Published in final edited form as:

Ann Behav Med. 2017 February ; 51(1): 79–93. doi:10.1007/s12160-016-9829-1.

The Impact of Accelerometers on Physical Activity and Weight Loss: A Systematic Review

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Abstract

Background—Regular physical activity is important for improving and maintaining health, but sedentary behavior is difficult to change. Providing objective, real-time feedback on physical activity with wearable motion-sensing technologies (activity monitors) may be a promising, scalable strategy to increase physical activity or decrease weight.

Purpose—We synthesized the literature on the use of wearable activity monitors for improving physical activity and weight-related outcomes and evaluated moderating factors that may have an impact on effectiveness.

Methods—We searched five databases from January 2000 to January 2015 for peer-reviewed, English-language randomized controlled trials among adults. Random-effects models were used to produce standardized mean differences (SMDs) for physical activity outcomes and mean differences (MDs) for weight outcomes. Heterogeneity was measured with I^2.

Results—Fourteen trials (2,972 total participants) met eligibility criteria; accelerometers were used in all trials. Twelve trials examined accelerometer interventions for increasing physical activity. A small significant effect was found for increasing physical activity (SMD 0.26; 95% CI 0.04 to 0.49; I^2=64.7%). Intervention duration was the only moderator found to significantly explain high heterogeneity for physical activity. Eleven trials examined effects of accelerometer

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CONFLICT OF INTEREST STATEMENT

This report is based on research conducted by the Evidence-based Synthesis Program (ESP) Center located at the Durham VA Medical Center, Durham, NC, funded by the Department of Veterans Affairs, Veterans Health Administration, Office of Research and Development, Quality Enhancement Research Initiative. The findings and conclusions in this document are those of the author(s) who are responsible for its contents; the findings and conclusions do not necessarily represent the views of the Department of Veterans Affairs or the United States government. Therefore, no statement in this article should be construed as an official position of the Department of Veterans Affairs.

No investigators have any affiliations or financial involvement (eg, employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties) that conflict with material presented in the report.

interventions on weight. Pooled estimates showed a small significant effect for weight loss (MD −1.65 kg; 95% CI −3.03 to −0.28; I^2=81%), and no moderators were significant.

Conclusions—Accelerometers demonstrated small positive effects on physical activity and weight loss. The small sample sizes with moderate to high heterogeneity in the current studies limit the conclusions that may be drawn. Future studies should focus on how best to integrate accelerometers with other strategies to increase physical activity and weight loss.

Keywords

Accelerometers; Weight loss; Physical activity

INTRODUCTION

Participation in regular physical activity is associated with a wide range of mental and physical health benefits. Patients with diabetes, obesity, or musculoskeletal disease, in particular, derive significant benefits from regular physical activity, including favorable effects on blood pressure, lipid profiles, joint pain, weight control, body composition, and psychological well-being [1]. Despite proven benefits and widespread public health and clinical calls to increase physical activity, sedentary behavior has proven difficult to change.

Self-monitoring is a key behavioral strategy to increase an individual's physical activity, and objective self-monitoring is considered the gold standard [2]. Pedometers are tools that can be used for objective self-monitoring and are designed to detect ambulatory activity to provide a simple estimate of physical activity volume. These devices provide several positive characteristics including simplicity, affordability, validity, and reliability, and they have been successfully implemented into physical activity and weight loss studies [3]. Pedometer usage has been associated with significant increases in physical activity and significant decreases in both body mass index, blood pressure [4] and weight loss, with interventions of longer duration leading to greater weight loss than shorter duration programs [5]. Pedometers continue to be widely used to monitor daily ambulation activity, as a tool for prescribing increased mobility (e.g., daily step targets), and for motivating individuals to increase their activity level [6,7] [8]. However, pedometers have limitations, such as producing step-count inaccuracies in overweight and obese populations and those with slower ambulation [9,10], as well as and the inability to capture exercise intensity [3]. Newer activity monitoring technologies, such as accelerometers, offer advantages over pedometers. These include the potential to detect lateral and vertical movements and measure the intensity of physical activity [6]. In addition, activity monitors used by consumers and researchers now have extensive feedback loops. These feedback loops provide real-time data to the wearer via computer programs and mobile applications that allow for tailoring intervention content [11–13]. Further, some devices provide an option to relay information to a third party such as family, friends, or clinicians. The ability to transmit data to patients' physicians and healthcare teams makes these devices attractive for clinical applications, although this capability is in its infancy of implementation and evaluation [11].

Newer, direct-to-consumer activity tracking devices are rarely examined as intervention tools. We are unaware of any systematic reviews that have quantitatively described outcomes

using devices such as accelerometers. Furthermore, factors that may moderate the effects of these newer self-monitoring technologies remain to be explored. Thus, the objectives of this literature synthesis were to (1) determine the effectiveness of newer activity monitoring technologies for increasing physical activity and decreasing body weight outcomes and (2) describe factors that impact the effectiveness of such technologies (i.e., chronic disease status, location where the device is worn on the body, the device's role in the overall intervention approach, and duration of the intervention).

METHODS

We followed a standard protocol for this review and conducted it in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement [14]. Each step was pilot-tested to train and calibrate study investigators. The PROSPERO registration number is CRD42015017343. This review is part of a larger report for the U.S. Veterans Health Administration's Evidence-based Synthesis Program to investigate existing evidence on wearable activity devices.

Data Sources and Search Strategy

We searched MEDLINE (via PubMed), Embase, CINAHL, SPORTDiscus, and Cochrane CENTRAL from January 1, 2000, to January 6, 2015 (Appendix). We used Medical Subject Heading (MeSH) terms and selected free-text terms for wearable activity monitors and for outcomes of interest (e.g., movement, exercise therapy, physical fitness) along with validated search terms for study designs of interest [15]. We also reviewed the bibliographies of included trials and systematic reviews [16–22] for missed publications. All citations were imported into two electronic databases (for referencing, EndNote® Version X5, Thomson Reuters, Philadelphia, PA; for data abstraction, DistillerSR; Evidence Partners Inc., Manotick, ON, Canada).

Inclusion Criteria and Screening

To be included, studies had to (1) include adults ≥18 years of age, (2) use a wearable activity monitor not described as a pedometer (i.e., measures vertical acceleration movement and provides objective feedback to the user), (3) report changes in the outcomes of physical activity or weight, (4) be a randomized controlled trial (RCT) with a total sample size >20 participants and outcomes ≥3 months, and (5) be published in an English-language peer-reviewed journal. Studies were excluded if they were not a population of interest, did not include an outcome of interest, used pedometers only, or used activity monitors that do not provide feedback to the wearer.

Two trained investigators screened titles and abstracts for relevance to the objectives of the study. Full-text articles identified by either investigator as potentially relevant were retrieved for further review and examined by two investigators against the eligibility criteria. Disagreements were resolved by discussion or by a third investigator. In addition, trials with three or more arms were examined for appropriateness of all arms for inclusion.

Data Abstraction

Data from included trials were abstracted into a customized database by a trained investigator and confirmed by a second investigator. Disagreements were resolved by consensus or by obtaining a third investigator's opinion when consensus could not be reached. Data elements included date of publication, sample size, population characteristics (e.g., chronic medical illness status, sex, age), and descriptors to assess applicability, quality elements, and outcomes. Key intervention characteristics abstracted were the type of activity monitor (e.g., brand, location worn on body), type of adjunctive intervention (e.g., behavioral weight management strategies, physical activity education), and duration and frequency of intervention.

Risk of Bias

We used key quality criteria described in the Cochrane Collaboration Risk of Bias Tool to assess risk of bias in each included study [23]. The tool evaluates 6 different domains across 7 questions: (1) selection bias (i.e., adequacy of random-sequence generation, allocation concealment); (2) performance bias for each outcome (i.e., knowledge of allocated intervention by participants and study personnel that could introduce bias); (3) detection bias for each outcome (i.e., knowledge of allocated intervention by outcome assessors); (4) attrition bias (i.e., amount, nature, or handling of incomplete outcome data); (5) reporting bias (i.e., selective outcome reporting); (6) other bias (e.g., differences in relation to baseline measures, reliable primary outcomes, protection against contamination).

