risk of bias*	No serious Inconsistency†	No serious Imprecision‡	Not assessed‖	234	242	MD = 8.79 (4.08 to 13.50)	□ + + Moderate
Physical Activity Levels (Steps)								
Short-term follow-up								
5 trials	Serious risk of bias*	No Serious Inconsistency†	Serious imprecision‡	Not assessed‖	147	115	MD = 1567.01 (885.89 to 2248.13)	□ + □ Low
Mobility Measures								
Short-term follow-up								
3 trials	Serious risk of bias*	Serious inconsistency†	Serious imprecision‡	Not assessed‖	166	125	SMD = 0.02 (-0.74 to 0.70)	□□□ Very Low

Note: MD = standardized mean difference; MD = mean difference.
*> 25% participants from studies with low methodological quality (PEDro score < 7).
†Wide variance of point estimates across studies or if the heterogeneity between trials was large [$I^2 > 50\%$].
‡Total number of participants < 300 for each outcome.
§Inspection of funnel plot asymmetry and the Egger test were not significant ($p = .311$).
‖Publication bias was not assessed because the meta-analysis included less than 10 pair-wise comparisons.

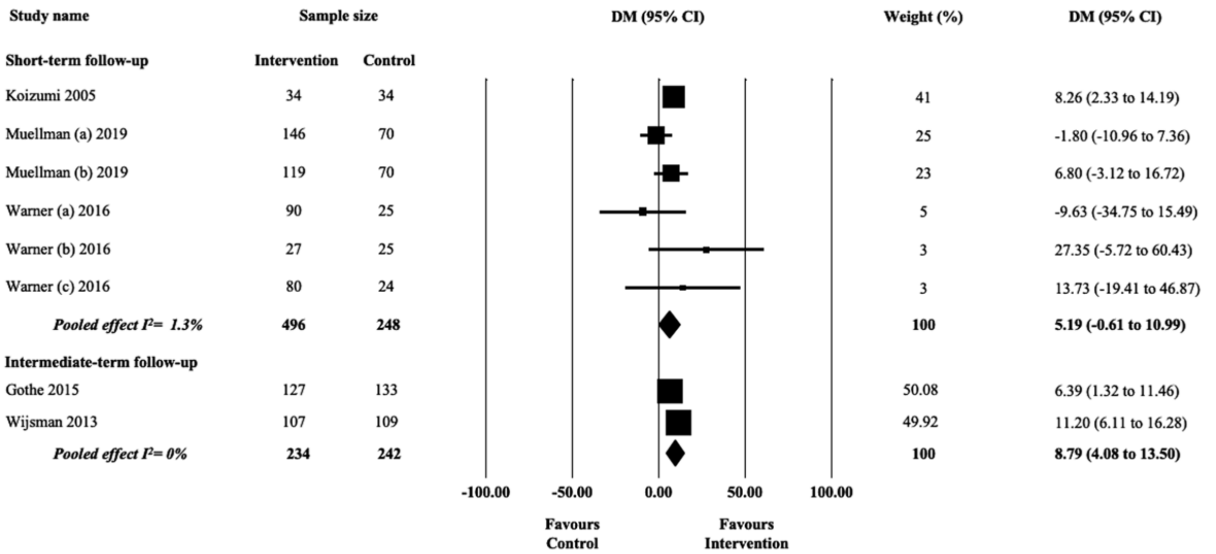

Figure 3. Meta-analyses of studies reporting time spent on moderate–vigorous physical activity as the outcome measure. MD = Mean difference; CI = 95% confidence interval.

