Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis

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ABSTRACT

Context Time spent in sedentary behaviours (SB) is associated with poor health, irrespective of the level of physical activity. The aim of this study was to evaluate the effect of interventions which included SB as an outcome measure in adults.

Methods Thirteen databases, including The Cochrane Library, MEDLINE and SPORTDiscus, trial registers and reference lists, were searched for randomised controlled trials until January 2014. Study selection, data extraction and quality assessment were performed independently. Primary outcomes included SB, proxy measures of SB and patterns of accumulation of SB. Secondary outcomes were cardiometabolic health, mental health and body composition. Intervention types were categorised as SB only, physical activity (PA) only, PA and SB or lifestyle interventions (PA/SB and diet).

Results Of 8087 records, 51 studies met the inclusion criteria. Meta-analysis of 34/51 studies showed a reduction of 22 min/day in sedentary time in favour of the intervention group (95% CI −35 to −9 min/day, n=5868). Lifestyle interventions reduced SB by 24 min/day (95% CI −41 to −8 min/day, n=3981, moderate quality) and interventions focusing on SB only by 42 min/day (95% CI −79 to −5 min/day, n=62, low quality). There was no evidence of an effect of PA and combined PA/SB interventions on reducing sedentary time.

Conclusions There was evidence that it is possible to intervene to reduce SB in adults. Lifestyle and SB only interventions may be promising approaches. More high quality research is needed to determine if SB interventions are sufficient to produce clinically meaningful and sustainable reductions in sedentary time.

INTRODUCTION

There is growing public health concern about the amount of time spent in sedentary behaviours (SB). SB are defined as behaviours where sitting or lying is the dominant posture and energy expenditure is very low.[1] Sedentary time accumulates daily while commuting, at work, at home and during leisure time.[2] Where studies have controlled for the influence of moderate-to-vigorous physical activity (MVPA), too much time spent in SB is associated with poor health, including elevated cardiometabolic risk markers, type 2 diabetes and premature mortality.[3–9] Where studies have controlled for the influence of total sedentary and moderate-to-vigorous activity time, increased breaks in sedentary time have been shown to be beneficially associated with waist circumference, body mass index (BMI), triglycerides and 2 h plasma glucose.[10] Interventions interrupting extended sitting with frequent short activity breaks have enhanced markers of cardio metabolic health.[11–13]

Recent systematic reviews have summarised the literature in respect to health implications,[14–18] measurement,[19] prevalence,[20] correlates[21] and interventions in young people.[22] To date, only one review of the evidence on interventions to influence total SB in adults has been published.[23] The review concluded that interventions with a specific goal of increasing PA levels and those which combined an increase in PA levels with a decrease in sedentary time resulted in modest reductions in SB, while interventions focusing on SB only resulted in greater reduction of sedentary time. The present systematic review expands this existing evidence[23] in five ways: (1) evaluating intervention effects using more precise categories of interventions; (2) assessing effects on pattern of SB accumulation; (3) conducting subgroup analyses; (4) including only randomised controlled trials (RCTs); and (5) assessing effects on health outcomes.

The primary aim of this review was to evaluate the effect of interventions which included an SB outcome measure in adults. The secondary aim was to determine the effects of interventions, which included an SB outcome, on measures of health.

METHODS

The protocol for this review is available online at the International Prospective Register for Systematic Reviews.[24]

Study selection criteria

Studies were eligible for inclusion if they met the following criteria:

Study design: RCTs

Population: Adults aged 18 years or more who have left school.

Intervention: Any intervention which included an SB outcome measure in free-living adults was eligible; those in clinical settings such as hospitals were excluded. Eligible control conditions were no intervention, waiting list, attention control (eg, general health information), usual care (eg, diabetes treatment involving lifestyle counselling) and alternative treatment conditions (eg, a structured exercise programme).

Outcomes: Studies reporting any of the following outcomes were included:

- Objectively measured SB obtained from accelerometers

- Objectively measured sitting time obtained from inclinometers
- Objectively or self-reported patterns of accumulation of SB
- Self-reported total sitting time
- Self-reported proxy measures of sitting time where it is not certain that people are sitting (eg, screen time and transport time) and proxy measures of overall SB (eg, occupational sitting time)

Other inclusion criteria: Only full text articles published in the English language were included in this review.