We evaluated each domain as low, unclear, or high risk of bias. The overall score of low risk of bias required selection bias related to random sequencing and allocation concealment; performance bias; and detection bias to be scored "low risk" with no other important concerns. For performance bias and detection bias, studies did not need to blind study personnel and participants to receive a low risk of bias if outcome measurement was not likely to be influenced by lack of blinding. A judgment of unclear risk of bias was assigned if 1 or 2 domains were scored "not clear" or "not done." Studies judged to be high risk of bias had more than 2 domains scored "not clear" or "not done."

Data Synthesis

When meta-analysis was feasible, we computed summary estimates of effect. We aggregated outcomes when there were at least three studies with the same outcome. Continuous outcomes were analyzed using standardized mean differences (SMDs) for physical activity outcomes and mean differences (MDs) for weight outcomes in a random-effects model with the Knapp-Hartung [24] correction to confidence intervals. The method we used to interpret the SMD as an effect size is as follows: small effect size, SMD=0.2; medium, SMD=0.5; and large, SMD≥0.8 [25]. We evaluated for statistical heterogeneity using visual inspection of forest plots and the I^2 statistic. We assessed for potential publication bias by comparing registered clinical trials in ClinicalTrials.gov with published literature. All quantitative analyses were performed in R (R Foundation for Statistical Computing, Vienna, Austria) with the metafor package [26].

We conducted analyses separately for interventions versus inactive controls (e.g., waitlist, usual care) and interventions versus active comparators (e.g., group weight loss, counseling). Three trials had more than one intervention arm [27–29]. Two of these trials compared different adjunctive interventions to continuous monitoring via accelerometers [27,28]. For these two studies, we selected the intervention with the less intensive adjuncts (e.g., monthly counseling vs. weekly counseling). The third trial tested the impact of continuous versus intermittent accelerometer feedback [29]. For this study, we selected the comparisons between continuous accelerometer use and control because this was the type of accelerometer use evaluated in all other studies.

If a quantitative synthesis was not feasible (due to less than 3 studies in a subgroup), we analyzed the data qualitatively. We gave more weight to the evidence from higher quality studies with more precise estimates of effect. We focused on documenting and identifying patterns of the intervention across outcome categories. We analyzed potential reasons for inconsistency in treatment effects across studies by evaluating differences in the study population, intervention, comparator, and outcome definitions.

Moderator Effects

We explored potential sources of heterogeneity, including characteristics of the population operationalized as overweight/obese/sedentary, older adults, healthy volunteers, and those with other chronic medical illnesses (e.g., diabetes), and the intervention duration in weeks, and location on the body where the device is worn. We aimed to assess the differential impact of type of adjunctive interventions (e.g., behavioral weight management intervention, physical activity education, goal-setting) as a source of potential heterogeneity. Because type and quantity of adjunctive interventions varied greatly from study to study, we operationalized this moderator as the role of the wearable activity monitor in the overall intervention (i.e., major vs. minor component). To be categorized as a major component of the intervention, the wearable activity monitor needed to be the central motivational enhancement strategy intended to improve the primary outcome of the study. Other adjunctive interventions might be included but played a minor role in enhancing physical activity. To be categorized as a minor component, the wearable activity device needed to be an integrated part of a suite of other motivation enhancement interventions, such as a structured exercise program, behavioral counseling, or disease self-management techniques. Two independent investigators categorized the role of the device, and another investigator reconciled any discrepancies.

RESULTS

Our search identified 6,196 citations and, after removing duplicates, we screened 4,787 titles and abstracts for eligibility criteria, leaving 176 citations for full-text review. In total, 14 trials met eligibility criteria (Figure 1). Across these, women were 62.5% of the population; median age was 49.7 years (range 28.7 to 79.8 years); and the intervention duration ranged from 12 to 52 weeks. Only 4 trials reported race. The majority of trials were conducted in the United States (n=8), and study sizes ranged from 20 to 544 participants (median n=62), with the majority of studies (n=8) randomizing fewer than 70 participants.

Table 1 summarizes the study characteristics of the 14 included studies. Twelve studies reported on outcomes related to physical activity [29–40] and 11 on outcomes related to weight [27–29,31–37,39]. Four trials were conducted with older adults; five with overweight, obese, or sedentary adults; three with participants with a chronic medical illness (e.g., chronic obstructive pulmonary disease, metabolic disease, diabetes); and two with healthy volunteers. The device—usually worn on the waist (n=8 trials)—was a major component of the intervention in nine trials and a minor component in five trials. While we searched broadly for wearable non-pedometer devices, all identified trials used some form of accelerometer-based motion-sensing technology. Comparators were active in 3 trials and inactive in 11 trials. The number of planned interactions with participants in the accelerometer interventions ranged from none to 52 weekly contacts. Trials used a wide variety of adjunctive interventions in conjunction with accelerometers, including intensive diet, weight, and physical activity behavioral counseling; tailored written feedback; and web-based supportive educational modules. A search of ClinicalTrials.gov identified one completed but unpublished trial (NCT00544245) that appeared to meet our inclusion criteria, which suggests little potential for publication bias.

Physical Activity

Figure 2 shows the effect of interventions that used accelerometers on physical activity with an overall pooled estimate and stratified pooled estimates by inactive and active comparator subgroups. The overall pooled estimate indicated a small, statistically significant effect for interventions using accelerometers to increase physical activity (SMD 0.26; 95% CI 0.04 to 0.49) with a high amount of heterogeneity (I^2=64.7%). A similar small effect was found for interventions using accelerometers to increase physical activity when compared with an inactive comparator (SMD 0.29; 95% CI 0.03 to 0.55). This summary estimate had high heterogeneity (I^2=70.3%). A small positive overall effect was also observed for accelerometer devices when compared with an active comparator, but this estimate was not statistically significant (SMD 0.17; 95% CI −1.09 to 1.43; moderate heterogeneity I^2=52.3%).

Weight Loss

Figure 3 shows the pooled effect of the accelerometer interventions on weight loss across the 11 included trials and stratified estimates by inactive and active comparator subgroups. Overall, the pooled estimate showed a small significant effect for weight loss (MD −1.65 kg; 95% CI −3.03 to −0.28; I^2=81%). Compared with inactive controls, the impact of accelerometer interventions on weight loss was similar to that observed in the overall summary estimate (MD −1.44 vs. −1.65 kg, respectively). However, the inactive pooled estimate was not statistically significant. Both the stratified and overall summary estimates displayed high heterogeneity as assessed by I^2 values >80%.

Two small trials judged to be at high risk of bias compared accelerometer interventions with active comparators [29,31]. While both trials demonstrated a positive trend of weight loss (MD −3.60 to −2.10), only one study [31] was statistically significant. In that study, the accelerometer was judged to play a minor role and was paired with adjunctive interventions consisting of structured and supervised exercise training, meal preparation twice daily, and

behavior counseling delivered over 5 months. In the study that was not statistically significant, the accelerometer played a major role, but the intervention was only 12 weeks [29].

Moderators

We examined several moderators (i.e., population characteristics, device location, major vs. minor role of accelerometer, intervention duration) as potentials sources to explain significant heterogeneity (Table 2). Only one study characteristic, intervention duration in weeks, was associated with a very small, negative effect on physical activity (moderator p=0.02; SMD −0.013; 95% CI −0.023 to −0.002) with low heterogeneity (I^2=21.1%, p=0.24) (Figure 4). This effect was not observed for the outcome of weight loss (moderator p=0.18; MD −0.06; 95% CI −0.15 to 0.03).