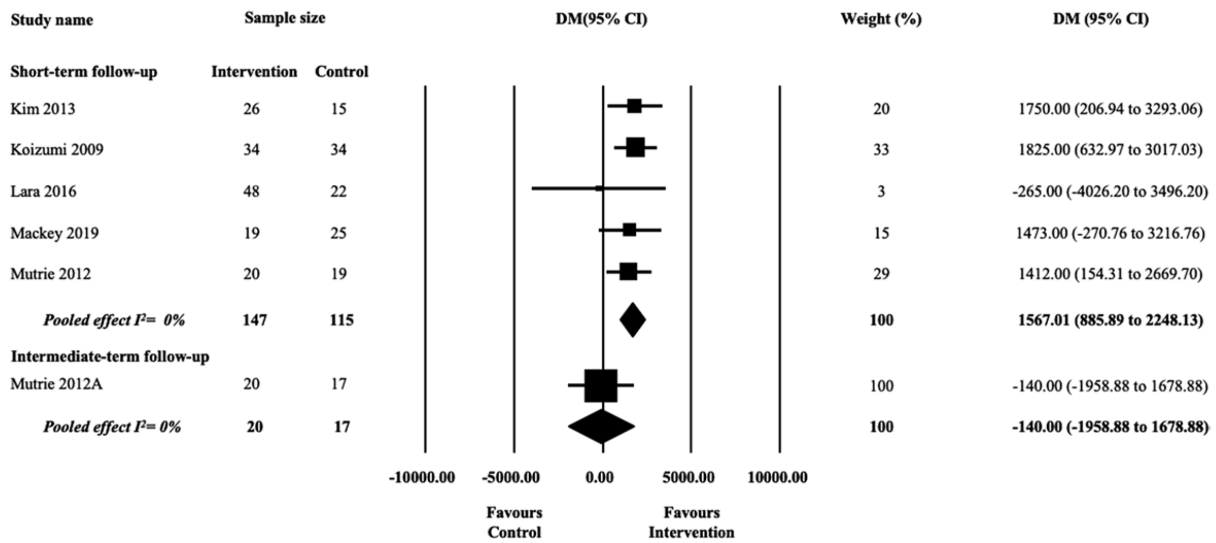

Figure 4. Meta-analyses of studies reporting step counts as the outcome measure. MD = Mean difference; CI = 95% confidence interval.

184 articles were excluded because they did not meet the inclusion criteria. We did not identify any additional studies by checking the reference list of included studies or previous systematic reviews. Finally, a total of 14 articles met the inclusion criteria (Conn, Burks, Minor, & Mehr, 2003; Gothe et al., 2015; Harris et al., 2018; Kim & Glanz, 2013; Koizumi et al., 2009; Lara et al., 2016; Mackey, Perkins, Hong Tai, Sims-Gould, & McKay, 2019; McMurdo et al., 2010; Muellmann et al., 2019; Mutrie et al., 2012; Oliveira et al., 2019; Sims, Smith, Duffy, & Hilton, 1999; Warner, Wolff, Ziegelmann, Schwarzer, & Wurm, 2016; Wijsman et al., 2013). Of these, 10 trials were parallel RCTs, two were three-arm RCTs, and two were four-arm RCTs. Regarding the unpublished or ongoing trials searches, we identified three ongoing studies. One ongoing study with a target sample of 160 older adults will investigate the effect of the combined use of smartphone and smartband technology for 3 months with brief counseling on physical activity levels comparing with counseling alone (Recio-Rodríguez et al., 2019). The OUTDOOR ACTIVE intervention trial is a cluster-randomized intervention including eight subdistricts that will investigate the effect of a program design to promote outdoor physical activity on physical activity levels compared with no intervention (Bammann, Drell, Lübs, & Stalling, 2018). Another ongoing study without a target sample compared a peer-led, multicomponent physical activity intervention in socioeconomically disadvantaged in community-dwelling older adults (Tully et al., 2018). Figure 1 shows the flow of studies through the review.

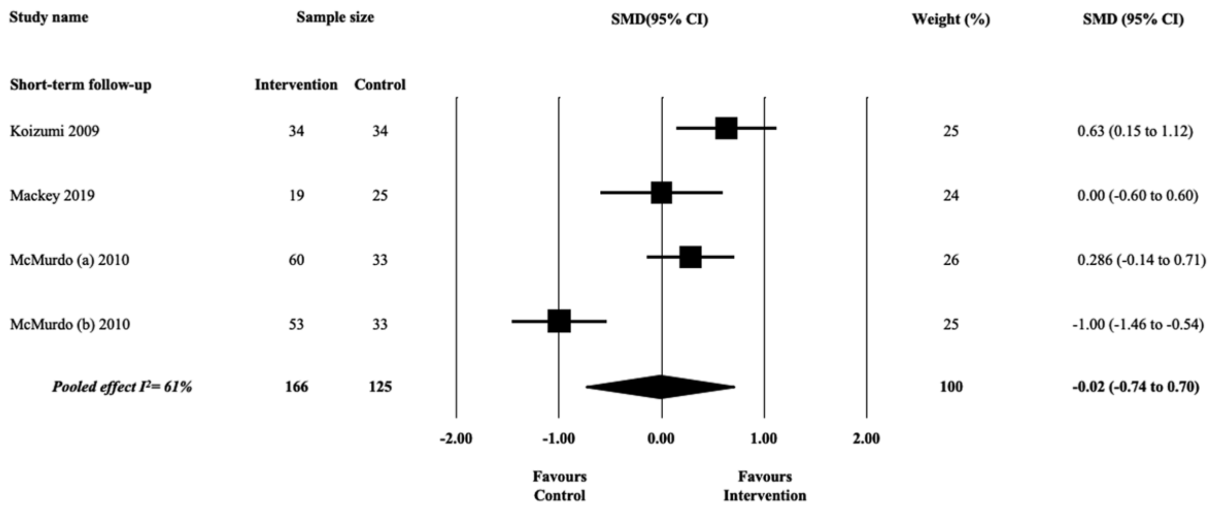

Figure 5. Meta-analysis of studies reporting mobility measures. SMD = Standardized Mean difference; CI = 95% confidence interval.

