Title: Where does the time go? Displacement of device-measured sedentary time in effective sedentary behaviour interventions: systematic review and meta-analysis.

Short title: Displacement of sedentary time in effective sedentary behaviour interventions

Corresponding Address: Víctor Segura-Jiménez, Instituto de Investigación Biosanitaria ibs.GRANADA,. Avda. de Madrid, 15, 18012 Granada. Email: victor.segura@uca.es

Authors: Víctor Segura-Jiménez[1,2,3,4], Stuart J.H. Biddle[5], Katrien De Cocker[5,6], Shahjahan Khan[5,7], Blanca Gavilán-Carrera[8]

Affiliations:

[1]Hospital Universitario Virgen de las Nieves of Granada, Granada, Spain

[2]Instituto de Investigación Biosanitaria ibs.GRANADA, Granada, Spain.

[3]GALENO research group, Department of Physical Education, Faculty of Education Sciences, University of Cádiz, Spain.

[4]Biomedical Research and Innovation Institute of Cádiz (INiBICA) Research Unit, Puerta del Mar University Hospital, Cádiz, Spain.

[5]Centre for Health Research, University of Southern Queensland, Queensland, Australia.

[6]Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium.

[7]School of Sciences, University of Southern Queensland, Queensland, Australia.

[8]Department of Physical Education and Sports, Faculty of Sports Science, University of Granada, Granada, Spain.

ORCID

VS-J: 0000-0001-8655-9857

SJHB: 0000-0002-7663-6895

KDC: 0000-0001-7510-4419

SK: 0000-0002-0446-086X

BG-C: 0000-0002-9223-7181

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Abstract

Background: Previous research has shown the effectiveness of sedentary behaviour interventions on reducing sedentary time. However, no previous systematic review has studied where the reduced sedentary time after such interventions is displaced to.

Objective: To synthesize the evidence from interventions that have reduced sedentary behaviour and test the displacement of sedentary time into physical activity (light physical activity [LPA], moderate-to-vigorous physical activity [MVPA], standing, and stepping).

Methods: Two independent researchers performed a systematic search in EBSCOhost, Pubmed, Scopus and Web of Science electronic databases. Meta-analyses were performed to examine the time reallocated from sedentary behaviour to physical activity during i) working time and ii) the whole day in intervention trials (randomized/non-randomized controlled/non controlled).

Results: A total of 36 studies met all the eligibility criteria and were included in the systematic review, with 26 studies included in the meta-analysis. Interventions showed a significant overall increase in worksite LPA (effect size [ES]=0.24, 95% CI: 0.05 to 0.43; $P<0.013$) and daily LPA (ES=0.62, 95% CI: 0.34 to 0.91; $P=0.001$). A statistically significant increase of daily MVPA was observed (ES=0.47, 95% CI: 0.26 to 0.67; $P<0.001$). There was a significant overall increase in worksite standing time (ES=0.76, 95% CI: 0.56 to 0.95; $P<0.001$), daily standing time (ES=0.52, 95% CI: 0.38 to 0.65; $P<0.001$), and in worksite stepping time (ES=0.12, 95% CI: 0.04 to 0.20; $P=0.002$).

Conclusions: Effective interventions aimed at reducing sedentary behaviour result in a consistent displacement of sedentary time to LPA and standing time both at worksites and across the whole day, while stepping time or MVPA are dependent on the intervention setting.

Strategies to reduce sedentary behaviour should not be limited to worksite settings and further efforts may be required to promote daily MVPA.

PROSPERO registration number CRD42020153958

1. INTRODUCTION

Reducing total sedentary time has recently been determined as a public health priority[1]. But given that time during an individual's waking hours is finite, reductions in sedentary time will be reflected in time spent in other more active behavious. Therefore, the effects of sedentary behaviour interventions on health depend not only on the activity that is targeted but also on the changes created in other activites[2]. A previous intervention study[3] and isotemporal substitution study[4] have shown that replacing sedentary time with standing, walking, and/or moderate-to-vigorous physical activity (MVPA), is related to cardiovascular disease biomarkers[3] and the risk of all-cause mortality[4]. Interestingly, a recent meta-analysis of device-measured studies pointed to the potential benefits of replacing sedentary time not only with MVPA, but also with light-intensity physical activity (LPA)[5]. Benefits are also observed with psychological outcomes[6].

Targeting reductions in sedentary behaviour may represent a strategy to improve health outcomes. Behaviour change interventions are a coordinated set of activities designed to change specified behaviour patterns[7]. Among the different contexts in which behavior change is possible, adults typically spend large amounts of time being sedentary in two domains —in the workplace and during non-occupational time[8]—. Therefore, these represent promising environments in which to undertake interventions to reduce sedentary time. An increased interest in sedentary behaviour has led to a number of systematic reviews and meta-analyses synthesising the effects of these interventions. However, reviews are largely heterogeneous, with some focusing on diverse health outcomes, others on behaviour change, and some reporting sedentary behaviour change from studies primarily aimed at increasing physical activity[8–11]. A previous meta-analysis has shown that interventions focusing on physical activity — alone or in combination with sedentary behaviour — have no effect for reducing sedentary behaviour[9]. In agreement, a recent review[10] showed that interventions mainly aimed at reducing sedentary behaviour rather than increasing physical activity are more promising in reducing sedentary behaviour.

Sedentary behaviours may be difficult to change because of their strong habitual component. Therefore, a reduction in a specific sedentary behaviour does not mean it will be replaced with only LPA or MVPA. It is also likely that some time will be allocated to other sedentary behaviours (e.g., screen time may be replaced by listening to music while sitting)[12]. Moreover, interventions to reduce occupational sedentary time might result in (i) compensatory effects by sitting for longer or being less active outside of work[13], or (ii) making people aware of the potential hazards of sedentary time, and not only reduce sedentary sitting time at work but possibly generalising to behaviours outside of work[8]. Since the distribution of time spent in sedentary behaviour, LPA and MVPA seems to be associated with a variety of health outcomes, it is important to consider tracking the reduction or increase in a specific behaviour and the distribution of time between the different behaviours.

Previous research has shown the effectiveness of sedentary behaviour interventions on reducing sedentary time[8]. However, no previous systematic review has studied where the reduced sedentary time after such interventions is displaced to. Therefore, the aim of the current systematic review and meta-analysis was to identify and synthesize the evidence concerning effective sedentary behaviour interventions. Specifically, we tested whether reduced sedentary time was displaced into non-sedentary or active behaviours (i.e., standing, stepping, LPA and MVPA) in healthy adults aged >=18.

2. METHODS

Inclusion/exclusion criteria and analytical methods were specified in advance and registered in the PROSPERO (http://www.crd.york.ac.uk/PROSPERO/) international database of systematic reviews (CRD42020153958). The study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[14]. A completed PRISMA checklist is available as **Table S1**.

2.1. Search strategy

The computerised search for literature was conducted in the EBSCOhost (including Academic Search Ultimate, CINAHL with full text, PsycARTICLES, Psychology and behavioural sciences collection, PsycINFO, and SPORTDiscuss with full text), Pubmed, Scopus and Web of Science electronic databases. Assistance from a research librarian was received to develop the search strategy, which included key words in five categories: sedentary behaviour, physical activity, measurement method, type of design, and population. The full search strategy is available as **Table S2**. After combining the results obtained in all databases, 6,948 records were retrieved. In addition, we used a snowball strategy so that the reference lists of the articles finally included (n=36) were checked for potential new articles eligible for this review (29 records selected by means of this method).

2.2. Inclusion criteria

The inclusion criteria were: (1) original research articles, excluding conference proceedings, letters to editor, and non-empirical research papers, published in peer-reviewed journals; (2) articles only published in English or Spanish; (3) healthy adult and elderly population (studies including individuals with any physical or psychological disorders were excluded); (4) use of devices to measure sedentary behaviour and physical activity; (5) intervention studies (randomized/non-randomized controlled/uncontrolled); (6) intervention focused on sedentary behaviour reduction only; (7) intervention being effective in reducing sedentary time; (8) inclusion of one or more of LPA, MVPA, standing, or stepping variables. Since these types of intervention are relatively novel, no publication date criterion was set. Lastly, intervention studies focussing on both sedentary behaviour reduction and physical activity promotion were excluded because they preclude drawing conclusions on the isolated effect of sedentary behaviour change.

2.3.Selection process

Based on the inclusion criteria, we carried out a two-step selection procedure with the articles initially identified: (1) two researchers (BGC and VSJ) independently identified suitable articles by screening the titles/abstracts; (2) full-text articles from first-stage selection were examined by the same two reviewers independently, with any discrepancies resolved with a consensus discussion (89% agreement prior to discussion). Disagreements in the previous phase were discussed and resolved (100% agreement) with a third reviewer (SJHB) to reach a final inclusion/exclusion of articles. Finally, a total of 36 original articles met the inclusion criteria and were included in the qualitative review, of which 26 were included in the meta-analysis. **Fig. 1** shows the flow diagram of the search and selection process.

2.4.Risk of bias

Risk of bias was assessed using the Quality Assessment Tool for Quantitative Studies of the Effective Public Health Practice Project[15] (Available from: http://www.ephpp.ca/tools.html). Studies were assessed for potential biases in six domains: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and drop-outs. Each potential source of bias was scored as strong, moderate, or weak quality (which represents low, medium, or high risk of bias, respectively), according to pre-specified dictionary (available from: http://www.ephpp.ca/tools.html). Risk of bias assessment was conducted independently by two reviewers (BGC and KDC) in order to assess the quality of studies. Discrepancies were identified and resolved through discussion (82% agreement prior to discussion), and the inclusion of a third reviewer (VSJ).

2.5.Data extraction

Two reviewers (BGC and VSJ) extracted data on publication details, study design, sample characteristics, measurement of sedentary behaviour, measurement of physical activity, and reported amount of sedentary behaviour and physical activity. A standardised pre-piloted data extraction form was used and discrepancies were resolved throughout discussion and consensus. When there was a lack of consensus, a third reviewer (SJHB) was consulted. When the variables were not reported as median (interquartile range) or data were missing, corresponding authors were contacted by email for additional information. A second reminder was sent when no response to the initial email was obtained. One out of 9 authors contacted provided the requested data. Two authors could not comply with the request due to no current access to the data. The remaining six authors did not reply to emails.