Risk of Bias

Figure 5 provides the risk of bias with our judgments for each individual domain per study, and Figure 6 provides the risk of bias with our judgments about each risk of bias item presented as total percentages across all included studies. The majority of studies (8 of 14 [57.1%]) were judged to be at high risk of bias, 4 (28.6%) were at unclear risk of bias, and only 2 studies (14.3%) were judged to be at low risk of bias. For risk of selection bias, 7 of the 14 trials (50.0%) did not give details about the method for generating the random sequence, resulting in a rating of unclear risk of bias. For the majority of trials (9 of 14 [64.3%]), there was an unclear risk of bias due to inadequate detail about allocation concealment provided by authors. In 9 of 12 trials (75.0%) involving the outcome of physical activity and 7 of 12 trials (58.3%) with the outcome of weight change, there is unclear risk of bias due to knowledge of the allocated intervention by study personnel (i.e., performance bias). In 7 of 12 trials (58.3%) involving the outcome of physical activity and 4 of 12 trials (30.8%) with the outcome of weight change, there is unclear risk of bias due to knowledge of the allocated intervention by the outcome assessor (i.e., detection bias). The majority of trials (13 of 14 [92.9%]) reported complete outcome data that included information on attrition and exclusions from analysis.

DISCUSSION

We systematically reviewed the literature on the effectiveness of newer wearable technology devices for increasing physical activity levels or decreasing body weight. We identified 14 trials that met our inclusion criteria. All included studies were published in the last 10 years, indicating the relatively new use of motion-sensing technologies in studies aimed at promoting physical activity or weight loss. Although we broadly searched for wearable motion sensing technologies, no included studies used types of technologies other than accelerometers (e.g., GPS, hand gesture, eye gesture, hand swipe). In addition, all of the studies used activity data captured directly from the activity monitor device rather than from a secondary or passive activity monitor such as a smartphone.

The use of pedometers has been found to produce significant and potentially clinically relevant changes in physical activity and weight [4,5]. However, due to improvements in

technology to provide more accurate measurement of movement and enhancements in delivery of feedback to participants, accelerometers are increasing in popularity. We found that interventions that integrate accelerometers produced relatively small clinical improvements in contrast to earlier finding of pedometers that reported more robust clinical improvements [5,41,42]. The differences between findings on pedometers and accelerometers are likely multifactorial and due, in part, to differences in accuracy of movement between pedometers and accelerometers, the role of devices in the overall intervention approaches, and variations in study design and risk of bias across studies.

The significant increase in physical activity levels and a significant decrease in body weight we report here were muted when accelerometer interventions were compared with more robust active comparators than with inactive controls. These main effect analyses, however, had substantial clinical and statistical heterogeneity. The variability is likely due to a combination of factors related to underlying differences in populations, comparators, interventions, and study quality issues. Further, there were substantial differences in types of outcome measures used in the physical activity studies (e.g., steps/day, hours/day, minutes/week, metabolic values), which led to challenges in conducting and interpreting the pooled estimates. Efforts to standardize collection and reporting are needed to improve interpretability across studies.

We sought to explore statistical heterogeneity in intervention effects on both physical activity and weight by multiple single factors (i.e., recruited populations, role of device relative to other motivational enhancement strategies, location of device as a proxy for ease of use, duration of intervention). Only duration of intervention was a statistically significant moderator in our analyses. Two previous systematic reviews [4,5] on pedometer-based walking programs found longer duration studies produced greater weight loss, which contrasts with our results finding no significant moderator effect with intervention duration. However, our results indicate that shorter duration programs produced a larger effect on increasing physical activity compared to longer duration programs. Several factors may influence our finding on intervention duration, including participant adherence to use of the accelerometers and the role of the accelerometer among the variety of adjunctive interventions used in these studies. Further, the majority of our included studies had an intervention duration of 12 to 24 weeks, with only a few studies reporting greater durations, which may limit our ability to fully examine the effect of studies with longer durations. However, this finding is indirectly supported by studies of supervised exercise [43,44]. In general, these studies have reported that outcomes may be influenced by an optimal and unknown intervention duration “sweet spot” that may also depend on intensity and frequency. It is also plausible that after the novelty of accelerometers wears off, so may the potential motivating effects. This reasoning is consistent with what others have found; more than half of individuals who purchase a wearable activity monitor stop using it and, of these, one-third stop use in the first months [45]. Our qualitative analyses also identified aspects that may explain the substantial variability among studies. In general, interventions that capitalized on the self-monitoring and tailored activity device-driven feedback capabilities were associated with greater decreases in weight loss. Effects were even greater when these strategies were paired with behavioral counseling focused on device feedback. The same

qualitative finding was not consistently seen for greater increases in physical activity with better implementation of device-driven feedback and self-monitoring functionality.

Our review identified several gaps in the literature. We found no head-to-head comparisons between accelerometers and pedometers for our outcomes. Thus, it is unclear whether accelerometers, either independently or when coupled with a variety of adjunctive interventions, improve physical activity or weight loss over pedometers. We identified only three studies among patients with chronic medical illnesses and five studies among those who are overweight, obese, or sedentary. Use and effectiveness of accelerometers may differ among participants who are motivated to use these devices to achieve different goals; for example, those who are trying to increase physical activity to reduce pain from osteoarthritis compared with participants whose goal is to lose weight. Because of the diversity of adjunctive interventions across included trials, our review was unable to provide guidance on the optimal adjunctive interventions needed to enhance functionally of accelerometers in motivating behavior change. Our results support diminished effects of accelerometers over time. Future research should measure how often participants wear accelerometers and how participants interact with their generated data to explore facilitators and barriers to sustained interaction with these devices. Furthermore, we did not find any studies that sought to integrate physical activity data from wearable accelerometers into patients' medical records to facilitate ongoing primary care and chronic disease management. Such research could be of real value to clinicians and policymakers. Also, the increasing inclusion of accelerometers directly into smartphones warrants clinical trials that evaluate the effectiveness of this technology.

Our review has a number of strengths, including a protocol-driven design, a comprehensive search, and careful quality assessment. Our review—and the literature—have limitations: the number of studies is small; many had design limitations (8 of 14 were judged to be at high risk of bias); the range of interventions evaluated was diverse; and the number and reporting of studies precluded any analyses of variability in accelerometers by more than one variable at a time. Our review was limited to English-language publications, but the likelihood of identifying relevant data unavailable from English-language sources is low. The small sample sizes of most included trials and the populations recruited also limited our findings. While we conducted subgroup analysis to explore multiple single factors that may contribute to heterogeneity, the observed heterogeneity is likely attributable to a combination of factors or to some that were unmeasured by our work or available in the current literature. The overall low number and small size of trials per outcome precluded us from conducting multivariable analyses.

CONCLUSION

To our knowledge, our review is the first quantitative synthesis of newer wearable activity devices and their potential effects on increasing physical activity and weight loss. We found that the use of accelerometers produces small positive effects on physical activity and weight. The small sample sizes with moderate to high heterogeneity in the current studies limit the conclusions that may be drawn. It is important to note that we were not able to isolate the individual impact of accelerometers as a standalone strategy to promote weight

loss or increase physical activity because all included studies contained some level of adjunctive intervention. Future studies should focus on how best to integrate accelerometers with other strategies to increase physical activity and weight loss.

Acknowledgments

The authors would like to thank Liz Wing, MA, for assistance with manuscript preparation. Ms. Wing is an employee of the Duke Clinical Research Institute, Durham, NC, and received no compensation for her work apart from her usual salary.