The included trials were published between 1999 and 2019. The included trials were conducted in seven countries, including Australia, Canada, United Kingdom, United States, Japan, Netherlands, and Germany. The sample size of the included studies ranged from 20 to 529 participants. We contacted the authors of one study to check the number of participants allocated to each group but the authors did not reply our email (Sims et al., 1999). Therefore, we opted to divide the total sample size by two assuming an equal number of participants per group, that is, 10 participants per group. The mean age of participants reported in the included trials ranged from 60.9 to 72.2 years. More than two thirds of the included trials (n = 11) recruited older adults from both sexes. One study (Warner et al., 2016) was a four-arm trial with unequal number of participants per group. Table 1 shows characteristics of included trials.

Regarding the PA-based interventions investigated, six trials investigated the use of motivational intervention delivered by face-to-face interactive group sessions (Mackey et al., 2019; Oliveira et al., 2019; Warner et al., 2016), face-to-face plus telephone calls (Conn et al., 2003), telephone calls only (Sims et al., 1999), and text messages (Kim & Glanz, 2013), two trials investigated the addition of PA monitors (i.e., pedometers and accelerometers) to the motivational intervention component (McMurdo et al., 2010; Mutrie et al., 2012), two trials investigated a pedometer and/or accelerometer-based intervention (Harris et al., 2018; Koizumi et al., 2009), three trials investigated a web-based motivational intervention (Lara et al., 2016; Muellmann et al., 2019; Wijsman et al., 2013), and one trial investigated a motivational DVD (Gothe et al., 2015).

Accelerometer was the objective PA measure most commonly used as an outcome (Gothe et al., 2015; Harris et al., 2018; Koizumi et al., 2009; Lara et al., 2016; McMurdo et al., 2010; Warner et al., 2016; Wijsman et al., 2013),

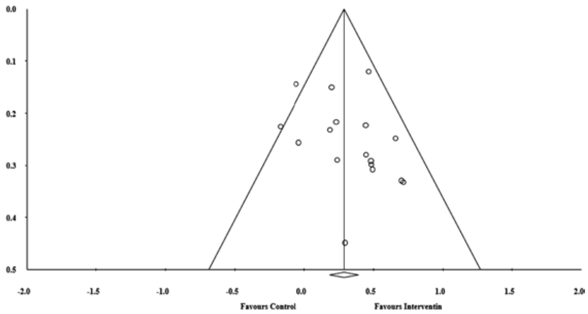

Figure 6. Funnel plot.

followed by pedometer (Conn et al., 2003; Kim & Glanz, 2013; Mackey et al., 2019; Muellmann et al., 2019; Mutrie et al., 2012; Oliveira et al., 2019) and heart-rate monitor (Sims et al., 1999). Detailed information about the assessment method, the number of monitoring days, and how a valid measurement day was defined in each study can be found in Table 1. Three trials investigated mobility as an outcome measure (Koizumi et al., 2009; Mackey et al., 2019; McMurdo et al., 2010), the 12-min walking test and the short physical performance battery (SPPB).

The assessment of risk of bias showed PEDro scores ranging from 3 to 8 (mean of 5). Most of the trials failed to blind the assessors (n = 8), conceal allocation (n = 8), and use intention-to-treat analysis (n = 9; Table 2). Nearly a third of the included trials showed dropout rates higher than 15%. Due to the nature of the PA-based interventions, all included studies were unable to blind those delivering the intervention or participants.

The meta-analyses combing data from all PA measures using the most conservative estimates are described in Figure 2. Pooled estimates showed that physical activity–based interventions were slightly effective when compared with minimal intervention at short-term

(n = 1605; SMD = 0.30; 95% CI = 0.17 to 0.43; I^2 = 0%) and intermediate-term follow-ups (n = 895; SMD = 0.27; 95% CI = 0.06 to 0.49; I^2 = 10%). However, there was no difference between groups at long-term follow-up (n = 323; SMD = 0.19; 95% CI = −0.03 to 0.41; Table 3). Considering that the inspection of the funnel plot showed no evidence of asymmetry and the Egger test showed no statistically significance (p = .311), there was no evidence of publication bias in our analyses (Figure 6). According to GRADE, the overall quality of evidence was moderate at short-term, intermediate-term, and long-term follow-ups (downgraded for risk of bias).