2.6.Data synthesis and analysis

Narrative and descriptive data syntheses are presented in text and tabular summaries (**Table 1** and **Table 2**). From each intervention, the behaviour change techniques used (this is an observable, replicable, and irreducible component of an intervention designed to alter behaviour[16]) were extracted. Since classification of behaviour change techniques used in interventions is highly extensive and heterogeneous [7], the taxonomy proposed by Michie et al.[17] to classify them into clustered techniques was used. Also, the intervention functions (this is, broad categories of means by which an intervention can change behaviour, taken from the Behaviour Change Wheel[7]) were also identified. Studies reporting data (pretest, posttest, and/or pretest-posttest difference) on main outcomes as mean (with standard deviation or 95% confidence interval) were used for quantitative synthesis. Since time spent in behaviours reported by different studies might differ depending on the total time that participants wore the device, to facilitate comparison across studies, raw data were homogenised in a common scale (percentage of wear time spent in specific behaviours) when necessary by dividing the time spent in each specific behaviour by total wear time (e.g., [sedentary behaviour / total wear time] × 100 = percentage of time spent in sedentary behaviours). When a study did not present exact P-values, in order to be conservative, the next proximal value was included instead (i.e. when reported $P<0.05$, value of $P=0.049$ was used, when reported $P<0.01$, value of $P=0.009$ was used, when reported $P<0.001$, value of $P=0.0009$ was used, and when reported $P>0.05$, value of $P=0.5$ was used). Meta-analyses on effect sizes (standardized difference in means) for main outcome variables were performed in 1) pre vs. post intervention values for each intervention group, and in those studies without a control group, and 2) intervention vs. control group in others. Pooled effect size of the effect of intervention on main outcomes was obtained using random-effects model, due to significant heterogeneity detected among the primary studies.

Confidence intervals (95%) were calculated for every population effect size. The heterogeneity between the included studies was measured with the Q statistic and I^2 index[18]. A significant Q-test and a high I^2 value (above 75%) are considered indicators of substantial heterogeneity[18]. Sub-group (categorical) and meta-regression analyses were conducted to investigate the contribution of specific variables to heterogeneity. Sub-group analyses were employed for a particular variable when more than four articles were available for each sub-group variable[19]. However, to report possible trends, sub-group analyses were also employed for particular variables when more than two articles were available for each sub-group. Consequently, two categorical variables were included in the sub-group analyses when possible: risk of bias (low-medium vs high risk) and intervention setting (worksite vs non-worksite). Meta-regression was used when ten or more studies were available for a particular behaviour[20]. However, to report possible trends, meta-regression was used when six or more studies were available for a particular behaviour. Three continuous variables were included in meta-regression when possible: study's publication date, mean sample age, and percentage of females in the sample. All analyses were conducted under the random-effects model, due to the presence of heterogeneity among the primary studies. For assessing the risk of potential publication bias, visual inspection of funnel plots was used and the P value of Egger's intercept was calculated. When suspected publication bias, the Duval and Tweedie "trim and fill" procedure as a method of adjustment was followed. In this procedure, pooled effect size (ES) was recalculated incorporating hypothetical missing studies as if they existed.

The contribution of each independent study in the pooled estimates values was detected using sensitivity analysis. P values of <0.05 were used for statistical significance. In cross-over trials with various intervention groups, the mean intervention effect on different behaviour variables were combined per condition and presented as a unique measure (this was the case for one study[21]). Statistical analysis was performed using Comprehensive Meta-analysis software, version 2 (CMA; Biostat Inc., Englewood, USA).

3. RESULTS

3.1. Study selection

A total of 6948 records were identified through searches and 29 additional records through a snowballing strategy[22]. Duplicate references were identified and removed (N=3066). After examining titles and abstracts, 154 full-text records were further screened and 36 studies met inclusion criteria and were included in the systematic review (17 studies presented information on sedentary time and time spent in physical activity intensity levels[21,23–38] and 22 studies presented information on sedentary time, stepping and standing time[13,29,33,38–56], thus results were clustered in two blocks). Of the articles included in the systematic review, 26 provided pre and post or mean difference intervention values for sedentary time and physical activity intensities and/or sedentary time and standing and stepping time, thus, were included in the meta-analysis (10 studies presented information on sedentary time and time spent in physical activity intensity levels[21,23,25,28,29,31–33,35,36] and 18 studies presented information on sedentary time, stepping and standing time[13,29,33,38–41,43–46,49,50,52–56]). The PRISMA flow diagram showing the study selection process of the systematic review and meta-analysis can be found in **Fig. 1**.

3.2. Study characteristics (qualitative synthesis)

The characteristics of the 36 studies included in the systematic review sorted by device measurement are available in **Table 1** and **Table 2**. A total of 12 studies were carried out in Australia[31,35,36,39–41,43–45,52,54,56], 13 in USA[21,23,24,26–30,32,33,37,48,53], 5 in UK[13,38,47,49,51], 2 in Denmark[34,50], and one each in Belgium[46], Canada[55], Finland[25], and Portugal[42]. The selected studies comprised 2383 participants. Sample sizes ranged from 9 to 175 participants; from 33.0% to 94.4% female, except in one study in which only women participated[27] and one study in which only women participated in the multicomponent intervention group[45]. The majority of the analysed studies (80%, N=29) were performed in adults[13,21,23–25,27,29,30,32,34–36,38–46,48–51,53–56], 6% of the studies (N=2) included only older adults >60 years[31,33,52] or >65 years[37] and 14% (N=5) included both adults and older adults 18-70 year[26], >50 and <80years[28], and >50 and <70 years[47].

The duration of the interventions ranged from 1 week to 1 year (interventions lasting 5 days[48], 1 month[50] and 3 months[13,45,56] were expressed as 1, 4 and 12 weeks, respectively): 14% of the studies (N=5) lasted 1 week[30,31,42,48,52,53], 11% (N=4) lasted 2 weeks[29,46,47,51], 3% (N=1) 3 weeks[24], 26% (N=9) 4 weeks[21,34,36,37,39,40,50,54,56], 3% (N=1) 5 weeks[44], 6% (N=2) 8 weeks[27,33], 23% (N=9) 12 weeks[13,23,26,28,35,45,49,55,56] and 14% (N=5) 1 year[25,32,38,41,43]. Approximately 58% of the interventions (N=21) were performed in the worksite [13,23,25,27,29,32,35,38–45,48–50,54–56], while 39% of the interventions (N=14) were performed in non-worksite settings [21,24,26,28,30,31,33,34,36,37,46,47,51,52]. Only 3% of interventions (N=1) were performed in both the work and non-worksite setting[53]. Approximately 11% (N=4) of interventions focused on one intervention function to change sedentary behaviours[29,32,34,55], 28% (N=10) on two functions[28–30,33,36,39,40,46,48], 25% (N=9) three functions[21,26,27,31,43,44,47,51,52], 25% (N=9) four functions[23,25,37,38,41,42,49,50,53], and 11% (N=4) five functions. The most frequent intervention functions employed persuasion (N=28, 80%), education (N=26, 74%), training (N=20, 57%) and enablement (N=19, 54%). Approximately 14% (N=5) of interventions focused on one behaviour change techniques cluster to change sedentary behaviours[29,32,34,36,55], 17% (N=6) on two clusters[24,39,40,44,51,56], 25% (N=9) on three clusters[13,29–31,33,37,46,47,52], 22% (N=8) on four clusters[21,23,25,27,35,43,49,53], and 17% (N=6) on five clusters[26,38,41,42,48,50]. The most frequent behaviour change techniques clusters were “shaping knowledge” (N=22, 61%), “goals and planning” (N=21, 58%), “feedback and monitoring” (N=20, 56%) and “antecedents” (N=14, 39%).

A total of 13 different models of accelerometers were used. Twelve studies used Actigraph (models 7164, GT1M, GT3X, GT3X+, and GT9X)[24,27–31,33–35,37,38,50], 22 used ActivPAL (models ActivPAL and ActivPAL3)[13,29,33,37–49,51–56], and 6 studies used other devices (Actical, GENEactiv, Hookie AM13, MUVE, Sensewear, Stepwatch). Uniaxial accelerometer models (the Actigraph 7164[24], Actigraph GT1M[31], the ActivPAL[29,33,39,42,49,51,53,55], and the Actical[32]) were used in 11 studies. Triaxial accelerometer models (the Actigraph GT3X[27–30,35], GT3X+[33,34,37,50], and GT9X[38], the ActivPAL3[13,37,38,40,41,43–48,52,54,56], the GENEactiv[26], the Hookie AM13[26], the MUVE[26], and the Sensewear[21]) were used in 28 studies. Only one study used a biaxial accelerometer (StepWatch)[23]. Devices were predominantly worn on the thigh (N=23)[13,29,33,34,37–56] and on the hip/waist/belt (N=12)[24,25,27–30,32–37]. In the rest of studies (N=4) the device was worn on other parts of the body, such as ankle[23], triceps[21], and wrist[26,38]. One study did not specify the location of the accelerometer to be worn[31]. Regarding accelerometer wear time, in 75% (N=27) of the studies participants wore the device for 7 days[13,23,25–28,30,33–45,49,51–56], in 14% (N=5) between 14 and 28 days[21,24,31,46,47], in 8% (N=3) less than 7 days[29,48,50], and in 3% (N=1) for 1 year[32].

A total of 19 studies showed the results of the intervention on different behaviours in the workplace[13,25,27,29,35,38–41,43–45,47–50,54–56], four studies included more than one intervention group in the same study[21,43,45,48]. A total of 24 studies showed the results of the intervention on different behaviours across the whole day[21,23,24,26,28,30–38,41–43,45–47,51–53,55,56], three studies included more than one intervention group in the same study[21,43,45]. The results of the interventions are described in the following paragraphs.

Study characteristics (qualitative synthesis) from interventions separated by blocks is presented in **Material S1**.