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APPENDIX

Database: MEDLINE (via PubMed)		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
1	“Accelerometry”[Mesh] OR “Magnetometry”[Mesh] OR “Motor Activity/instrumentation”[Mesh] OR fitness track*[tiab] OR activity track*[tiab] OR fitness monitor*[tiab] OR gps[tiab] OR “global positioning”[tiab] OR activity monitor*[tiab] OR motion sens*[tiab] OR accelerometer[tiab] OR accelerometers[tiab] OR accelerometry[tiab] OR gyroscope[tiab] OR gyroscopic[tiab] OR gyroscopes[tiab] OR actograph[tiab] OR actographic[tiab] OR actography[tiab] OR actographs[tiab] OR wearable system[tiab] OR wearable systems[tiab] OR wearable sensor[tiab] OR wearable sensors[tiab] OR ((step[tiab] OR steps[tiab]) AND (counting[tiab] OR counted[tiab] OR counter[tiab] OR counters[tiab] OR count[tiab])) OR actigraph[tiab] OR (basis[tiab] AND peak[tiab]) OR “bowflex boost”[tiab] OR “fit link”[tiab] OR (misfit[tiab] AND shine[tiab]) OR (polar[tiab] AND loop[tiab]) OR bodybugg[tiab] OR bodymedia[tiab] OR fitbit[tiab] OR fitbug[tiab] OR fuelband[tiab] OR garmin[tiab] OR gowear[tiab] OR gruve[tiab] OR ibitz[tiab] OR iqua[tiab] OR	52,751

Database: MEDLINE (via PubMed)		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
	lumo[tiab] OR motoactiv[tiab] OR runtastic[tiab] OR scosche[tiab] OR smartband[tiab] OR striiv[tiab] OR tomtom[tiab] OR vivofit[tiab] OR vivosmart[tiab] OR wahoo[tiab] OR wakemate[tiab] OR withings[tiab]	
2	"Movement"[Mesh] OR "Exercise Movement Techniques"[Mesh] OR "Exercise Therapy"[Mesh] OR "Physical Fitness"[Mesh] OR "Physical Endurance"[Mesh] OR "Physical Exertion"[Mesh] OR fitness[tiab] OR activity[tiab] OR active[tiab] OR walk*[tiab] OR run*[tiab] OR step[tiab] OR steps[tiab] OR exercise[tiab] OR move*[tiab]	3,555,057
3	(randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomization[tiab] OR randomisation[tiab] OR randomly[tiab] OR trial[tiab] OR groups[tiab]) NOT (Editorial[ptyp] OR Letter[ptyp] OR Case Reports[ptyp] OR Comment[ptyp])	2,079,904
4	#1 AND #2 AND #3	4858
5	#4 NOT ("Child"[Mesh] NOT "Adult"[Mesh])	4355
6	#5, English, 2000 – present	3506
Database: Embase		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
1	'accelerometry'/exp OR 'magnetometry'/exp OR (fitness NEAR/2 track*):ab,ti OR (activity NEAR/2 track*):ab,ti OR (fitness NEAR/2 monitor*):ab,ti OR gps:ab,ti OR 'global positioning':ab,ti OR (activity NEAR/2 monitor):ab,ti OR (motion NEAR/2 sens*):ab,ti OR accelerometer:ab,ti OR accelerometers:ab,ti OR accelerometry:ab,ti OR gyroscope:ab,ti OR gyroscopic:ab,ti OR gyroscopes:ab,ti OR actograph:ab,ti OR actographic:ab,ti OR actography:ab,ti OR actographs:ab,ti OR 'wearable system':ab,ti OR 'wearable systems':ab,ti OR 'wearable sensor':ab,ti OR 'wearable sensors':ab,ti OR ((step OR steps):ab,ti AND (counting OR counted OR counter OR counters OR count):ab,ti) OR actigraph:ab,ti OR (basis NEAR/3 peak):ab,ti,df OR 'bowflex boost':ab,ti,df OR 'fit link':ab,ti,df OR (misfit NEAR/3 shine):ab,ti,df OR (polar NEAR/3 loop):ab,ti,df OR bodybugg:ab,ti,df OR bodymedia:ab,ti,df OR fitbit:ab,ti,df OR fitbug:ab,ti,df OR fuelband:ab,ti,df OR garmin:ab,ti,df OR gowear:ab,ti,df OR gruve:ab,ti,df OR ibitz:ab,ti,df OR iqua:ab,ti,df OR lumo:ab,ti,df OR motoactiv:ab,ti,df OR runtastic:ab,ti,df OR scosche:ab,ti,df OR smartband:ab,ti,df OR striiv:ab,ti,df OR tomtom:ab,ti,df OR vivofit:ab,ti,df OR vivosmart:ab,ti,df OR wahoo:ab,ti,df OR wakemate:ab,ti,df OR withings:ab,ti,df	45,316
2	'movement (physiology)'/exp OR 'physical activity, capacity and performance'/exp OR 'kinesiotherapy'/exp OR 'fitness'/exp OR fitness:ab,ti OR activity:ab,ti OR active:ab,ti OR walk*:ab,ti OR run*:ab,ti OR step:ab,ti OR steps:ab,ti OR exercise:ab,ti OR move*:ab,ti	4,564,954
3	('randomized controlled trial'/exp OR 'crossover procedure'/exp OR 'double blind procedure'/exp OR 'single blind procedure'/exp OR random*:ab,ti OR factorial*:ab,ti OR crossover*:ab,ti OR (cross NEAR/1 over*):ab,ti OR (doubl* NEAR/1 blind*):ab,ti OR (singl* NEAR/1 blind*):ab,ti OR assign*:ab,ti OR allocat*:ab,ti OR volunteer*:ab,ti) NOT ('case report'/exp OR 'case study'/exp OR 'editorial'/exp OR 'letter'/exp OR 'note'/exp)	1,431,100
4	#1 AND #2 AND #3	3250
5	#4 NOT ('child'/exp NOT 'adult'/exp)	2888
6	#5 AND [embase]/lim NOT [medline]/lim	1051
7	#6, Limits: English, 2000-	988
Database: CINAHL		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
1	(MH "Accelerometry") OR (MH "Magnetics+") OR TI ("fitness track*" or "activity track*" or "fitness monitor*" or gps or "global positioning" or "activity monitor*" or	14,089

Database: MEDLINE (via PubMed)		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
	"motion sens*" or accelerometer or accelerometers or accelerometry or gyroscope or gyroscopic or gyroscopes or actograph or actographic or actography or actographs or "wearable system" or "wearable systems" or "wearable sensor" or "wearable sensors" or ((step or steps) and (counting or counted or counter or counters or count)) or actigraph or (basis and peak) or "bowflex boost" or "fit link" or (misfit and shine) or (polar and loop) or bodybugg or bodymedia or fitbit or fitbug or fuelband or garmin or gowear or gruve or ibitz or iqua or lumo or motoactiv or runtastic or scosche or smartband or striiv or tomtom or vivofit or vivosmart or wahoo or wakemate or withings) OR AB ("fitness track*" or "activity track*" or "fitness monitor*" or gps or "global positioning" or "activity monitor*" or "motion sens*" or accelerometer or accelerometers or accelerometry or gyroscope or gyroscopic or gyroscopes or actograph or actographic or actography or actographs or "wearable system" or "wearable systems" or "wearable sensor" or "wearable sensors" or ((step or steps) and (counting or counted or counter or counters or count)) or actigraph or (basis and peak) or "bowflex boost" or "fit link" or (misfit and shine) or (polar and loop) or bodybugg or bodymedia or fitbit or fitbug or fuelband or garmin or gowear or gruve or ibitz or iqua or lumo or motoactiv or runtastic or scosche or smartband or striiv or tomtom or vivofit or vivosmart or wahoo or wakemate or withings)	
2	(MH "Movement+") OR (MH "Exercise+") OR (MH "Therapeutic Exercise+") OR (MH "Physical Activity") OR (MH "Physical Fitness+") OR (MH "Exertion+") OR TI (OR fitness OR activity OR active OR walk* OR run* OR step OR steps OR exercise OR move*) OR AB (OR fitness OR activity OR active OR walk* OR run* OR step OR steps OR exercise OR move*)	361,653
3	(MH "Treatment Outcomes+") OR randomized OR PT clinical trial	317,587
4	#1 AND #2 AND #3	636
5	#4, English, 2000-	602
Database: SPORTDiscus		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
1	DE "ACCELEROMETERS" OR TI ("fitness track*" or "activity track*" or "fitness monitor*" or gps or "global positioning" or "activity monitor*" or "motion sens*" or accelerometer or accelerometers or accelerometry or gyroscope or gyroscopic or gyroscopes or actograph or actographic or actography or actographs or "wearable system" or "wearable systems" or "wearable sensor" or "wearable sensors" or ((step or steps) and (counting or counted or counter or counters or count)) or actigraph or (basis and peak) or "bowflex boost" or "fit link" or (misfit and shine) or (polar and loop) or bodybugg or bodymedia or fitbit or fitbug or fuelband or garmin or gowear or gruve or ibitz or iqua or lumo or motoactiv or runtastic or scosche or smartband or striiv or tomtom or vivofit or vivosmart or wahoo or wakemate or withings) OR AB ("fitness track*" or "activity track*" or "fitness monitor*" or gps or "global positioning" or "activity monitor*" or "motion sens*" or accelerometer or accelerometers or accelerometry or gyroscope or gyroscopic or gyroscopes or actograph or actographic or actography or actographs or "wearable system" or "wearable systems" or "wearable sensor" or "wearable sensors" or ((step or steps) and (counting or counted or counter or counters or count)) or actigraph or (basis and peak) or "bowflex boost" or "fit link" or (misfit and shine) or (polar and loop) or bodybugg or bodymedia or fitbit or fitbug or fuelband or garmin or gowear or gruve or ibitz or iqua or lumo or motoactiv or runtastic or scosche or smartband or striiv or tomtom or vivofit or vivosmart or wahoo or wakemate or withings)	6204
2	(random* OR trial)	56299
3	#1 AND #2	639
4	#3, English, 2000-, Academic Journals	543
Database: Cochrane CENTRAL		
Search date: 01/06/15		
Set	**Search Terms**	**Results**