For the secondary analyses, pooling data were possible for two physical activity measures: moderate–vigorous physical activity (MVPA) and steps/week. Figure 3 shows the pooled effects for those trials reporting time spent on MVPA per day. Although there was no significant difference at short-term follow-up (n = 744; MD = 5.19; 95% CI = −0.61 to 10.99; I^2 = 1.3%), physical activity–based interventions were more effective compared with minimal intervention in increasing MVPA at intermediate follow-up (n = 476; MD = 8.80; 95% CI = 4.09 to 13.52; I^2 = 0.0%). None of the studies reported data for this outcome at long-term follow-up. The overall quality of evidence was moderate (downgraded for risk of bias) at short-term and intermediate follow-ups.

Figure 4 shows the pooled effect for those trials reporting steps counts per day. Pooled estimate showed that physical activity–based interventions were more effective compared with minimal intervention in increasing steps per day at short-term follow-up (n = 262; MD = 1567.01; 95% CI = 885.89 to 2248.13; I^2 = 0%). One study reported steps per day at intermediate-term follow-up and showed no significant differences between groups (n = 37; MD = −140.0; 95% CI = −1958.9 to 1678.9; Mutrie et al., 2012). The overall quality of evidence was low (downgraded for risk of bias and imprecision) at short-term follow-up.

For the secondary outcome, only three studies evaluated mobility (Koizumi et al., 2009; Mackey et al., 2019; McMurdo et al., 2010). Although Mc Murdo and colleagues and Mackey and colleagues used the SPPB to measure mobility, Koizumi and colleagues measured the distance walked during the 12-min walking test. Figure 5 shows the pooled effect for mobility outcomes. Pooling showed that physical activity–based interventions were slightly more effective compared with minimal intervention at short-term follow-up (n = 291; SMD = −0.02; 95% CI = −0.74 to 0.70; I^2 = 61%). The overall quality of evidence was very low (downgraded for risk of bias, inconsistency and imprecision; Figure 5).

Discussion

The results of this systematic review and meta-analysis show that PA-based interventions are effective for increasing objectively measured PA levels at the short-term and intermediate-term follow-up among community-dwelling older adults when compared with no/minimal interventions. Two studies reported PA measures at long-term follow-up, but there was no intervention impact on physical activity. The overall quality of the evidence was considered to be moderate, meaning that PA-based intervention probably improves objectively measured PA levels.

A previous systematic review investigating the effect of PA-based interventions designed to increase PA behavior among community-dwelling older adults showed a statistically significant difference between groups (SMD = 0.18; 95% CI = 0.10 to 0.26; Chase, 2015); however, the small magnitude of the effect may not be considered clinically relevant for older adults. The small effect found in the previous systematic review might be attributable to the combination of objective and self-reported PA measures which show low to moderate correlation (Skender et al., 2016). Furthermore, 48 studies included in the meta-analysis were not RCTs and the authors did not assess the risk of bias and overall quality of the evidence (Morelhao, Oliveira, & Franco, 2016). Another systematic review (Conn, Valentine, & Cooper, 2002), adopted the same approach of combining evidence from objective and self-reported PA measures found also a small effect (SMD, 0.26 ± 0.5) favoring physical activity–based intervention over the control. Other important methodological limitations are inclusion of studies based on the mean age of 60 years and the inclusion of populations with specific health conditions which prevent us from generalizing the results to older adults living in the community. Therefore, to the best of our knowledge, the present systematic review is the first to meta-analyze data from objective PA measures to evaluate the short- and long-term effect of PA-based interventions in community-dwelling older adults.

Regarding the secondary outcome of this review, the meta-analysis results show that PA-based interventions may slightly improve mobility compared with the control group (Figure 5). These results corroborate with another study which demonstrated that older adults undertaking physical activity showed better mobility compared with those not undertaking physical activity (Landi & Calvani, 2018). Nevertheless, given the low quality of evidence with pooling of data from only two RCTs, further studies are needed to determine whether interventions aimed at promoting PA also improve mobility performance of older people living in the community.