Data sources and searches

In January 2014, the Cochrane Central Register of Controlled Trials (Issue 12 of 12 December 2013), MEDLINE (1946-November week 3 2013), EMBASE (1980-week 1 2014), PsycINFO (1806-November week 5 2013), SPORTDiscus (1975-7 January 2014), CINAHL (1937-7 January 2013), Cochrane Database of Systematic Reviews (Issue 1 of 12 January 2014), Database of Health Promotion Research (Biblomap, Issue 4 of 4, October 2013), Database on Obesity and SB Studies (16 January 2014), Conference Proceedings Citation Indexes (Web of Science, 1900 to current), controlled-trials.com (16 January 2014), WHO International Clinical Trial Registry (16 January 2014) and the Networked Digital Library of Theses and Dissertations (1900-current) were searched. The search strategy for MEDLINE is listed in online supplementary 1. Reference lists and citations of relevant studies were examined and experts in the field contacted for details of ongoing and unpublished studies.

Study selection

At least two reviewers independently screened the titles/abstracts (AM, RJ) and full text articles (AM and RJ, CF or DHS). Eligibility disagreements were resolved by a third reviewer (NM).

Data extraction and quality assessment

Duplicate data extraction was performed independently for 10% of the included studies (AM and RJ, CF or DHS) and discrepancies resolved through discussion. The following secondary outcomes for this review were recorded from included studies:

- Biomarkers of cardiometabolic risk including blood glucose levels, blood lipid levels, total cholesterol levels, glycosylated haemoglobin, blood pressure
- Mental health outcomes including depression and anxiety
- Objectively obtained BMI, waist circumference and/or fat mass.

The full list of extracted data items can be obtained from the study protocol.[24]

Quality of all studies was assessed by two reviewers (AM, DHS) using the Tool for Assessing Risk of Bias from the Cochrane Collaboration.[25] Risk of bias was scored as 'high', 'unclear' or 'low' for the following domains: (1) participant selection bias, (2) intervention performance bias, (3) effect detection bias, (4) outcome reporting bias, (5) attrition bias and (6) bias due to comparability of baseline groups.

Publication bias was examined using a funnel plot whenever meta-analyses included 10 or more studies.[25]

Quality of evidence for primary outcomes was assessed using the GRADEpro software developed by the Grading of Recommendations Assessment Development and Evaluation (GRADE) Working Group.[26] An overall quality score is based on the assessment of risk of bias, indirectness, imprecision, inconsistency and publication bias of primary outcomes. The GRADE Working Group grades of evidence are high, moderate, low and very low quality.

Data synthesis and analysis

Studies reporting similar outcome measures were combined in meta-analyses using random effects models to account for intervention heterogeneity. Where suitable data were not reported, efforts were made to obtain the data from study authors. To account for variability between studies, inverse variance was used, giving more weight for studies with less variability. Effect sizes were estimated as mean differences (min/day) between the intervention and control groups. Review Manager 5.2 was used for quantitative analysis.[27]

For cluster RCTs where control of clustering was missing, intervention effects were approximately corrected by reducing the sample size of each trial to its 'effective sample size'. The sample size was divided by the design effect, which is $[1+(M-1)\times ICC]$, where M is the average of cluster size and ICC is the intracluster correlation coefficient.[25] An ICC of 0.01 was used.

Where suitable data were available, studies were combined in a meta-analysis regardless of whether missing data were imputed by authors. Variation in the degree of missing data was considered as a potential source of heterogeneity of results. A sensitivity analysis to examine the effect of inclusion of complete cases on robustness of intervention effects was performed.

Further heterogeneity of findings was assessed by comparing similarity of included studies in terms of study design, participants, interventions, outcomes and study quality. The cause of heterogeneity was evaluated by conducting subgroup and sensitivity analyses. Statistical heterogeneity was assessed by calculating the I^2 statistic indicating the variability of the intervention effect due to heterogeneity. Variability of more than 50% may indicate moderate to substantial heterogeneity of intervention effects according to the Cochrane Handbook.[25]

Subgroup analyses within this review focused on:

- Intervention type (SB, PA/SB or lifestyle which, in addition to PA/SB, also included a dietary/nutrition component)
- Gender (men, women, men and women)
- Intervention duration (<3 months, 3–6 months, >6 months)
- Follow-up duration (<3 months, 3–6 months, 7–12 months, >12 months)
- Intervention setting (work place vs home/community)
- Outcome measurement tool (objective measurement tool, sitting time self-report, proxy measurement tool)
- Study aim (SB as a primary vs secondary study aim)

Sensitivity analyses were used to test the effect of including studies which were cluster designs, used usual care or alternative treatment control groups, or were at 'high risk' of performance and attrition bias.