Database: MEDLINE (via PubMed)		
Search date: 01/06/15		
Set	**Search Terms**	**Results**
1	[mh Accelerometry] OR [mh Magnetometry]	341
2	"fitness track*":ab,ti or "activity track*":ab,ti or "fitness monitor*":ab,ti or gps:ab,ti or "global positioning":ab,ti or "activity monitor*":ab,ti or "motion sens*":ab,ti or accelerometer:ab,ti or accelerometers:ab,ti or accelerometry:ab,ti or gyroscope:ab,ti or gyroscopic:ab,ti or gyroscopes:ab,ti or actograph:ab,ti or actographic:ab,ti or actography:ab,ti or actographs:ab,ti or "wearable system":ab,ti or "wearable systems":ab,ti or "wearable sensor":ab,ti or "wearable sensors":ab,ti or ((step:ab,ti or steps:ab,ti) and (counting:ab,ti or counted:ab,ti or counter:ab,ti or counters:ab,ti or count:ab,ti)) or actigraph:ab,ti or (basis:ab,ti and peak:ab,ti) or "bowflex boost":ab,ti or "fit link":ab,ti or (misfit:ab,ti and shine:ab,ti) or (polar:ab,ti and loop:ab,ti) or bodybugg:ab,ti or bodymedia:ab,ti or fitbit:ab,ti or fitbug:ab,ti or fuelband:ab,ti or garmin:ab,ti or gowear:ab,ti or gruve:ab,ti or ibitz:ab,ti or iqua:ab,ti or lumo:ab,ti or motoactiv:ab,ti or runtastic:ab,ti or scosche:ab,ti or smartband:ab,ti or striiv:ab,ti or tomtom:ab,ti or vivofit:ab,ti or vivosmart:ab,ti or wahoo:ab,ti or wakemate:ab,ti or withings:ab,ti	2945
3	#1 OR #2	3204
4	[mh "Movement"] OR [mh "Exercise Movement Techniques"] OR [mh "Exercise Therapy"] OR [mh "Physical Fitness"] OR [mh "Physical Endurance"] OR [mh "Physical Exertion"]	29,268
5	fitness:ab,ti OR activity:ab,ti OR active:ab,ti OR walk*:ab,ti OR run*:ab,ti OR step:ab,ti OR steps:ab,ti OR exercise:ab,ti OR move*:ab,ti	134,034
6	#4 OR #5	140,071
Set	**Search Terms**	**Results**
7	#3 AND #6	1630
8	#5, 2000 – present, In Trials	1281