This systematic review followed a registered protocol and did not limit the inclusion of studies by language or date. A strength of this review is the use of a comprehensive search strategy including five electronic databases to locate published studies as well as the main clinical trials registers to locate unpublished and ongoing trials. Another strength is the use of objective PA measures as the primary outcome, as previous studies in older adults indicated weak convergent validity between objective and self-reported measures (Harris et al., 2009). A weakness of the available literature is the high variability in the objective measures reported and the use of different data processing techniques indicated by the small number of studies consistently providing data to allow pooling of outcomes such as MVPA and daily steps. The meta-analyses for these outcomes suggest only low (or very low) quality of evidence, meaning that more studies are still needed to better quantify the magnitude of effect in terms of time spent on MVPA and steps counts. We would encourage more research in this area as the magnitude of the effect in such terms would help us to better inform clinicians and patients about the efficacy of PA-based interventions. At present, the results from our secondary analysis with data from four small trials suggest that the PA-based interventions may promote an average increase of 1,567 steps compared with the control intervention. Future research is also needed to identify the optimal dose, intensity, and mode of delivery of interventions to maximize the impact on physical activity. Another limitation of the included studies is the use of a variety of methods to objectively measure physical activity levels, such as differences in the intensity cutoffs, placement of the device, and the number of monitoring and valid measurement days. Therefore, future studies in this area should follow recent recommendations for reporting objective PA measures such as placement of accelerometer and side of body, number of valid measurement days and minutes per day to be included in the analysis, criteria for defining non-wear time, and number of participants non-compliant (Montoye et al., 2018). In addition, based on the methodological limitations of the included studies, future studies should investigate long-term effects and minimize bias, such as lack of intention-to-treat analysis, concealed allocation, assessor blinding, and higher dropout rates. Another limitation is that our findings can only be applied to older adults living in the community and may not be generalizable to older adults with specific health conditions. Further studies should investigate the effect of physical activity–based interventions in other populations such as older adults with chronic pain, chronic conditions, or disabilities. When there is a bigger pool of available studies, future reviews could use meta-regression to assess whether these factors impact on intervention effects.

Our findings showed that the included studies investigated PA-based interventions using behavioral and/or lifestyle components to increase PA levels in older adults. This is in line with systematic review evidence showing that behavior change techniques can promote physical activity in other populations (Samdal, Eide, Barth, Williams, & Meland, 2017). Given that our review did not identify any structured exercise interventions, it appears that trials investigating the effect of this type of intervention do not include objective-measured PA levels as outcome measures. So, it is unclear whether structured exercise interventions affect daily free-living PA. Future studies in this area should investigate whether structured exercise interventions are able to increase objective PA levels in older adults.

Our search for registered clinical trials identified three (Bammann et al., 2018; Recio-Rodríguez et al., 2019; Tully et al., 2018) ongoing studies that will be included in future update of this review, so the estimated effect reported in this review may change. As technology advances and devices that objectively measured PA levels become more accessible, new research that investigates how to improve and maintain PA levels among older adults is warranted.

Conclusion

This systematic review with meta-analysis identified a significant impact on objectively measured PA levels from interventions designed to promote PA among older community-dwelling people. However, the results should be interpreted with caution due to the paucity of high-quality studies. More well-designed randomized controlled trials are still needed to better understand the characteristics of PA-based interventions required to increase physical activity levels of older adults living in the community. Future studies should also address current methodological flaws such as intention-to-treat analysis, concealed allocation, and assessor blinding.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

Funding

None reported.

Conflict of Interest

None reported.

References

Atkins, D., Best, D., Briss, P. A., Eccles, M., Falck-Ytter, Y., Flottorp, S.,…Zaza, S.; GRADE Working Group. (2004). Grading quality of evidence and strength of recommendations. *BMJ (Clinical Research ed.)*, **328**, 1490. doi:10.1136/bmj.328.7454.1490

Australian Institute of Health and Welfare. (2014). *Australia's health 2014. Australia's health series no. 14. Cat. no. AUS 178*. Canberra: AIHW. Retrieved 05 February, 2019 from www.aihw.gov.au/getmedia/d2946c3e-9b94-413c-898caa5219903b8c/16507.pdf.aspx?inline=true

Bammann, K., Drell, C., Lübs, L. L., & Stalling, I. (2018). Cluster-randomised trial on participatory community-based outdoor physical activity promotion programs in adults aged 65-75 years in Germany: protocol of the OUTDOOR ACTIVE intervention trial. *BMC Public Health*, **18**, 1197. doi:10.1186/s12889-018-6124-z

Chandler, J., Cumpston, M., Thomas, J., Higgins, J. P. T., Deeks, J. J., Clarke, M. J. (2019). Chapter I: Introduction. In: J. P. T. Higgins,

J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, V. A. Welch (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions version 6.0. Cochrane, 2019*. Retrieved 14 October, 2019 from www.training.cochrane.org/handbook

Chase, J. A. (2015). Interventions to Increase Physical Activity Among Older Adults: A Meta-Analysis. *The Gerontologist*, **55**, 706–718. doi:10.1093/geront/gnu090

Clark, F., Jackson, J., Carlson, M., Chou, C. P., Cherry, B. J., Jordan-Marsh, M.,…Azen, S. P. (2012). Effectiveness of a lifestyle intervention in promoting the well-being of independently living older people: results of the Well Elderly 2 Randomised Controlled Trial. *Journal of Epidemiology and Community Health*, **66**, 782–790. doi:10.1136/jech.2009.099754