3.2.1. *Block 1: interventions including sedentary time and time spent in different physical activity intensity levels.*

Worksite physical activity. Regarding the results of the interventions, from all the studies included assessing sedentary behaviour, and physical activity levels, 31% (N=5) presented information on these behaviours in the worksite[25,27,29,35,38]. Greater levels of LPA after the intervention were found in 3 studies[25,29,35], whereas one study did not find pre-post differences in LPA[27]. The 3 studies assessing MVPA showed no differences in pre-post values of MVPA[25,35,38], and one study showed no differences in pre-post values of moderate PA[27]. Greater levels of moderate physical activity after the intervention were found in 1 study[29], but no pre-post differences in vigorous physical activity were found[29]. One study showed increases in total physical activity after the intervention[25].

All day physical activity. From all the studies included assessing sedentary behaviour, and physical activity levels, 81% (N=13) presented changes on sedentary behaviour and physical activity during the whole day[21,23,24,26,28,31–38]. Greater levels of LPA after the intervention were found in 6 studies (8 intervention groups)[21,26,31,33,36,37]. By contrast, 3 studies showed no pre-post differences in LPA[23,28,35]. After the intervention, MVPA increased in 8 studies (10 intervention groups)[21,26,28,31,33,35–37]. By contrast, 3 studies showed no pre-post differences in MVPA[23,34,38]. One study did not assess physical activity intensity levels, but total physical activity instead (measured in activity units), showing an increase in this outcome after the intervention[32]. Bouts greater than 10 minutes in MVPA increased in the only study that showed this information[24].

3.2.2. *Block 2: interventions including sedentary, standing, and stepping time.*

Worksite physical activity. From all the studies included assessing sedentary behaviour, standing, and stepping time, 68% (N=15) of the studies presented information on these behaviours in the worksite[13,29,38–41,43–45,48–50,54–56]. Standing time at work increased in 13 studies (15 intervention groups) after the interventions[13,38–41,43–45,48–50,54–56]. Only 3 studies showed differences in pre-post values of stepping time[13,43,50], whereas 12 studies (13 intervention groups) did not find pre-post differences[38–41,43–45,48,49,54–56]. There were 2 studies that presented information on number of steps instead of stepping time[50,55]. There was 1 study that did not exclude night-time sleeping data from sedentary behaviour[51]. Additionally, 2 studies showed that prolonged sedentary behaviour in bouts ≥30 min in the worksite also decreased after their intervention[38,41]; however 1 study showed no reduction[45].

All day physical activity. From all the studies including sedentary behaviour, standing, and stepping time, 59% (N=13) presented information on these behaviours during the whole day[33,38,41–43,45–47,51–53,55,56]. Greater standing time after the intervention was found in 10 studies (12 intervention groups)[33,38,41–43,45,46,52,55,56]. By contrast, 3 studies showed no pre-post differences in standing time[47,51,53]. After the intervention, stepping time increased in 4 studies[41,42,51,53] while 9 studies (11 intervention groups) showed no pre-post differences[33,38,43,45–47,52,55,56].

3.3. Risk of bias

Methodological quality assessment is shown in **Table S3**. Selection bias was scored as weak/moderate in 97% of the studies. Quality of the study design was high in 45% and moderate in 55% of the studies. Control of confounders was weak in 40% and strong in 60% of the studies. Blinding process was weak in 91% of the studies. Data collection methods were overall strong (85% of the studies). Approximately 43% of the studies showed a low-moderate withdrawals and dropouts method. Overall, the quality of the included studies was low. The majority of studies were classified as presenting high risk of bias (N=25, 71.5%) according to the composite risk of bias score.

3.4. Effects of interventions (Quantitative synthesis using meta-analysis)

Studies were pooled according to outcome measure: time spent in physical activity intensity levels (LPA and MVPA), standing and stepping. Sub-group (categorical) and meta-regression analyses are presented in **Material S2**. Sub-group analyses according to intervention functions and study designs were not possible due to high heterogeneity.

3.4.1. Block 1: interventions including sedentary time and time spent in different physical activity intensity levels.

Worksite sedentary time. Four studies were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on sedentary time at worksites[25,27,29,35]. There were insufficient studies reporting on point estimates of sedentary time to allow for the conduct of heterogeneity analyses. A significant pooled ES (ES=-0.31, 95% CI=-0.42 to -0.19; $P<0.001$) was observed (**Fig. 2a**). A significant publication bias was estimated by both the Egger's test ($P=0.033$) and by visual asymmetry of the funnel plot (**Fig. S1a**). The effect of interventions on sedentary time was not diminished when the ‘trim and fill’ procedure of publication bias was applied (ES=-0.28; 95% CI=-0.37 to -0.18).

Total sedentary time. Seven studies (9 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on sedentary time during the whole day[21,23,28,31,33,35,36]. Heterogeneity was significant and high (Q=24.58, df=6, $P<0.001$; $I^2=75.59$). A significant pooled effect size (ES=-0.67, 95% CI=-0.92 to -0.42; $P<0.001$) was observed (**Fig. 2b**). No significant publication bias estimated by either the Egger's test ($P=0.168$) or by visual asymmetry of the funnel plot (**Fig. S1b**) was observed.

Worksite LPA. Four studies were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on LPA at work[25,27,29,35]. Heterogeneity was significant and moderate (Q=7.13, df= 3, *P*=0.068; I^2=57.93). A significant pooled ES (ES=0.24, 95% CI=0.05 to 0.43; *P*<0.013) was observed (**Fig. 3a**). No significant publication bias estimated by either the Egger's test (*P*=0.406) or by visual asymmetry of the funnel plot (**Fig. S2a**) was observed.

Total LPA. Six studies (8 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on LPA during the whole day[21,23,31,33,35,36]. Heterogeneity was significant and high (Q=19.93, df=5, *P*<0.001; I^2=74.91). A significant pooled ES (ES=0.62, 95% CI=0.34 to 0.91; *P*=0.001) was observed (**Fig. 3b**). No significant publication bias estimated by either the Egger's test (*P*=0.338) or by visual asymmetry of the funnel plot (**Fig. S2b**) was observed.

Worksite MVPA. Four studies were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on MVPA at work[25,29,35,38]. Heterogeneity was moderate but not significant (Q=7.18, df=3, *P*=0.066; I^2=58.19). No significant pooled ES (ES=0.16, 95% CI=-0.01 to 0.32; *P*=0.059) was observed (**Fig. 4a**). No significant publication bias estimated by either the Egger's test (P=0.681) or by visual asymmetry of the funnel plot (**Fig. S3a**) was observed.

Total MVPA. Eight studies (10 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on MVPA during the whole day[21,23,28,31,33,35,36,38]. Heterogeneity was significant and high (Q=26.58, df=7, *P*<0.001; I^2=73.67). A significant pooled ES (ES=0.47, 95% CI=0.26 to 0.67; *P*<0.001) was observed (**Fig. 4b**). No significant publication bias estimated by either the Egger's test (*P*=0.361) or by visual asymmetry of the funnel plot (**Fig. S3b**) was observed.

3.4.1.1. *Intervention effects of controlled trials*.

Worksite physical activity. From all the studies included assessing sedentary behaviour and physical activity levels, only one study (N=1; 6%) presented information on these behaviours in the worksite[38]. No differences between intervention and control group were observed on MVPA[38]. The low number of studies did not allow us to perform meta-analysis.

All day physical activity. From all the studies included assessing sedentary behaviour and physical activity levels, 25% (N=4) presented information on these behaviours during the whole day[23,26,28,38]. No between group differences in LPA after the intervention were found in 3 studies showing LPA information[23,26,28]. After the intervention, 1 study showed between group differences in MVPA[28]. By contrast, 3 studies showed no between group differences in MVPA[23,26,38]. The low number of studies did not allow us to perform meta-analysis.

3.4.2. Block 2: interventions including sedentary, standing, and stepping time.

Worksite sedentary time. Fourteen studies (16 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on sedentary time at work[13,29,38–41,43–45,49,50,54–56]. Heterogeneity was significant and high (Q=57.18, df=13, P<0.001; I^2=77.26). A significant pooled ES (ES=−0.77, 95% CI=–0.96 to -0.59; P<0.001) was observed (**Fig. 5a**). A significant publication bias estimated by either the Egger's test (P=0.009) or by visual asymmetry of the funnel plot (**Fig. S4a**) was observed. Nonetheless, the effect of interventions on sedentary time was not considerably diminished when the 'trim and fill' procedure of publication bias was applied (ES=-0.58; 95% CI=-0.77 to -0.39).

Total sedentary time. Eleven studies (13 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on sedentary time during the whole day[13,33,38,41,43,45,46,52,53,55,56]. Heterogeneity was significant and moderate

(Q=23.86, df=10, *P*=0.008; I^2=58.08). A significant pooled ES (ES=-0.56, 95% CI=-0.71 to -0.40; *P*<0.001) was observed (**Fig. 5b**). A significant publication bias estimated by either the Egger's test (*P*=0.02) or by visual asymmetry of the funnel plot (**Fig. S4b**) was observed. Nonetheless, the effect of interventions on sedentary time was not considerably diminished when the 'trim and fill' procedure of publication bias was applied (ES=-0.46; 95% CI=-0.63 to -0.29).

Worksite standing time. Fourteen studies (16 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on standing time at work[13,29,38–41,43–45,49,50,54–56]. Heterogeneity was significant and moderate (Q=63.35, df=13, *P*<0.001; I^2=79.48). A significant pooled ES (ES=0.76, 95% CI=0.57 to 0.95; *P*<0.001) was observed (**Fig. 6a**). A significant publication bias estimated by either the Egger's test (*P*=0.036) or by visual asymmetry of the funnel plot (**Fig. S5a**) was observed. Nonetheless, the effect of interventions on standing time was not affected when the 'trim and fill' procedure of publication bias was applied (ES=0.56, 95% CI=0.36 to 0.76).