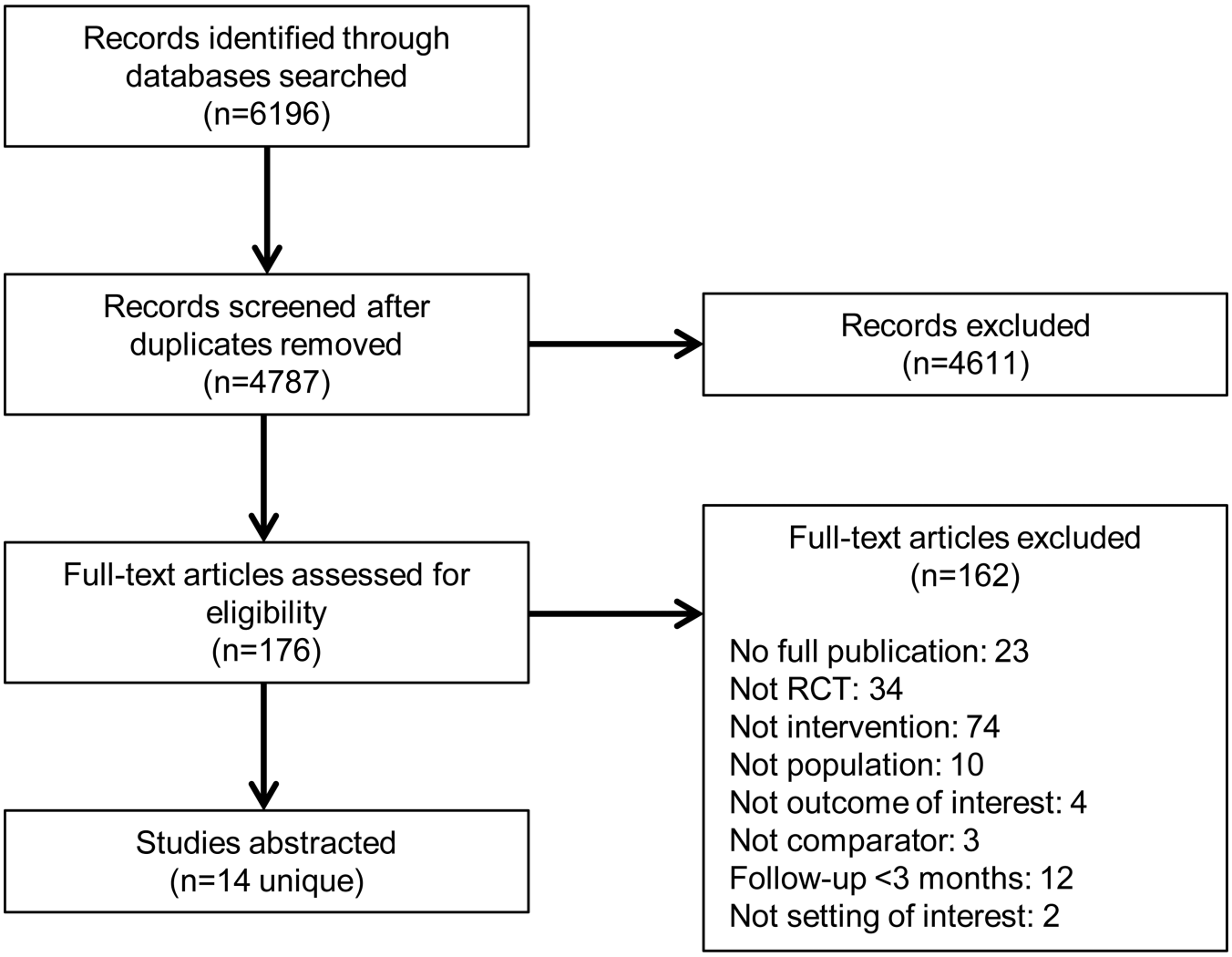

Figure 1.
Literature flow diagram

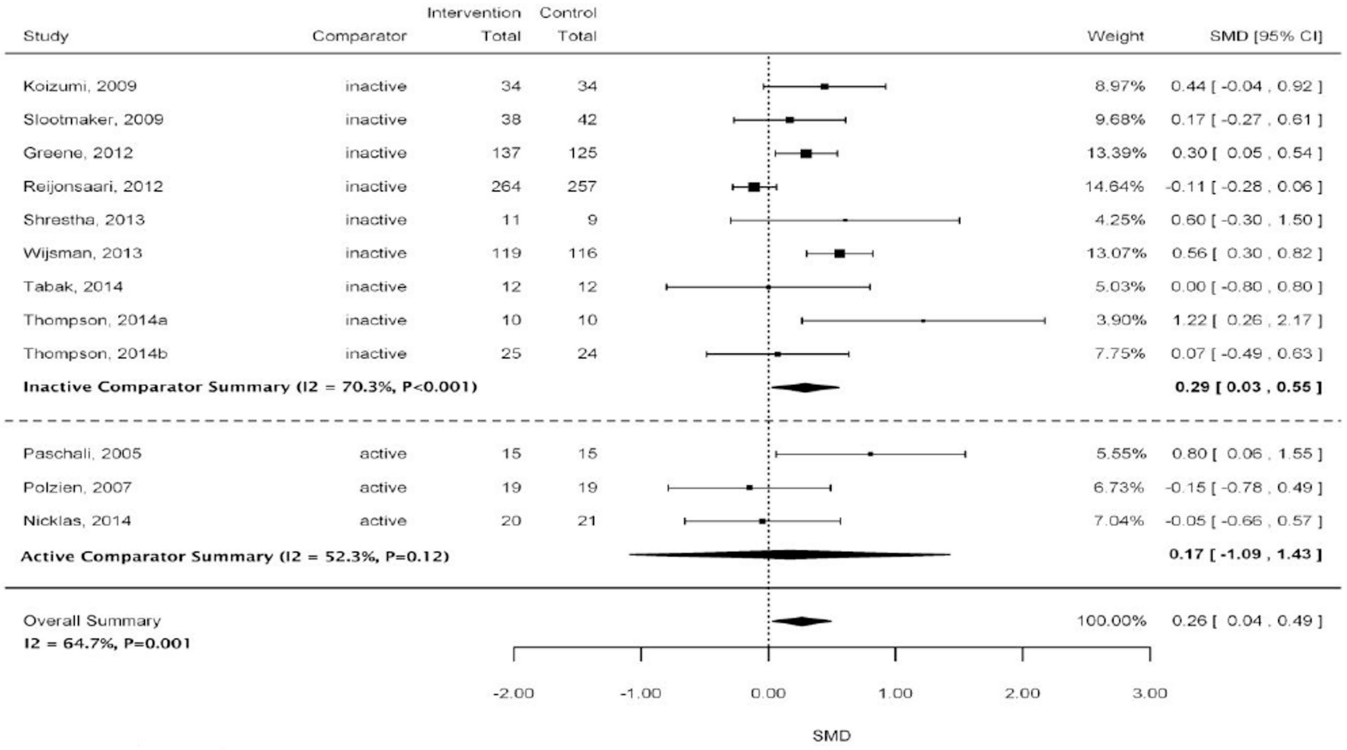

Figure 2.

Forest plot of studies included in physical activity meta-analysis stratified by active and inactive comparators

Abbreviations: CI=confidence interval; SMD=standardized mean difference

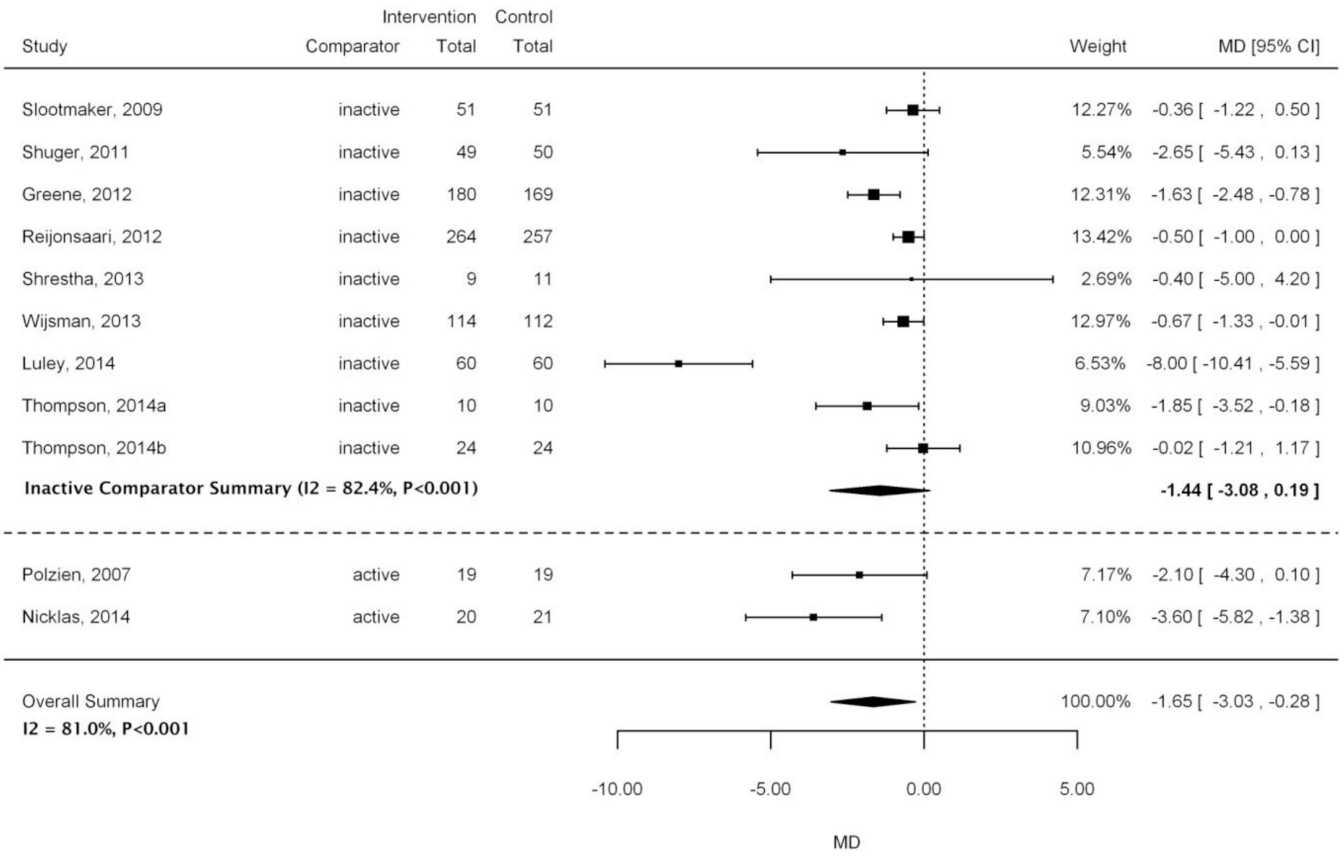

Figure 3.