Conn, V. S., Burks, K. J., Minor, M. A., & Mehr, D. R. (2003). Randomized trial of 2 interventions to increase older women's exercise. *American Journal of Health Behavior*, **27**, 380–388. doi:10.5993/ajhb.27.4.10

Conn, V. S., Valentine, J. C., & Cooper, H. M. (2002). Interventions to increase physical activity among aging adults: a meta-analysis. *Annals of Behavioral Medicine*, **24**, 190–200. doi:10.1207/S15324796ABM2403_04

Delbaere, K., Hauer, K., & Lord, S. R. (2010). Evaluation of the incidental and planned activity questionnaire (IPEQ) for older people. *British Journal of Sports Medicine*, **44**, 1029–1034. doi:10.1136/bjsm.2009.060350

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W.,…Pratt, M.; Lancet Physical Activity Series 2 Executive Committee. (2016). The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet (London, England)*, **388**, 1311–1324. doi:10.1016/S0140-6736(16)30383-X

Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ (Clinical Research ed.)*, **315**, 629–634. doi:10.1136/bmj.315.7109.629

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. *The Cochrane Database for Systematic Reviews* (9), Cd007146. doi: 10.1002/14651858.CD007146.pub3

Gothe, N. P., Wójcicki, T. R., Olson, E. A., Fanning, J., Awick, E., Chung, H. D.,…McAuley, E. (2015). Physical activity levels and patterns in older adults: the influence of a DVD-based exercise program. *Journal of Behavioral Medicine*, **38**, 91–97. doi:10.1007/s10865-014-9581-6

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*, **380**(9838), 247–257. doi: 10.1016/s0140-6736(12)60646-1

Harris, T., Kerry, S. M., Limb, E. S., Furness, C., Wahlich, C., Victor, C. R.,…Cook, D. G. (2018). Physical activity levels in adults and older adults 3-4 years after pedometer-based walking interventions: Long-term follow-up of participants from two randomised controlled trials in UK primary care. *PLoS Medicine*, **15**, e1002526. doi:10.1371/journal.pmed.1002526

Harris, T. J., Owen, C. G., Victor, C. R., Adams, R., Ekelund, U., & Cook, D. G. (2009). A comparison of questionnaire, accelerometer, and pedometer: measures in older people. *Medicine and Science in Sports and Exercise*, **41**, 1392–1402. doi:10.1249/MSS.0b013e31819b3533

Higgins, J. P. T., Green, S. (Eds.) (2011). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]*. The Cochrane Collaboration. Retrieved from www.handbook.cochrane.org.

Howe, T. E., Rochester, L., Neil, F., Skelton, D. A., & Ballinger, C. (2011). Exercise for improving balance in older people. *The Cochrane Database for Systematic Reviews* (11), Cd004963. doi: 10.1002/14651858.CD004963.pub3

Kim, B. H., & Glanz, K. (2013). Text messaging to motivate walking in older African Americans: a randomized controlled trial. *American Journal of Preventive Medicine*, **44**, 71–75. doi:10.1016/j.amepre.2012.09.050

Koizumi, D., Rogers, N. L., Rogers, M. E., Islam, M. M., Kusunoki, M., & Takeshima, N. (2009). Efficacy of an accelerometer-guided physical activity intervention in community-dwelling older women. *Journal of Physical Activity and Health*, **6**, 467–474. doi:10.1123/jpah.6.4.467

Kowalski, K., Rhodes, R., Naylor, P. J., Tuokko, H., & MacDonald, S. (2012). Direct and indirect measurement of physical activity in older adults: a systematic review of the literature. *The International Journal of Behavioral Nutrition and Physical Activity*, **9**, 148. doi:10.1186/1479-5868-9-148

Landi, F., Calvani, R., Picca, A., Tosato, M., Martone, A. M., D'Angelo, E.,…Marzetti, E. (2018). Impact of habitual physical activity and type of exercise on physical performance across ages in community-living people. *PLoS One*, **13**, e0191820. doi:10.1371/journal.pone.0191820

Lara, J., O'Brien, N., Godfrey, A., Heaven, B., Evans, E. H., Lloyd, S.,…Mathers, J. C. (2016). Pilot randomised controlled trial of a web-based intervention to promote healthy eating, physical activity and meaningful social connections compared with usual care control in people of retirement age recruited from workplaces. *PLoS One*, **11**, e0159703. doi:10.1371/journal.pone.0159703

Löllgen, H., Böckenhoff, A., & Knapp, G. (2009). Physical activity and all-cause mortality: an updated meta-analysis with different intensity categories. *International Journal of Sports Medicine*, **30**, 213–224. doi:10.1055/s-0028-1128150

Mackey, D. C., Perkins, A. D., Hong Tai, K., Sims-Gould, J., & McKay, H. A. (2019). Men on the move: A randomized controlled feasibility trial of a scalable, choice-based, physical activity and active transportation intervention for older Men. *Journal of Aging and Physical Activity*, **27**, 489–502. doi:10.1123/japa.2018-0137

Maher, C. G., Sherrington, C., Herbert, R. D., Moseley, A. M., & Elkins, M. (2003). Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy*, **83**, 713–721.