Total standing time. Eleven studies (13 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on standing time during the whole day[13,33,38,41,43,45,46,52,53,55,56]. Heterogeneity was significant and moderate (Q=21.69, df=10, *P*=0.017; I^2=53.91). A significant pooled ES (ES=0.54, 95% CI=0.39 to 0.69; *P*<0.001) was observed (**Fig. 6b**). Non-significant publication bias estimated by either the Egger's test (*P*=0.165) or by visual asymmetry of the funnel plot (**Fig. S5b**) was observed.

Worksite stepping time. Twelve studies (14 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on stepping time at worksite[13,29,38–41,43–45,49,54,56]. Heterogeneity was not significant and low (Q=15.81, df=13, *P*=0.259; I^2=17.79). A significant pooled ES (ES=0.12, 95% CI=0.04 to 0.20; *P*=0.002) was observed (**Fig. 7a**). No significant publication bias estimated by either the Egger's test (P=0.580) or by visual asymmetry of the funnel plot (**Fig. S6a**) was observed.

Total stepping time. Ten studies (12 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (post vs. pre) on stepping time during the whole day[13,33,38,41,43,45,46,52,53,56]. Heterogeneity was significant and moderate (Q=27.40, df=11, P=0.001; I^2=67.15). No significant pooled ES (ES=0.08, 95% CI=-0.09 to 0.24; P=0.355) was observed (**Fig. 7b**). Non-significant publication bias estimated by either the Egger's test (P=0.373) or by visual asymmetry of the funnel plot (**Fig. S6b**) was observed.

3.4.2.1.Intervention effects of controlled trials.

Worksite sedentary time. Eleven studies (13 intervention groups)[38–41,44,45,48,50,54–56] were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on sedentary time at work. Heterogeneity was significant and high (Q=41.16, df=10, P<0.001; I^2=75.70). A significant pooled ES (ES=−1.10, 95% CI=–1.40 to -0.80; P<0.001) was observed (**Fig. 8a**). A significant publication bias estimated by either the Egger's test (P=0.002) or by visual asymmetry of the funnel plot (**Fig. S7a**) was observed. Nonetheless, the effect of interventions on sedentary time was not considerably diminished when the 'trim and fill' procedure of publication bias was applied (ES=-1.02; 95% CI=-1.32 to -0.72).

Total sedentary time. Six studies were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on sedentary during the whole day[38,41,42,46,55,56]. Heterogeneity was significant and moderate (Q=12.80, df=5, P=0.025; I^2=60.93). A significant pooled ES (ES=−0.79, 95% CI=–1.14 to -0.44; P<0.001) was observed (**Fig. 8b**). No significant publication bias estimated by either the Egger's test (P=0.075) or by visual asymmetry of the funnel plot (**Fig. S7b**) was observed.

Worksite standing time. Eleven studies (13 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on standing time at work[38–41,44,45,48,50,54–56]. Heterogeneity was significant and high (Q=38.87, df=10, $P<0.001$; $I^2=74.27$). A significant pooled ES (ES=1.12, 95% CI=0.83 to 1.41; $P<0.001$) was observed (**Fig. 9a**). A significant publication bias estimated by either the Egger's test ($P<0.001$) or by visual asymmetry of the funnel plot (**Fig. S8a**) was observed. Nonetheless, the effect of interventions on sedentary time was not considerably diminished when the 'trim and fill' procedure of publication bias was applied (ES=1.05; 95% CI=0.75 to 1.35).

Total standing time. Six studies were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on standing time during the whole day[38,41,42,46,55,56]. Heterogeneity was non-significant and low (Q=5.79, df=5, $P=0.327$; $I^2=13.68$). A significant pooled ES (ES=0.64, 95% CI=0.46 to 0.82; $P<0.001$) was observed (**Fig. 9b**). No significant publication bias estimated by either the Egger's test ($P=0.162$) or by visual asymmetry of the funnel plot (**Fig. S8b**) was observed.

Worksite stepping time. Nine studies (11 intervention groups) were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on stepping time at work[38–41,44,45,48,54,56]. Heterogeneity was non-significant and low (Q=3.68, df=8, $P=0.885$; $I^2=0.000$). No significant pooled ES (ES=0.02, 95% CI=-0.13 to 0.17; $P=0.805$) was observed (**Fig. 10a**). No significant publication bias estimated by either the Egger's test ($P=0.834$) or by visual asymmetry of the funnel plot (**Fig. S9a**) was observed.

Total stepping time. Five studies were included in the meta-analysis of sedentary behaviour intervention effects (intervention vs. control) on stepping time during the whole day[38,41,42,46,56]. Heterogeneity was significant and high (Q=14.82, df=4, $P=0.005$; $I^2=73.01$). A significant pooled ES (ES=0.17, 95% CI=-0.24 to 0.58; $P=0.418$) was observed

(**Fig. 10b**). No significant publication bias estimated by either the Egger's test (P=0.118) or by visual asymmetry of the funnel plot (**Fig. S9b**) was observed.

A summary of effects of interventions (Quantitative synthesis using meta-analysis) is presented in **Table 3.**

4. DISCUSSION

This review aimed, for the first time, to synthesise evidence on how interventions designed to reduce sedentary behaviour affect the distribution of time spent in different physical activity categories assessed during working time (worksite) and the whole day (daily). Our findings suggest that interventions that successfully reduced sedentary behaviour showed an increase in worksite and daily LPA and standing time. However, stepping time and MVPA were sometimes affected but this depended on the context of assessment, being worksite stepping and daily MVPA increased after the interventions. These findings suggest that sedentary behaviour reductions might lead to concomitant increases in certain physical activity categories, and especially of light intensity. As these effects might depend on intervention settings, strategies aimed at reducing sedentary behaviour might be enhanced by being implemented beyond the worksite.

The findings of the current study suggest that sedentary time reductions occurred accompanied by consistent increases in LPA and standing time while stepping time and MVPA increased depending on the context. This suggests that: i) sedentary behaviour reductions might not necessarily increase all types of movement, and ii) sedentary behaviour and physical activity should be considered as distinct but interrelated behaviours. In line with these ideas, previous systematic reviews showed that physical activity interventions might not necessarily lead to sedentary behaviour reductions[10,57]. The unique characteristics in behavioural barriers and facilitators of sedentary behaviour and physical activity could lead to these distinct effects, depending on the focus of the intervention (reducing sedentary time/increasing physical activity). Indeed, recent health promotion approaches stress the relevance of strategies specifically designed for targeting sedentary behaviour or physical activity[57]. For example, targeting sedentary behaviour alone might be more effective than combining sedentary behaviour and physical activity for sedentary behaviour reductions[57]. But given that time taken away from sedentary behaviour must be replaced with another movement (or sleep) behaviour, reductions might occur along with interesting increases in certain physical activities. It is therefore relevant that interventions specifically target standing, stepping, LPA, and MVPA for maximizing time spent in active behaviours. Further research could help us to better understand how physical activity components can be incorporated effectively into a sedentary behaviour intervention.

According to the evidence gathered in the present review, sedentary behaviour reductions might lead to increases in LPA, standing and stepping assessed at worksite, and LPA, standing and MVPA assessed during the whole day but had no effect on worksite MVPA or daily stepping. It could be hypothesized that the restrictions imposed by working context (e.g. working at a desk) mainly lead to opportunities to stand but limit some other active behaviours (e.g. activities at moderate-to-vigorous intensity). On the other hand, standing or activities of light intensity could be easily increased in any context. Although the context where the behaviours were assessed did not always concur with the intervention setting, the quantitative and qualitative comparisons between worksite vs. non-worksite settings confirmed the superiority of non-working interventions to increase MVPA. More numerous and engaging opportunities for moving into MVPA activities could be found out of work during leisure time (for instance, walking, going to the gym, or playing some sports). The relevance of targeting out of work contexts is also supported by the idea that workers who are most sedentary at work could be also more sedentary outside of work[58]. Therefore, given the importance of MVPA for health benefits[1], it seems of interest that sedentary behaviour interventions are conducted, where possible, across the whole day.

There is an increasing concern about the negative impact of sedentary behaviour on several health outcomes[1]. Reducing sedentary behaviour is recommended and possible, as shown in several reviews that confirmed the effectiveness of sedentary behaviour interventions in different settings and age groups[8,57,59]. However, it is unclear in which other health-related behaviours the reduced sedentary time after such interventions is displaced to. For this purpose, this review focused entirely on interventions successfully reducing sedentary time. It is difficult to establish the best approach to reduce sedentary behaviour given the variety of strategies and frameworks used so far[59] and the heterogeneity on its report. The present review used the taxonomy proposed by Michie et al.[17] in an attempt to draw conclusions on the most frequently used behaviour change techniques. Qualitative data from the current study indicated that "goals and planning", "feedback and monitoring", "shaping knowledge", and "antecedents" were the most promising clusters of behaviour change techniques to reduce sedentary behaviour. Also, the most common functions used in sedentary behaviour interventions were, in general, "persuade" the population by inducing positive or negative emotions around the behaviour and "educate" them on the need for change. These results are consistent with a previous review that identified self-monitoring, problem solving, and restructuring the social or physical environment as particularly promising behaviour change techniques[10]. Also, education, environmental restructuring, and persuasion were identified as relevant functions for a potential reduction in sedentary behaviour among adults[10]. Our findings additionally indicate that the intervention setting can determine the relevance of these functions as training and environmental restructuring were also frequent functions for interventions in worksite whereas enablement was a relevant function in non-working sites. These findings support the hypothesis proposed in a recent systematic review[59], suggesting that contexts in which there is more control (i.e. workplace), less complex interventions targeting environmental determinants may be required for sedentary behaviour reductions. On the contrary, in less controlled contexts (i.e. non-working environments), more encompassing forms of enablement or acting through other mechanisms might be required. It was also observed that it was uncommon to focus an intervention in a unique function or behaviour change technique, with a combination of two to four functions/techniques the most frequent format. This could be particularly relevant in the case of sedentary behavior as it is a multi-faceted behavior influenced by several factors that should be better targeted through several functions[59]. Future studies might provide greater insights on the most effective combination of functions and behaviour change techniques to reduce sedentary behavior.