Included studies lacking data suitable for meta-analysis are described narratively.

RESULTS

Results of the literature search

Figure 1 displays the PRISMA diagram of the literature search. Inclusion criteria were met by 57 records which comprised 51 studies. Thirty-six studies provided adequate data to be included in meta-analyses.

Characteristics of included studies

Study and participant characteristics are summarised in table 1 of the online supplementary material. Of the 51 included studies (18 480 participants), 44 were RCTs[28–70] and seven were cluster RCTs[71–77] conducted in Europe (n=25), the USA (n=18), Australia (n=7) and China (n=1). The majority of studies were carried out in a mixed gender population (n=35); 13 studies

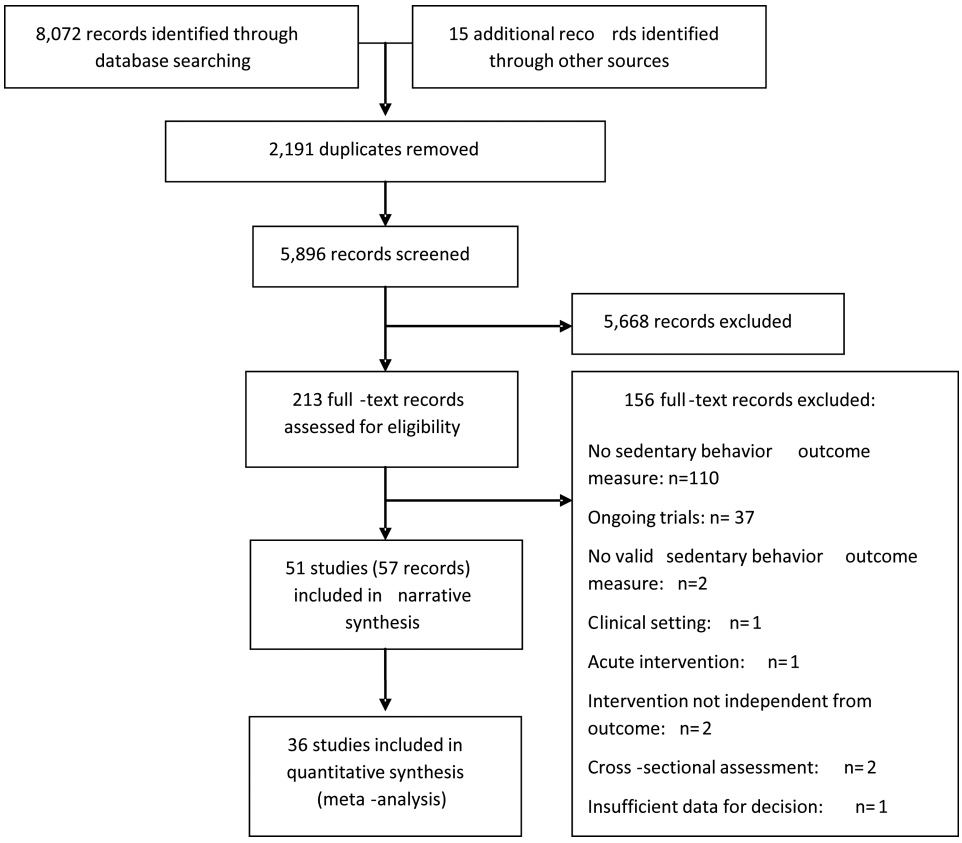

Figure 1 PRISMA diagram of the literature search results.

targeted women only[29 42 50 51 56 57 60 61 67 69 71 76] and three studies targeted men only.[29 31 44] Most studies included participants aged between 18–60 years (n=44), while seven studies included participants older than 60 years of age.[33 35 37 38 48 62 72] Twenty-three studies were conducted in overweight or obese adults, five studies in participants with type 2 diabetes mellitus and three studies in participants with high levels of cardiovascular risk factors. Two studies were conducted in pregnant women.