Forest plot of studies included in weight loss meta-analysis stratified by active and inactive comparators

Abbreviations: CI=confidence interval; MD=mean difference

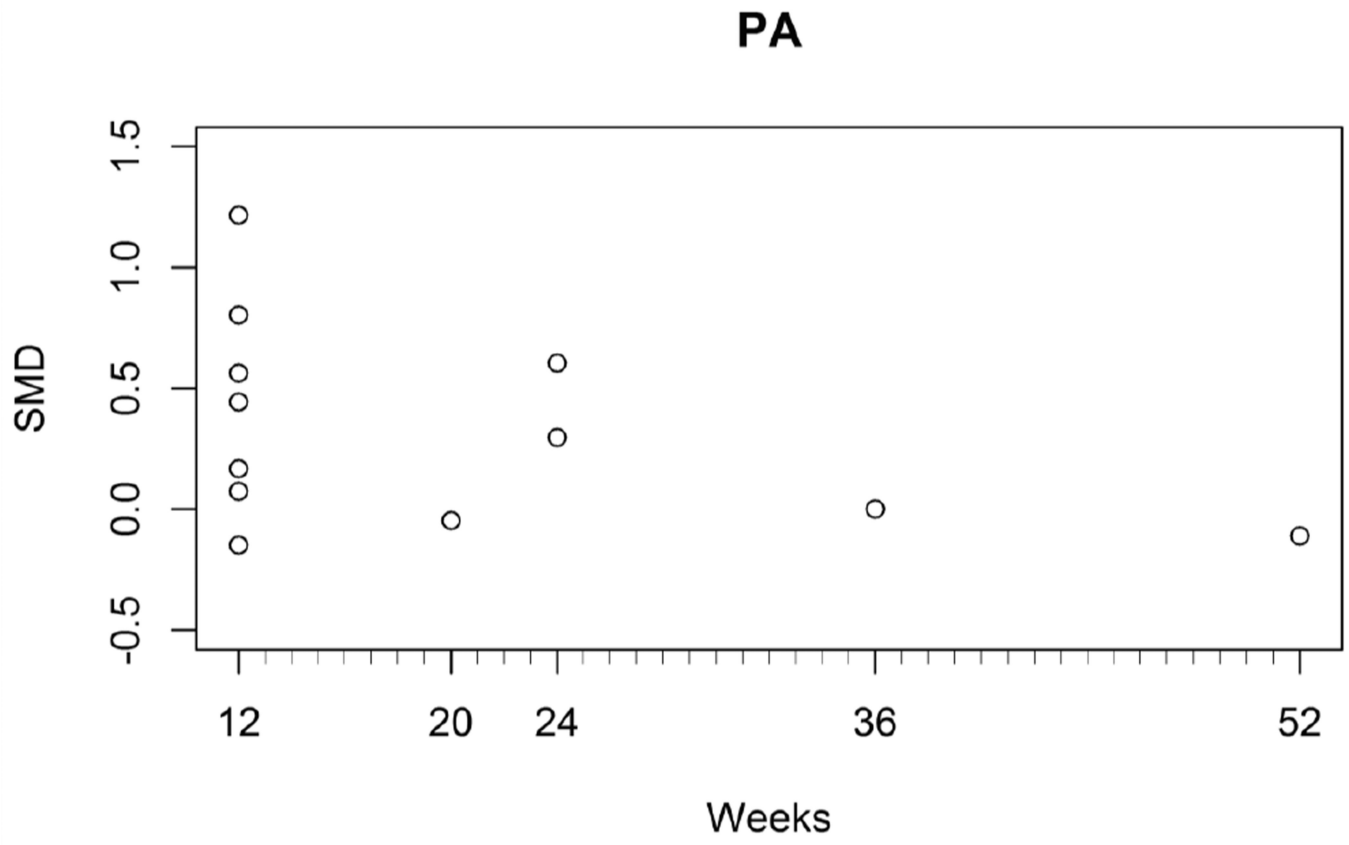

Figure 4.

Relationship between weeks of physical activity intervention duration and standardized mean difference

Abbreviations: PA=physical activity; SMD=standardized mean difference

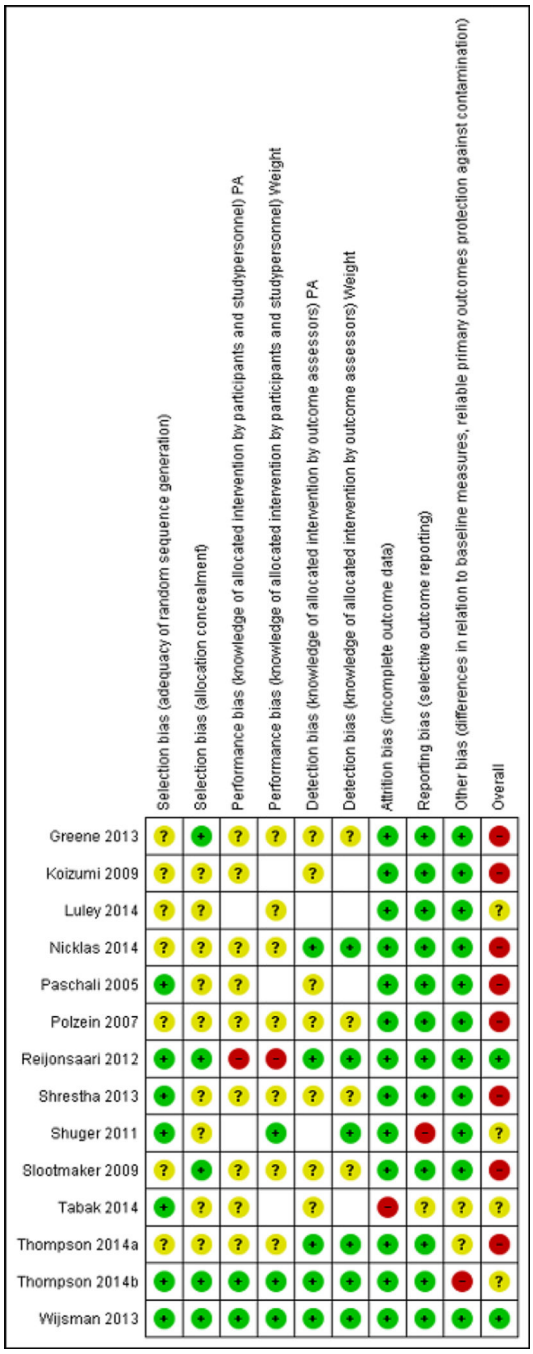

Figure 5.

Risk of bias summary: review authors' judgments about risk of bias item for each included study

Green=low risk of bias; Yellow=unclear risk of bias; Red=high risk of bias; White=not reported Abbreviation: PA=physical activity

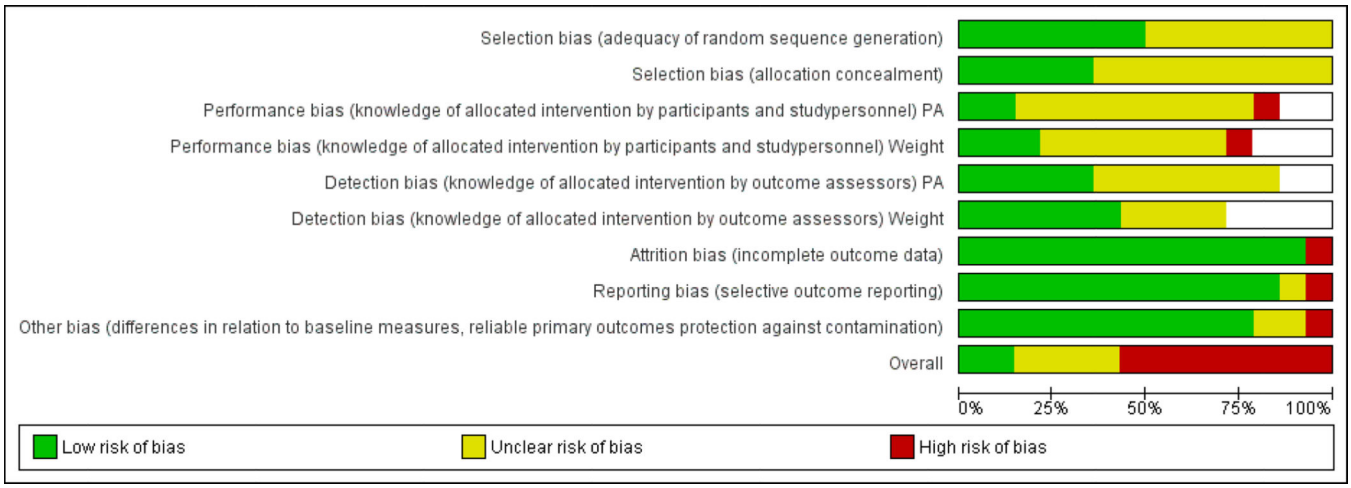

Figure 6.