Some limitations of this review should be considered. First, the heterogeneity in interventions prevented us from performing a robust meta-analysis on behaviour change techniques, intervention functions, placement site and long-term effects, as well as drawing firm conclusions on the effect of risk of bias and intervention setting. In addition, the quality of the included studies was graded generally low and the majority of studies presented high risk of bias. Due to the low number of controlled trials, it is difficult to confirm whether behaviour changes were caused by the experimental treatment and not by other variables. In fact, the results obtained for LPA and MVPA could not be confirmed with quantitative data from controlled trials, although data for standing and stepping from controlled trials were generally in agreement with the conclusions of the present review. The present findings need to be interpreted with caution as there were very few studies in some analyses. Also, study duration ranged from 1 week to 1 year, which could have influenced the change observed in sedentary behaviour. The strengths of this study include the consideration of device-measured data to avoid issues related to self-reporting. However, this approach did not allow us to analyse different components of behaviour, such as differentiating domains of sedentary behaviour reduction. Furthermore, we identified a total of 13 different device models and several placement sites. This, together with the discrepancies between devices (sampling frequency, filter, epoch length, wear time validation, non-wear time definition, cut-off points, etc)[13] might have affected the results. This review also offered a comprehensive study of different active behaviours throughout waking time (LPA, MVPA, standing, stepping) and in different contexts. By including sleeping time, future interventions might complement the whole spectrum of co-dependent behaviours throughout the day related to health. Also, the present review provided updated and greater insights on the more frequent functions of behaviour change to successfully reduce sedentary behaviour. Future studies require to specify its framework, functions and behaviour change techniques to better understand causal mechanisms that produce effective sedentary behaviour reductions.

5. CONCLUSIONS

Effective interventions aimed at reducing sedentary behaviour entail a consistent displacement of sedentary time to LPA and standing time both at worksites and across the whole day. Changes in other behaviours might be setting-dependant with stepping time being increased at work and MVPA during the whole day. Strategies to reduce sedentary behaviour might benefit from being carried out beyond worksite settings, and further work is required to achieve greater displacement of sedentary time into light and moderate intensity physical activities.

Key points

- Effective sedentary behaviour interventions involve a displacement of sedentary time to light physical activity, standing and stepping time at work.
- Effective sedentary behaviour interventions entail a displacement of sedentary time to light physical activity, moderate-to-vigorous physical activity and standing time across the whole day.

- Sedentary behaviour interventions should be focused on reducing this behaviour during the whole day instead of working time solely.

Declarations

Conflict of interest

Víctor Segura-Jiménez, Stuart Biddle, Katrien De Cocker, Shahjahan Khan and Blanca Gavilán-Carrera declare that they have no conflicts of interest relevant to the content of this review.

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Patient and public involvement

Not applicable.

Ethical approval information

This study did not require research ethics approval because it did not involve human participants or animal subjects.

Code availability

Not applicable

Availability of data and material

Data were obtained from previously published scientific research and can be obtained from research studies referenced in the current meta-analysis.

Authors' contribution

VSJ participated in the conceptualization of the study and contributed to data collection, data analysis, draft preparation, interpretations of the results, writing, review and editing. BGC contributed to the conceptualization of the study, data collection, interpretations of the results, writing, review and editing. SJHB and KDC contributed to the conceptualization of the study, interpretations of the results, review and editing. SK contributed to data analysis, interpretations of the results and review. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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Table 1. Characteristics of the studies including information on time spent in sedentary behaviour and physical activity (PA) intensity levels.

Author, year, country	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, setting, intervention function, behaviour change technique)	**Device** (model, placement, wear time)	**Results** (worksite)	**Results** (all day)
Aittasalo et al., 2017 [25] *Finland*	**NRUT** IG: 175 adults (64.0 % female) with a mean age of 42.6±10.9	**Duration**: 1 year **Setting**: worksite **Intervention function:** education, persuasion, training, enablement **Behaviour change technique**: discussion meeting, goal setting, action planning, training, review outcome goals, extra support, workshops on reducing SB, internet- based platform self-monitoring, campaigns, feedback on implementation and results **Behaviour change technique taxonomy:** goals and planning, feedback and monitoring, social support, shaping knowledge.	**Model:** Hookie AM13 (triaxial) **Placement:** Right Hip **Wear time:** 7 days	SB (↓) LPA (↑) MVPA (NS) TPA (↑)	
Barwais and Cuddihy, 2015 [36] *Australia*	**RUT** IG: 18 adults (33.3 % female) with a mean age of 29.0±4.4	**Duration**: 4 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement **Behaviour change technique**: self-monitoring of physical activity. **Behaviour change technique taxonomy: f**eedback and monitoring.	**Model:** MUVE, Incs. Gruve-Technologies™ (triaxial) **Placement:** Waist **Wear time:** 7 days		SB (↓) LPA (↑) MPA (↑) VPA (↑)
Bond et al., 2014 [21] *U.S.A.*	**CONRUT** IG: 30 adults (83.3 % female) with a mean age of 47.5±13.5	**Duration**: 4 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement, education **Behaviour change technique**: self-monitoring, goal-setting, prompting, and feedback. IG1: 3-min PA break IG2: 6-min PA break IG3: 12-min PA break **Behaviour change technique taxonomy: f**eedback and monitoring. goals and planning, associations, repetition and substitution	**Model:** SenseWear Mini Armband (triaxial) **Placement:** Upper right triceps muscle **Wear time:** 28 days		SB (↓) LPA (↑) MVPA (↑)
Carr et al.,2013 [23] *USA*	**RCT** IG: 23 adults (86.9 % female) with a mean age of 42.6±8.9	**Duration**: 12 weeks **Setting**: worksite	**Model:** StepWatch (biaxial) **Placement:** Ankle		SB (↓) LPA (NS) MPA (NS)

	CG: 17 adults (94.1 % female) with a mean age of 47.6±9.9	**Intervention function:** environmental restructuring, education, persuasion, enablement **Behaviour change technique**: pedal machine at their worksite, motivational website to receive tips and reminders focused on reducing sedentary behaviours, self-monitoring pedometer. **Behaviour change technique taxonomy: a**ntecedents, feedback and monitoring, shaping knowledge, repetition and substitution	**Wear time:** 7 days		VPA (NS)
Edwardson et al., 2018 [38] *UK*	**CRCT** IG: 77 adults (56.0 % female) with a mean age of 41.7±11.0 CG: 69 adults (60.0 % female) with a mean age of 40.8±11.3	**Duration**: 1 year **Setting**: worksite **Intervention function:** education, persuasion, environmental restructuring, training **Behaviour change technique**: organizational strategies (regular e-newsletter sent to all staff), environmental strategies (a height adjustable desk or desk platform), individual and group strategies (group based education seminar, action plan and goal setting, self-monitoring, coaching sessions) **Behaviour change technique taxonomy: s**haping knowledge, antecedents, goals and planning, feedback and monitoring, social support	**Model:** ActiGraph GT9X Link (triaxial) **Placement:** Non-dominant wrist **Wear time:** 7 days	SB (↓) MVPA (NS)	SB (↓) MVPA (NS)
Gardiner et al., 2011 [31] *Australia*	**NRUT** IG: 59 adults (74.6% female) with a mean age of 74.3±9.3	**Duration**: 1 week **Setting**: non-worksite **Intervention function:** education, persuasion, enablement **Behaviour change technique**: goal-setting, feedback on SB, action planning, self-monitoring of SB (on request), tips to reduce SB **Behaviour change technique taxonomy: s**haping knowledge, goals and planning, feedback and monitoring	**Model:** Actigraph GT1M (uniaxial) **Placement:** Not specified **Wear time:** 15 days		SB (↓) LPA (↑) MVPA(↑)
Kendzor et al., 2016 [30] *USA*	**NRCT** IG: 95 adults (70.0% female) with a mean age of 46.8±11.0	**Duration**: 1 week **Setting**: non-worksite **Intervention function:** education, persuasion **Behaviour change technique**: prompts to interrupt SB, information about the negative health impact of prolonged SB, daily reminders for less SB. **Behaviour change technique taxonomy:** associations, natural consequences, repetition and substitution.	**Model:** Actigraph GT3X (triaxial) **Placement:** Right Waist **Wear time:** 7 days		SB (↓) LPA (↑) MPA (NS)
Koepp et al., 2013 [32]	**NRUT**	**Duration**: 1 year **Setting**: worksite	**Model:** Actical (uniaxial)		ST (↓) TPA (↑)

USA	IG: 36 adults (69.4 % female) with a mean age of 42.0 ±9.9	**Intervention function:** environmental restructuring **Behaviour change technique**: Treadmill desks **Behaviour change technique taxonomy:** antecedents	**Placement:** Belt **Wear time:** 1 year		
Koltyn et al., 2019 [37] *USA*	**NRUT** IG: 12 adults (83.3% female) with a mean age of 68.7±4.53	**Duration**: 4 weeks **Setting**: non-worksite **Intervention function:** education, training, persuasion, enablement **Behaviour change technique**: workshop on how reduce SB, information dissemination, goal setting, action planning, self-monitoring, group discussions, and problem solving activities. **Behaviour change technique taxonomy: s**haping knowledge, goals and planning, feedback and monitoring	**Model:** Actigraph GT3X+ (triaxial) **Placement:** Hip **Wear time:** 7 days **Model:** activPAL3 **Placement:** Thigh **Wear time:** 7 days		SB (↓) LPA (↑) MVPA (↑) 4-week post intervention follow-up SB (↓)
Mailey et al., 2016 [27] *USA*	**RUT** IG: 25 adults (100% female) with a mean age of 38.9 ± 7.9	**Duration**: 8 weeks **Setting**: worksite **Intervention function:** education, training, persuasion **Behaviour change technique**: orientation session, identification of strategies to take daily activity breaks, barriers identification, tips to reduce SB, mobile app for prompts. Participants instructed to stand-move for 1-2 min every 30 min **Behaviour change technique taxonomy: s**haping knowledge, goals and planning, associations, repetition and substitution	**Model:** Actigraph GT3X (triaxial) **Placement:** Left hip **Wear time:** 7 days	SB (↓) LPA (NS) MPA (NS)	
Mitchell et al., 2019 [26] *Australia*	**RCT** IG: 86 adults (83,7% female) with a mean age of 49.5 ± 12.2 CG: 85 adults (72,9% female) with a mean age of 51.7 ± 12.8	**Duration**: 12 weeks **Setting**: non-worksite **Intervention function:** persuasion, education, enablement **Behaviour change technique**: website feedback, step goal setting, telephone support, shared experiences, information on guidelines, motivational interviewing, reinforcement. Comparison group received paper diary and generic step goals **Behaviour change technique taxonomy:** feedback and monitoring, goals and planning, social support, shaping knowledge, reward and threat	**Model:** GENEActiv (triaxial) **Placement:** Non-dominant wrist **Wear time:** 7 days		SB (↓) LPA (↑) MVPA (↑) 12-month follow-up: SB (↓) LPA (NS) MVPA (NS)
Overgaard et al., 2018 [34] *Denmark*	**RUT** IG: 23 adults (65,2% female) with a mean age of 45.0 ± 11.5	**Duration**: 4 weeks **Setting**: non-worksite **Intervention function:** training	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh		SB (↓) MVPA (NS)