Matthews, C. E., George, S. M., Moore, S. C., Bowles, H. R., Blair, A., Park, Y.,…Schatzkin, A. (2012). Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *The American Journal of Clinical Nutrition*, **95**, 437–445. doi:10.3945/ajcn.111.019620

McMurdo, M. E., Sugden, J., Argo, I., Boyle, P., Johnston, D. W., Sniehotta, F. F., & Donnan, P. T. (2010). Do pedometers increase physical activity in sedentary older women? A randomized controlled trial. *Journal of the American Geriatrics Society*, **58**, 2099–2106. doi:10.1111/j.1532-5415.2010.03127.x

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G.; PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine*, **6**, e1000097. doi:10.1371/journal.pmed.1000097

Morelhao PK, Oliveira CB, & Franco MR. (2017). Interventions to increase physical activity among older adults (PEDro synthesis). *British Journal of Sports Medicine*, 51, 1375–1376. doi:10.1136/bjsports-2016-096859

Montoye, A. H. K., Moore, R. W., Bowles, H. R., Korycinski, R., & Pfeiffer, K. A. (2018). Reporting accelerometer methods in physical activity intervention studies: a systematic review and recommendations for authors. *British Journal of Sports Medicine*, **52**, 1507–1516. doi:10.1136/bjsports-2015-095947

Moore, D. S., Ellis, R., Allen, P. D., Cherry, K. E., Monroe, P. A., O'Neil, C. E., & Wood, R. H. (2008). Construct validation of physical activity surveys in culturally diverse older adults: a comparison of four commonly used questionnaires. *Research Quarterly for Exercise and Sport*, **79**, 42–50. doi:10.1080/02701367.2008.10599459

Muellmann, S., Buck, C., Voelcker-Rehage, C., Bragina, I., Lippke, S., Meyer, J.,...Pischke, C. R. (2019). Effects of two web-based interventions promoting physical activity among older adults compared to a delayed intervention control group in Northwestern Germany: Results of the PROMOTE community-based intervention trial. *Preventive Medicine Reports*, **15**, 100958. doi:10.1016/j.pmedr.2019.100958

Mutrie, N., Doolin, O., Fitzsimons, C. F., Grant, P. M., Granat, M., Grealy, M.,...Skelton, D. A. (2012). Increasing older adults' walking through primary care: results of a pilot randomized controlled trial. *Family Practice*, **29**, 633–642. doi:10.1093/fampra/cms038

Nations, U. Department of Economic and Social Affairs, Population Division. (2017). *World Population Ageing 2017 - Highlights*.

Nations, U. World Economic and Social Survey 2007: Development in an Ageing World. (2007). Retrieved 24 July, 2019, from http://www.un.org/en/development/desa/policy/wess/wess_archive/2007wess.pdf

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C.,...Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, **39**, 1435–1445. doi:10.1249/mss.0b013e3180616aa2

Olanrewaju, O., Kelly, S., Cowan, A., Brayne, C., & Lafortune, L. (2016). Physical activity in community dwelling older people: a systematic review of reviews of interventions and context. *PLoS One*, **11**, e0168614. doi:10.1371/journal.pone.0168614

Oliveira, J. S., Sherrington, C., Paul, S. S., Ramsay, E., Chamberlain, K., Kirkham, C.,...Tiedemann, A. (2019). A combined physical activity and fall prevention intervention improved mobility-related goal attainment but not physical activity in older adults: a randomised trial. *Journal of Physiotherapy*, **65**, 16–22. doi:10.1016/j.jphys.2018.11.005

Pinto, R. Z., Maher, C. G., Ferreira, M. L., Hancock, M., Oliveira, V. C., McLachlan, A. J.,...Ferreira, P. H. (2012). Epidural corticosteroid injections in the management of sciatica: a systematic review and meta-analysis. *Annals of Internal Medicine*, **157**, 865–877. doi:10.7326/0003-4819-157-12-201212180-00564

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Connor Gorber, S., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, **5**, 56. doi:10.1186/1479-5868-5-56