Risk of bias as a percentage of all included studies

White=not reported

Abbreviation: PA=physical activity

Table 1

Description of included studies

Study	Population (N)	Device Name	Intervention (weeks duration)	Comparator	Outcome
Greene, 2013 [35]	Healthy volunteers (513)	Not Reported	Access to online social network + continuous accelerometer use and feedback Duration: 24 weeks	Inactive: Printed lifestyle guidelines on diet and exercise	PA Weight
Koizumi, 2009 [38]	Older adults (68)	Kenz Lifecorder	Accelerometer with feedback + goal-setting Duration: 12 weeks	Inactive: 12 weeks of blinded accelerometer use	PA
Luley, 2014 [27]	Chronic medical illness (184)	Aipermoti on 440	3-arm study (2 interventional) Intervention arm 1: 1-time instruction on iet and physical activity + accelerometer use + 52 weekly individual letters with feedback. Intervention arm 2: Instruction on diet and physical activity + accelerometer use + 12 monthly counseling calls Duration: 52 weeks	Inactive: 1-time, 1-hour session consisting of diet education, diet regimen, and physical activity education	Weight
Nicklas, 2014 [31]	Older adults (48)	Lifecorder PlusVR tri-axial	Weight loss intervention that included hypocaloric diet (2 prepared meals a day) + 4 days/week supervised exercise + self-regulatory wearing an accelerometer, documenting activity, and 6 weekly session of behavioral counseling Duration: 20 weeks	Active: 5-month weight loss intervention consisting of diet education and physical activity education, structured exercise and in-person counseling	PA Weight
Paschali, 2005 [40]	Chronic medical illness (30)	BioTrainer	Continuous accelerometer use and feedback + 4 monthly in-person	Active: Accelerometer use with 4 monthly in-	PA

Study	Population (N)	Device Name	Intervention (weeks duration)	Comparator	Outcome
			exercise behavioral counseling sessions + workbook Duration: 12 weeks	person counseling, walking plan, education, behavioral self-management, goal-setting, and monitoring	
Polzien, 2007 [29]	Overweight/ obese and/or sedentary (57)	SenseWear Pro Armband	Intervention arm 1: *Continuous* technology-based behavioral weight control program: individualized counseling sessions + continuous accelerometer use and feedback. Intervention arm 2: *Intermittent* technology-based behavioral weight control program: individualized counseling sessions + 3 weeks of accelerometer use and feedback Duration: 12 weeks	Active: 7 in-person individualized counseling sessions consisting of diet education, diet regimen (1200 to 1500 kcal/day; dietary fat <20% of total energy intake), physical activity education, and weight goal-setting	PA Weight
Reijonsaari, 2012 [37]	Healthy volunteers (544)	Uni-axial	12 months of continuous accelerometer use and feedback + access to telephone counseling (frequency not defined) Duration: 52 weeks	Inactive: Physical exams explanation and information on physical activity and occupational healthcare	PA Weight
Shrestha, 2013 [36]	Overweight/ obese and/or sedentary (28)	Polar FA20	1-time 1.5-hour lifestyle instruction + 6 months of continuous accelerometer use and feedback Duration: 24 weeks	Inactive: Self-directed exercise and/or U.S. Army physical training	PA Weight
Shuger, 2011 [28]	Overweight/ obese and/or sedentary (197)	BodyMedia SenseWear Armband	Intervention arm 1: 14 group weight loss sessions + 6 phone calls + workbook. Intervention arm 2: Accelerometer alone:	Inactive: Self-directed weight loss manual with diet education, physical activity	Weight

Study	Population (N)	Device Name	Intervention (weeks duration)	Comparator	Outcome
			Continuous accelerometer use and feedback Intervention arm 3: Continuous accelerometer use and feedback + 14 group weight loss sessions + 6 individual phone calls + workbook Duration: 36 weeks	education, and weight goal-setting	
Slootmaker, 2009 [39]	Overweight/ obese and/or sedentary (102)	PAM (model AM101)	3 months of continuous accelerometer use + tailored physical activity feedback and motivational tips via web-based portal Duration: 12 weeks	Inactive: A single written brochure with brief physical activity recommendations	PA Weight
Tabak, 2014 [30]	Chronic medical illness (29)	Activity Coach	Web-based exercise program, accelerometer-based activity senor and motivational messaging, COPD self-management module, and as needed web-portal teleconsultation Duration: 36 weeks	Inactive: Usual care	PA
Thompson, 2014 [32]	Overweight/ obese and/or sedentary (20)	GRUVE triaxial	12 weeks of continuous accelerometer use and feedback + weekly brief counseling sessions on increasing activity + treadmill desk Duration: 12 weeks	Inactive: 12 weeks of blinded accelerometer use	PA Weight
Thompson, 2014 [34]	Older adults (49)	FitBit	24 weeks of continuous accelerometer use and feedback + weekly brief telephone counseling sessions focused on accelerometer feedback + in-person counseling. Duration: 12 weeks	Inactive: 24 weeks of blinded accelerometer use	PA Weight

Study	Population (N)	Device Name	Intervention (weeks duration)	Comparator	Outcome
Wijsman, 2013 [33]	Older adults (235)	DirectLife	12 weeks of continuous accelerometer use and feedback + personal website + personal e-coach who gives updates on activity status and advice via web portal Duration: 12 weeks	Inactive: 3-month waitlist control	PA Weight

Abbreviations: COPD=chronic obstructive pulmonary disease; PA=physical activity

Table 2

Subgroup analyses by population, location of accelerometer, and intervention role

Outcome	Population			
	Overweight/Obese/ Sedentary	**Older Adults**	**Healthy Volunteers**	**Chronic Medical Illnesses**
	4 studies	4 studies	2 studies	2 studies
Physical activity	SMD 0.35 (95% CI −0.52 to 1.22)	SMD 0.34 (95% CI −0.11 to 0.80)	SMD range −0.11 to 0.30	SMD range 0.00 to 0.80
	5 studies	3 studies	2 studies	1 study
Weight	MD −1.22 kg (95% CI −2.48 to 0.02)	MD −1.08 kg (95% CI, −5.22 to 3.06)	MD range −1.63 to −0.50 kg	MD −8.00 kg (95% CI −10.41 to −5.59)
	Location of Accelerometer			
	Waist	**Arm**	**Wrist**	**Multisite**
	7 studies	2 studies	1 study	1 study
Physical activity	SMD 0.24 (95% CI −0.15 to 0.63)	SMD range −0.15 to 0.60	SMD 0.56 (95% CI 0.30 to 0.82)	SMD 0.00 (95% CI −0.80 to 0.80)
	6 studies	3 studies	1 study	No studies
Weight	MD −2.01 (95% CI −4.99 to 0.97)	MD −2.08 (95% CI −4.13 to −0.02)	MD −0.67 (95% CI −1.33 to −0.01)	
	Role of Accelerometer			
	Major Role		**Minor Role**	
Physical activity	SMD 0.26 (95% CI −0.02 to 0.54)		SMD 0.28 (95% CI −0.43 to 1.00)	
Weight	MD −1.47 kg (95% CI −3.47 to 0.53)		MD −1.99 kg (95% CI −4.10 to 0.12)	

Abbreviations: CI=confidence interval; MD=mean difference; SMD=standardized mean difference