		Behaviour change technique: instructions to reduce sedentary behaviour (IG1: sit less group). **Behaviour change technique taxonomy: s**haping knowledge	**Wear time:** 7 days **Model:** Actigraph GT3X+ (triaxial) **Placement:** Right hip **Wear time:** 7 days		
Parry et al., 2013 [35] *Australia*	**RCT** IG: 62 adults (81.0% female) with a mean age of 43.5±6.4	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** environmental restructuring, training, education, persuasion, enablement **Behaviour change technique**: active work-stations (treadmill or treadmill + stationary cycle ergometer) and recommendations to use it, active emails, recommendations, strategies to promote physical activity in breaks and increasing the use of active transport, pedometer challenge as a motivational tool, reinforcement of active sitting, use of air cushion. **Behaviour change technique taxonomy:** antecedents, shaping knowledge, goals and planning, reward and threat	**Model:** Actigraph™ GT3X (triaxial) **Placement:** Right hip **Wear time:** 7 days	SB (↓) LPA (↑) MVPA (NS)	SB (↓) LPA (NS) MVPA (↑)
Rosenberg et al., 2015 [33] *USA*	**NRUT** IG: 23 adults (70% female) with a mean age of 71.4±6.4	**Duration**: 8 weeks **Setting**: non-worksite **Intervention function:** **Behaviour change technique**: phone calls, motivational interviewing, prompt, self-monitoring, graphical feedback. **Behaviour change technique taxonomy:** feedback and monitoring, associations, social support	**Model:** ActiGraph WGT3X+ (triaxial) **Placement:** Waist **Wear time:** 7 days		SB (↓) LPA (↑) MVPA (↑)
Siddique et al., 2017 [24] *USA*	**RUT** IG: 95 adults (79% female) with a mean age of 33±10	**Duration**: 3 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement, education, training, incentivisation **Behaviour change technique**: decision support, remote behavioural coaching, financial incentives to increase PA (IG2) **Behaviour change technique taxonomy: s**ocial support, reward and threat	**Model:** ActiGraph 7164 (uniaxial) **Placement:** Waist **Wear time:** 21 days		SB (↓) MVPA bouts (↑)

Swartz et al., 2014 [29] *USA*	**NRUT** IG: 67 adults (71.6% female) with a mean age of 45±11	**Duration**: 2 weeks **Setting**: worksite **Intervention function:** persuasion **Behaviour change technique**: Combination of prompts to interrupt prolonged sitting (60 min) through device and app. **Behaviour change technique taxonomy:** associations, repetition and substitution, feedback and monitoring.	**Model:** Actigraph GTX3 (triaxial) **Placement:** Right hip **Wear time:** 3 days	SB (↓) LPA (↑) MPA (↑) VPA (NS)	
Swartz et al., 2018 [28] *USA*	**RCT** IG: 84 adults (76.2% female) with a mean age of 63.7±5.9 CG: 36 adults (75.0% female) with a mean age of 62.1±6.6	**Duration**: 12 weeks **Setting**: non-worksite **Intervention function:** education, persuasion **Behaviour change technique**: targets to increase steps **Behaviour change technique taxonomy:** goals and planning	**Model:** Actigraph GT3X (triaxial) **Placement:** Hip **Wear time:** 7days		SB (↓) LPA (NS) MVPA (↑)

CONRUT: cross-over non-randomized uncontrolled trial, CRCT: cluster randomized controlled trial, LPA: light physical activity, MVPA: moderate-to-vigorous physical activity, NRCT: non-randomized controlled trial, NRUT: Non-randomized uncontrolled trial, NS: not significant, RCT: randomized controlled trial, RUT: randomized uncontrolled trial, SB: sedentary behaviour, ↓: significant reduction after intervention, ↑: significant increment after intervention. Behaviour change technique taxonomy was grouped based on previous suggested taxonomic method [17]. Intervention functions were based on the Behaviour Change Wheel[7]).

Table 2. Characteristics of the studies including time spent in sedentary behaviour, standing, and stepping.

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
Alkhajah et al., 2012 [56] *Australia*	**NRCT** IG: 18 adults (94.4% female) with a mean age of 33.5±8.7 CG: 12 adults (85.7% female) with a mean age of 39.9±7.2	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** environmental restructuring, training **Behaviour change technique**: sit-stand workstation installed and instructions on how to use it **Behaviour change technique taxonomy:** antecedents, shaping knowledge	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	SB (↓) Standing (↑) Stepping (NS)
Arrogi et al., 2019 [46] *Belgium*	**RCT** IG: 30 adults (54.8% female) with a mean age of 33.6±8.3 CG: 26 adults (48.1% female) with a mean age of 39.2±11.5	**Duration**: 2 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement **Behaviour change technique**: stAPP app including tailored feedback, score system, real-time monitoring of SB **Behaviour change technique taxonomy:** feedback and monitoring, reward and threat, goals and planning	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 14 days		Week-days SB (↓) SB bouts (↓) Standing (↑) Stepping (NS)
Brakenridge et al., 2016 [43] *Australia*	**CRUT** IG1: 87 adults (40% female) with a mean age of 40.0 ± 8.0 IG2: 66 adults (53% female) with a mean age of 37.6 ± 7.8	**Duration**: 1 year **Setting**: worksite **Intervention function:** education, persuasion, enablement **Behaviour change technique**: booklet, tip emails (IG1), plus activity tracker (real-time feedback and prompts on SB) (IG2) **Behaviour change technique taxonomy:** feedback and monitoring, shaping knowledge, associations, repetition and substitution	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	IG1: SB (↓) Standing (↑) Stepping (NS) IG2: SB (↓) Standing (↑) Stepping (↑)	IG1: SB (↓) Standing (↑) Stepping (NS) IG2: SB (↓) Standing (↑) Stepping (NS)
Chau et al., 2014 [40] *Australia*	**CORCT** IG: 42 adults (86.0% female) with a mean age of 38.0±11.0	**Duration**: 4 weeks **Setting**: worksite **Intervention function:** environmental restructuring, training **Behaviour change technique**: sit-stand workstation and instructions in how to use it.	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
	CG: 42 adults (86.0% female) with a mean age of 38.0±11.0	**Behaviour change technique taxonomy:** antecedents, shaping knowledge			
Danquah et al., 2017 [50] *Denmark*	**RCT** IG: 173 adults (61% female) with a mean age of 46 ±10 CG: 144 adults (73% female) with a mean age of 45±11	**Duration**: 4 weeks **Setting**: worksite **Intervention function:** enablement, education, persuasion, training **Behaviour change technique**: social support, goal setting, high meeting tables, routs for walking meeting, lectures, workshops, emails and text messages to use sit-stand desk, break up SB, having standing and walking meeting, goal setting. **Behaviour change technique taxonomy: s**ocial support, goals and planning, antecedents, shaping knowledge, repetition and substitution	**Model:** ActiGraph GT3X+ (triaxial) **Placement:** Thigh **Wear time:** 5 days	SB (↓) Standing (↑) Steps (↑) 3-month follow up SB (↓) Standing (↑) Steps (↑)	
Dewitt et al., 2019 [49] *UK*	**NRUT** IG: 16 adults (72 % female) with a mean age of 42.6±8.9	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** persuasion, training, environmental restructuring, **Behaviour change technique**: SB feedback, tailored behaviour change guidance, Sit-stand workstation, reminders. **Behaviour change technique taxonomy:** feedback and monitoring, goals and planning, antecedents, associations	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	
Edwardson et al., 2018 [38] *UK*	**CRCT** IG: 77 adults (56.0 % female) with a mean age of 41.7±11.0 CG: 69 adults (60.0 % female) with a mean age of 40.8±11.3	**Duration**: 1 year **Setting**: worksite **Intervention function:** education, persuasion, environmental restructuring, training, enablement **Behaviour change technique**: Organizational strategies (regular e-newsletter sent to all staff), environmental strategies (a height adjustable desk or desk platform, individual and group strategies (group based education seminar, action plan and goal setting, self-monitoring, coaching sessions) **Behaviour change technique taxonomy:** shaping knowledge, antecedents, goals and planning, feedback and monitoring, social support	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) SB bouts (↓) Standing (↑) Stepping (NS)	SB (↓) SB bouts (↓) Standing (↑) Stepping (NS)