Prince, M. J., Wu, F., Guo, Y., Gutierrez Robledo, L. M., O'Donnell, M., Sullivan, R., & Yusuf, S. (2015). The burden of disease in older people and implications for health policy and practice. *Lancet (London, England)*, **385**, 549–562. doi:10.1016/S0140-6736(14)61347-7

Rantakokko, M., Iwarsson, S., Kauppinen, M., Leinonen, R., Heikkinen, E., & Rantanen, T. (2010). Quality of life and barriers in the urban outdoor environment in old age. *Journal of the American Geriatrics Society*, **58**, 2154–2159. doi:10.1111/j.1532-5415.2010.03143.x

Recio-Rodríguez, J. I., Lugones-Sanchez, C., Agudo-Conde, C., González-Sánchez, J., Tamayo-Morales, O., Gonzalez-Sanchez, S.,...Garcia-Ortiz, L. (2019). Combined use of smartphone and smartband technology in the improvement of lifestyles in the adult population over 65 years: study protocol for a randomized clinical trial (EVIDENT-Age study). *BMC Geriatrics*, **19**, 19. doi:10.1186/s12877-019-1037-y

Rikli, R. E. (2000). Reliability, validity, and methodological issues in assessing physical activity in older adults. *Res Q Exerc Sport*, **71** (Suppl 2), 89–96. doi: 10.1080/02701367.2000.11082791

Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *The International Journal of Behavioral Nutrition and Physical Activity*, **14**, 42. doi:10.1186/s12966-017-0494-y

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine*, **37**, 197–206; discussion 206. doi:10.1136/bjsm.37.3.197

Sherrington, C., Fairhall, N. J., Wallbank, G. K., Tiedemann, A., Michaleff, Z. A., Howard, K.,...Lamb, S. E. (2019). Exercise for preventing falls in older people living in the community. *The Cochrane Database of Systematic Reviews*, **1**, CD012424. doi:10.1002/14651858.CD012424.pub2

Skender, S., Ose, J., Chang-Claude, J., Paskow, M., Brühmann, B., Siegel, E. M., . . . Ulrich, C. M. (2016). Accelerometry and physical activity questionnaires—A systematic review. *BMC Public Health*, 16(1), 515. doi:10.1186/s12889-016-3172-0

Silva, F. G., Oliveira, C. B., Hisamatsu, T. M., Filho, R. F. N., Rodrigues, C. R. D., Franco, M. R., & Pinto, R. Z. (2019). Critical evaluation of physical activity questionnaires translated To Brazilian-Portuguese: a systematic review on cross-cultural adaptation and measurements properties. *Brazlian Journal of Physical Therapy*, doi.org/10.1016/j.bjpt.2019.04.002

Sims, J., Smith, F., Duffy, A., & Hilton, S. (1999). The vagaries of self-reports of physical activity: a problem revisited and addressed in a study of exercise promotion in the over 65s in general practice. *Family Practice*, **16**, 152–157. doi:10.1093/fampra/16.2.152

Sun, F., Norman, I. J., & While, A. E. (2013). Physical activity in older people: a systematic review. *BMC Public Health*, **13**, 449. doi:10.1186/1471-2458-13-449

Tully, M. A., Cunningham, C., Cupples, M. E., Farrell, D., Hardeman, W., Hunter, R. F.,…Kee, F. (2018). Walk with Me: a protocol for a pilot RCT of a peer-led walking programme to increase physical activity in inactive older adults. *Pilot and Feasibility Studies*, **4**, 117. doi:10.1186/s40814-018-0308-2

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *CMAJ*, **174**(6), 801–809. doi: 10.1503/cmaj.051351

Warner, L. M., Wolff, J. K., Ziegelmann, J. P., Schwarzer, R., & Wurm, S. (2016). Revisiting self-regulatory techniques to promote physical activity in older adults: null-findings from a randomised controlled trial. *Psychology & Health*, **31**, 1145–1165. doi:10.1080/08870446.2016.1185523

Washburn, R. A., McAuley, E., Katula, J., Mihalko, S. L., & Boileau, R. A. (1999). The physical activity scale for the elderly (PASE): evidence for validity. *Journal of Clinical Epidemiology*, **52**, 643–651. doi:10.1016/s0895-4356(99)00049-9

WHO. (2010). Global recommendations on physical activity for health. Retrieved 05 February, 2019 from www.who.int/dietphysicalactivity/global-PA-recs-2010

Wijsman, C. A., Westendorp, R. G., Verhagen, E. A., Catt, M., Slagboom, P. E., de Craen, A. J.,…Mooijaart, S. P. (2013). Effects of a web-based intervention on physical activity and metabolism in older adults: randomized controlled trial. *Journal of Medical Internet Research*, **15**, e233. doi:10.2196/jmir.2843