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
Fitzsimons et al., 2013 [51] *UK*	**NRUT** IG: 12 adults (55.0% female) with a mean age of 31.9±8.3	**Duration**: 2 weeks **Setting**: non-worksite **Intervention function:** education, persuasion, training **Behaviour change technique**: consultation targeting SB, individualized goal setting, visual feedback of ActivPAL **Behaviour change technique taxonomy:** goals and planning, feedback and monitoring	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days		SB (↓) Standing (NS) Stepping (↑)
Healy et al., 2013 [54] *Australia*	**NRCT** IG: 18 adults (77.0% female) with a mean age of 42.4±10.6 CG: 18 adults (33.0% female) with a mean age of 42.9±10.3	**Duration**: 4 weeks **Setting**: worksite **Intervention function:** education, training, persuasion, environmental restructuring, enablement **Behaviour change technique**: information, organization-specific strategies, workshops for health consequences, tip emails, sit-stand workstation, instructions on how to use it, consultations with a coach, goal setting, self-monitoring, prompts and problem solving, feedback, recommendations **Behaviour change technique taxonomy:** shaping knowledge, social support, natural consequences, antecedents, goals and planning, feedback and monitoring, associations	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	
Healy et al., 2016 [41] *Australia*	**CRCT** IG: 136 adults (65.4% female) with a mean age of 44.6±9.1 CG: 95 adults (72.6% female) with a mean age of 47.0±9.7	**Duration**: 1 year **Setting**: worksite **Intervention function:** education, training, persuasion, enablement **Behaviour change technique**: face to face coaching sessions, feedback, goal identification, individual behaviour change strategies, instructions to change postures, personalized emails, telephone calls for support **Behaviour change technique taxonomy:** shaping knowledge, social support, goals and planning, feedback and monitoring, comparison of behaviour	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) SB bouts (↓) Standing (↑) Stepping (NS)	SB (↓) Standing (↑) Stepping (↑)
Júdice et al., 2015 [42]	**CORCT**	**Duration**: 1 week **Setting**: worksite	**Model:** ActivPAL (uniaxial)		Between group: SB (↓)

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
Portugal	IG: 10 adults (50% female) with a mean age of 50.4±11.5 CG: 10 adults (50% female) with a mean age of 50.4±11.5	**Intervention function:** persuasion, education, enablement, training **Behaviour change technique**: screen-prompts to reduce prolonged SB, individual goals for steps, SB reduction strategies, text messages, calls, daily steps report in a diary **Behaviour change technique taxonomy:** associations, goals and planning, shaping knowledge, feedback and monitoring, repetition and substitution	**Placement:** Thigh **Wear time:** 7 days		Standing (↑) Stepping (↑)
Kerr et al., 2016 [47] *UK*	**RUT** IG: 15 adults (73.0% female) with a mean age of 61.6±6.0	**Duration**: 2 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement, education, **Behaviour change technique**: self-monitoring, goal setting, feedback, problem solving and action planning in both interventions. Information through emails and phone calls, written educational material. IG1 aimed to reduce SB two hours per day **Behaviour change technique taxonomy:** goals and planning, feedback and monitoring, shaping knowledge	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 21 days		SB (↓) Standing (NS) Stepping (NS)
Kozey-Keadle et al., 2012 [53] *USA*	**NRUT** IG: 14 adults (75 % female) with a mean age of 46.5 ± 10.8	**Duration**: 1 week **Setting**: work and non-worksite **Intervention function:** education, persuasion, training, enablement **Behaviour change technique**: information health risks of SB, strategies to reduce sedentary time, pedometer, reminders to reduce prolonged SB, identification of barriers, goal-setting, instructed to accumulate steps in short bouts **Behaviour change technique taxonomy:** natural consequences, goals and planning, repetition and substitution, shaping knowledge	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days		SB (↓) Standing (NS) Stepping (↑)
Larouche et al., 2018 [48] *USA*	**CORCT** IG1: 19 adults (78.9% female) with a mean age of 39.4±10.7	**Duration**: 1 week **Setting**: worksite **Intervention function:** persuasion, education **Behaviour change technique**: email prompts to stand (IG1) or encompassing different constructs (IG2, self-efficacy, outcome expectancies, and proximal goal setting).	**Model:** activPAL3 (triaxial) **Placement:** Thigh **Wear time:** 5 working days	**IG1:** SB (↓) Standing (↑) Stepping (NS) **IG2:**	

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
	IG2: 19 adults (78.9% female) with a mean age of 39.4±10.7 CG: 19 adults (78.9% female) with a mean age of 39.4±10.7	**Behaviour change technique taxonomy:** associations, repetition and substitution, goals and planning, self-belief, comparison of outcomes		SB (↓) Standing (↑) Stepping (NS)	
Lewis et al., 2016 [52] *Australia*	**NRUT** IG: 27 adults (63% female) with a mean age of 71.7±6.5	**Duration**: 1 week **Setting**: non-worksite **Intervention function:** education, training, persuasion **Behaviour change technique**: workbook with general information and feedback, normative feedback on SB, goal setting **Behaviour change technique taxonomy:** goals and planning, feedback and monitoring, shaping knowledge	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days		SB (↓) SB bouts (↓) Standing (↑) Stepping (NS)
Li et al., 2017 [39] *Australia*	**RCT** IG: 17 adults (82.0% female) with a mean age of 42.0±11 CG: 9 adults (67.0% female) with a mean age of 41.0±8.0	**Duration**: 4 weeks **Setting**: worksite **Intervention function:** environmental restructuring, training **Behaviour change technique**: sit-stand workstation, instructions to vary their work position, instructions to use the workstation **Behaviour change technique taxonomy:** antecedents, Shaping knowledge	**Model:** activPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	
MacEwen et al., 2017 [55] *Canada*	**RCT** IG: 15 adults (81.3% female) with a mean age of 43.2±9.7 CG: 10 adults (83.3% female) with a mean age of 48.9±11.4	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** environmental restructuring **Behaviour change technique**: Sit-stand workstation. **Behaviour change technique taxonomy:** antecedents	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Steps (NS)	SB (↓) Standing (NS) Steps (NS)
Mansoubi et al., 2016 [13] *UK*	**NRUT** IG: 40 adults (55.0% female) with a mean age of 31.9±8.3	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** education, environmental restructuring	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh	SB (↓) Standing (↑) Stepping (↑)	

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
		Behaviour change technique: sit-to-stand workstation, information about the advantages of sit-to-stand working **Behaviour change technique taxonomy:** antecedents, shaping knowledge, natural consequences	**Wear time:** 7 days		
Neuhaus et al., 2014 [45] *Australia*	**RCT** IG1 (multicomponent): 12 adults (100.0% female) with a mean age of 37.3±10.7 IG2 (workstations only): 13 adults (78.6% female) with a mean age of 43.0±10.2 CG: 13 adults (71.0% female) with a mean age of 48.0±11.6	**Duration**: 12 weeks **Setting**: worksite **Intervention function:** education, persuasion, enablement, environmental restructuring, training **Behaviour change technique**: IG1 Multi-component intervention (organizational, environmental and individual strategies) including consultation, information session and encouragement emails, adjustable workstation, training on how to use it and postures, face to face coaching, tailored email, phone calls, information booklets, self-monitoring. IG2 Workstations-only intervention. **Behaviour change technique taxonomy:** antecedents, goals and planning, shaping knowledge, social support, comparison of behaviour, reward and threat, feedback and monitoring	**Model:** activPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	**IG1:** SB (↓) SB bouts (NS) Standing (↑) Stepping (NS) **IG2:** SB (NS) SB bouts (NS) Standing (NS) Stepping (NS)	**IG1:** SB (↓) SB bouts (NS) Standing (↑) Stepping (NS) **IG2:** SB (↓) SB bouts (NS) Standing (↑) Stepping (NS)
Rosenberg et al., 2015 [33] *USA*	**NRUT** IG: 23 adults (70% female) with a mean age of 71.4±6.4	**Duration**: 8 weeks **Setting**: non-worksite **Intervention function:** persuasion, enablement **Behaviour change technique**: Phone calls, motivational interviewing, prompt, self-monitoring, graphical feedback **Behaviour change technique taxonomy:** feedback and monitoring, Associations, Social support	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 7 days		SB (↓) Standing (↑) Stepping (NS)
Swartz et al., 2014 [29] *USA*	**NRUT** IG: 67 adults (71.6% female) with a mean age of 45±11	**Duration**: 2 weeks **Setting**: worksite **Intervention function:** persuasion, enablement **Behaviour change technique**: Combination of prompts to interrupt prolonged sitting (60 min) through device and app	**Model:** ActivPAL (uniaxial) **Placement:** Thigh **Wear time:** 3 weekdays	SB (↓) Standing (NS) Stepping (↑)	

Author, ***country***	**Design & sample characteristics** (n, % female, age)	**Intervention** (duration, behaviour change strategy, setting)	**Device** (type, placement, days)	**Results** (worksite)	**Results** (all day)
		Behaviour change technique taxonomy: associations, repetition and substitution, feedback and monitoring			
Tobin et al., 2016 [44] *Australia*	**RCT** IG: 18 adults (89.0% female) with a mean age of 34.8±10.5 CG: 19 adults (84.0% female) with a mean age of 34.3±8.9	**Duration**: 5 weeks **Setting**: worksite **Intervention function:** environmental restructuring, education, training **Behaviour change technique**: sit-stand workstations, ergonomic assessment and advice **Behaviour change technique taxonomy:** antecedents, shaping knowledge	**Model:** ActivPAL3 (triaxial) **Placement:** Thigh **Wear time:** 7 days	SB (↓) Standing (↑) Stepping (NS)	

CRUT: cluster randomized uncontrolled trial, CORCT: cross-over randomized controlled trial, CORNCT: cross-over randomized uncontrolled trial, CRCT: cluster randomized controlled trial, NRCT: non-randomized controlled trial, NRUT: Non-randomized uncontrolled trial, NS: not significant, RCT: randomized controlled trial, RUT: randomized uncontrolled trial, SB: sedentary behaviour, ↓: significant reduction after intervention, ↑: significant increment after intervention. interventions lasting 5 days [48], 1 month [50] and 3 months [13,45,56] were expressed as 1, 4 and 12 weeks, respectively. Behaviour change technique taxonomy was grouped based on previous suggested taxonomic method [17]. Intervention functions were based on the Behaviour Change Wheel[7]).

Table 3. Summary of effects of interventions (quantitative synthesis using meta-analysis).

Accelerometer outcome	**Results (worksite)**	**Results (all day)**
Block 1: interventions including sedentary time and time spent in different physical activity intensity levels (post vs. pre)		
Sedentary time	N/IG=4/4 **ES=-0.31, 95% CI=-0.42 to -0.19; *P*<0.001**	N/IG=7/9 **ES=-0.67, 95% CI=-0.92 to -0.42; *P*<0.001**
LPA	N/IG=4/4 **ES=0.24, 95% CI=0.05 to 0.43; *P*<0.013**	N/IG=6/8 **ES=0.62, 95% CI=0.34 to 0.91; *P*=0.001**
MVPA	N/IG=4/4 ES=0.16, 95% CI=-0.01 to 0.32; *P*=0.059	N/IG=8/10 **ES=0.47, 95% CI=0.26 to 0.67; *P*<0.001**
Block 1: interventions including sedentary time and time spent in different physical activity intensity levels (controlled trials)		
Sedentary time	N/IG=1/1 ES=Not applicable	N/IG=4/4 ES=Not applicable
LPA	N/IG=0/0 ES=Not applicable	N/IG=3/3 ES=Not applicable
MVPA	N/IG=1/1 ES=Not applicable	N/IG=4/4 ES=Not applicable
Block 2: interventions including sedentary, standing, and stepping time (post vs. pre).		
Sedentary time	N/IG=14/16 **ES=−0.77, 95% CI=–0.96 to -0.59; *P*<0.001**	N/IG=11/13 **ES=-0.56, 95% CI=-0.71 to -0.40; *P*<0.001**
Standing	N/IG=14/16 **ES=0.76, 95% CI=0.57 to 0.95; *P*<0.001**	N/IG=11/13 **ES=0.54, 95% CI=0.39 to 0.69; *P*<0.001**
Stepping	N/IG=12/14 **ES=0.12, 95% CI=0.04 to 0.20; *P*=0.002**	N/IG=10/12 ES=0.08, 95% CI=-0.09 to 0.24; *P*=0.355
Block 2: interventions including sedentary, standing, and stepping time (controlled trials)		
Sedentary time	N/IG=11/13	N/IG=6/6

Accelerometer outcome	**Results (worksite)**	**Results (all day)**
	ES=−1.10, 95% CI=–1.40 to -0.80; *P*<0.001	**ES=−0.79, 95% CI=–1.14 to -0.44; *P*<0.001**
Standing	N/IG=11/13 **ES=1.12, 95% CI=0.83 to 1.41; *P*<0.001**	N/IG=6/6 **ES=0.64, 95% CI=0.46 to 0.82; *P*<0.001**
Stepping	N/IG=9/11 ES=0.02, 95% CI=-0.13 to 0.17; *P*=0.805	N/IG=5/5 ES=0.17, 95% CI=-0.24 to 0.58; *P*=0.418

CI= confidence interval; ES= effect size; IG= number of intervention groups; LPA= light physical activity; MVPA= moderate-to-vigorous physical activity; N= number of studies. Statistically significant results are highlighted in bold.

Table S1. Prisma checklist.

Table S2. Full search strategy.

	Different parts of the search strategy	Justification of search
#1	(sedentary OR sitting OR seated OR sit OR sits OR inactiv*) AND ("physical activity" OR active OR activit*)	Focuses on studies including sedentary time and physical activity variables
#2	(actigraph* OR wearable OR activPAL OR "motion sensor" OR "activity monitor" OR device* OR acceleromet* OR objectively OR "objective measure*")	Focuses on studies using device measures only
#3	(intervention? OR program* OR trial? OR strateg*)	Focuses on intervention studies only
#4	#1 AND #2 AND #3	
#5	(child* OR teenage* OR adolescen*)	Focuses on ineligible participants groups
	Complete final search strategy: #1 AND #2 AND #3 NOT #5	
#6	(sedentary OR sitting OR seated OR sit OR sits OR inactiv*) AND ("physical activity" OR active OR activit*) AND (actigraph* OR wearable OR activPAL OR "motion sensor" OR "activity monitor" OR device* OR acceleromet* OR objectively OR "objective measure*") AND (intervention? OR program* OR trial? OR strateg*) NOT (child* OR teenage* OR adolescen*)	
#7	Limit to: articles only	
#8	Limit to: English and Spanish language	

All searches were performed on the fields: Title OR abstract OR keywords. EBSCOhost included: Academic Search Ultimate, CINAHL with full text, PsycARTICLES, Psychology and behavioural sciences collection, PsycINFO, SPORTDiscuss with full text.

Table S3. Risk of bias.

Study	Component rating (1-3)						Overall rating (1-3)
	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	
Aittasalo et al., 2017	Weak	Moderate	Strong	Weak	Moderate	Weak	Weak
Alkhajah et al., 2012	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Arrogi et al., 2019	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Barwais & Cuddihy, 2015	Weak	Moderate	Weak	Weak	Weak	Strong	Weak
Bond et al., 2014	Weak	Moderate	Weak	Weak	Moderate	Strong	Weak
Brakenridge et al., 2016	Moderate	Moderate	Strong	Weak	Strong	Weak	Weak
Carr et al., 2013	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Chau et al., 2014	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Danquah et al., 2017	Strong	Strong	Strong	Weak	Strong	Strong	Moderate
Dewitt et al., 2019	Weak	Moderate	Weak	Weak	Strong	Weak	Weak
Edwardson et al., 2018	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong
Fitzsimons et al., 2013	Weak	Moderate	Weak	Weak	Strong	Strong	Weak
Gardiner et al., 2011	Weak	Moderate	Weak	Weak	Strong	Strong	Weak
Healy et al., 2013	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Healy et al., 2016	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Júdice et al., 2015	Moderate	Strong	Weak	Weak	Strong	Strong	Weak
Kendzor et al., 2016	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
Kerr et al., 2016	Moderate	Moderate	Strong	Moderate	Strong	Strong	Strong
Koepp et al., 2013	Moderate	Moderate	Weak	Weak	Weak	Strong	Weak
Koltyn et al., 2019	Weak	Moderate	Weak	Weak	Strong	Weak	Weak
Kozey-Keadle et al., 2012	Weak	Moderate	Weak	Weak	Strong	Weak	Weak
Larouche et al., 2018	Moderate	Moderate	Strong	Weak	Strong	Strong	Moderate
Lewis et al., 2016	Moderate	Moderate	Weak	Weak	Strong	Strong	Weak
Li et al., 2017	Weak	Strong	Strong	Weak	Strong	Strong	Weak
MacEwen et al., 2017	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
Mailey et al., 2016	Moderate	Moderate	Weak	Weak	Strong	Moderate	Weak

Mansoubi et al., 2016	Weak	Moderate	Weak	Weak	Strong	Strong	Weak
Mitchell et al., 2019	Moderate	Strong	Strong	Weak	Moderate	Moderate	Moderate
Neuhaus et al., 2014	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Overgaard et al., 2018	Moderate	Moderate	Strong	Weak	Strong	Moderate	Moderate
Parry et al., 2013	Moderate	Strong	Strong	Weak	Strong	Weak	Weak
Rosenberg et al., 2015	Moderate	Moderate	Weak	Weak	Strong	Moderate	Weak
Siddique et al., 2017	Moderate	Moderate	Weak	Weak	Strong	Strong	Weak
Swartz et al., 2018	Weak	Strong	Strong	Weak	Strong	Weak	Weak
Swartz et al., 2014	Weak	Moderate	Strong	Weak	Strong	Moderate	Weak
Tobin et al., 2016	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate

Fig. 2. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) sedentary time measured by accelerometry. The size of the square represents the weight of each study. Bond et al., 2014 [21] statistics are based on the combination of the different intervention groups.

Fig. 3. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) light physical activity (LPA) measured by accelerometry. The size of the square represents the weight of each study. Bond et al., 2014 [21] statistics are based on the combination of the different intervention groups.

Fig. 4. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) moderate-to-vigorous physical activity (LPA) measured by accelerometry. The size of the square represents the weight of each study. Bond et al., 2014 [21] statistics are based on the combination of the different intervention groups.

Fig. 5. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) sedentary time measured by activPAL accelerometer. The size of the square represents the weight of each study. Brakenridge et al., 2016 [43] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. 6. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) standing time measured by activPAL accelerometer. The size of the square represents the weight of each study. Brakenridge et al., 2016 [43] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. 7. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour interventions (pre vs. post) on worksite (a) and whole day (b) stepping time measured by activPAL accelerometer. The size of the square represents the weight of each study. Brakenridge et al., 2016 [43] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. 8. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour intervention vs. control group on worksite (a) and whole day (b) sedentary time measured by activPAL accelerometer. The size of the square represents the weight of each study. Larouche et al., 2018 [48] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. 9. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour intervention vs. control group on worksite (a) and whole day (b) standing time measured by activPAL accelerometer. The size of the square represents the weight of each study. Larouche et al., 2018 [48] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. 10. Meta-analysis of the pooled effect size (ES) and confidence intervals (CI) (95%) of sedentary behaviour intervention vs. control group on worksite (a) and whole day (b) stepping time measured by activPAL accelerometer. The size of the square represents the weight of each study. Larouche et al., 2018 [48] and Neuhaus et al., 2014 [45] statistics are based on the combination of the different intervention groups.

Fig. S1. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) sedentary time measured by accelerometry in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of sedentary time.

Fig. S2. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) light physical activity (LPA) measured by accelerometry in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of LPA.

Fig. S3. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) moderate-to-vigorous physical activity (MVPA) measured by accelerometry in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of MVPA.

Fig. S4. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) sedentary time measured by activPAL accelerometer in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of sedentary time.

Fig. S5. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) standing time measured by activPAL accelerometer in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of standing time.

Fig. S6. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) stepping time measured by activPAL accelerometer in post vs. pre analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of stepping time.

Fig. S7. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) sedentary time measured by activPAL accelerometer in exercise vs. control analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of sedentary time.

Fig. S8. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) standing time measured by activPAL accelerometer in exercise vs. control analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of standing time.

Fig. S9. Funnel plots to assess publication bias in effects of sedentary behaviour intervention on worksite (a) and whole day (b) stepping time measured by activPAL accelerometer in exercise vs. control analysis included in the meta-analysis. Each white point represents a meta-analysed group. Diagonal lines represent pseudo-95% confidence intervals. In reference of Y axis, studies located at the lower part of the graph have a higher standard error (a lower weight in the pooled analysis). The vertical line represents the calculated estimate effect of stepping time.