Types of intervention and control conditions varied substantially between included studies (see online supplementary table S1). Three studies employed an intervention specifically to reduce SB,[40 44 63] 16 studies aimed at increasing PA levels,[30 35 36 39 41 46 48 49 55 58–60 64 66 72 78] nine studies combined both approaches of reducing SB and increasing PA levels,[32 43 53 62 65 68 70 76 77] one study assessed the effect of a dietary intervention on SB,[61] and 22 studies (20 reports) applied a multicomponent lifestyle intervention and observed effects on sedentary behaviour (among other outcomes).[29 33 34 37 38 42 45 47 50–52 54 56 57 67 69 71 73 74 75] Twenty studies offered an alternative intervention,[30 36 39–41 45 46 49 52–55 59 61–63 68 72 77] 10 studies the usual/routine care,[29 37 38 42 50 51 67 71 74 75] seven studies used a waiting list control,[29 34 48 64 69 76 78] five studies an attention control,[35 44 56 57 60] and control participants of seven studies received no intervention at all.[32 33 43 47 58 66 70 73]

Risk of bias of included studies

Figure 2 shows each risk of bias item presented as percentages across all included studies.

Selection bias

Correct randomisation was used in 65% of the studies (33/51), and therefore there was low risk of bias in these studies. However, for the remaining studies, insufficient details were reported and thus assessed as 'unclear'. In nearly 70% (35/51) of the studies, there was lack of reporting on whether or not participants knew in advance their group allocation, and thus there was an unclear risk of bias. For studies that provided information, studies were judged to be at low risk of allocation concealment bias.

Performance bias

It is recognised that in lifestyle interventions it is not possible to blind participants and researchers delivering the intervention to group allocation and this creates high risk of bias. However, 67% (34/51) of included studies were considered at low risk of performance bias because SB was not the primary outcome. A further 31% (16/51) of included studies were judged to be at high risk of performance bias because the participants and researchers delivering the intervention were not blinded to the purpose of the intervention, which was reducing SB. Risk of performance bias was unclear for one study[33] due to insufficient information provided.

Detection bias

Sixty-one per cent of the studies (31/51) assessed SB through self-reports and thus were at high risk for detection bias. The risk of cross-contamination was 'low' in half of the studies and 'unclear' in the other half.

Attrition bias

The issue of incomplete outcome data was sufficiently addressed in 47% (24/51) of the studies, and thus these studies were at low risk of attrition bias. However, 43% (22/51) of the studies did not account for missing data and thus were at high risk of attrition bias. Five studies were at 'unclear' risk of attrition bias.

Comparability of baseline groups

Over 50% (29/51) of the studies were at low risk of bias. Apparent flaws in the randomisation process were found in

Table 1 Intervention effects for change of sedentary behaviour by subgroups

Subgroup	Studies	Participants	Intervention effect (min/day), MD (95% CI, I^2)
Sex*			
Men	2	434	−57.94 (−86.14 to −29.74; 0%)
Women	10	1541	−5.97 (−23.51 to 11.57; 33%)
Men/women	22	3893	−25.32 (−42.94 to −7.69; 83%)
Intervention duration†			
≤3 months	14	1474	−47.51 (−76.57 to −18.46; 81%)
3–6 months	11	2119	−15.20 (−33.08 to 2.68; 67%)
>6 months	9	2275	0.30 (−17.83 to 18.44; 61%)
Follow-up duration‡			
<3 months	17	1954	−42.17 (−67.31 to −17.02; 84%)
3–6 months	13	2489	−22.29 (−41.61 to −2.96; 77%)
7–12 months	11	2327	−26.60 (−45.95 to −7.24; 73%)
>12 months	5	1264	−3.06 (−34.05 to 27.94; 83%)
Intervention setting‡			
Workplace	8	1790	−8.93 (−26.64 to 8.78; 66%)
Other	26	4078	−28.21 (−46.34 to −10.09; 80%)
Assessment tool‡			
*activ*PAL	2	67	−45.37 (−87.99 to −2.74; 76%)
Actigraph	4	334	−27.93 (−70.71 to 14.85; 75%)
Sitting time questionnaire	12	2576	−10.92 (−30.59 to 8.74; 57%)
Proxy measure questionnaire	17	2983	−29.39 (−50.56 to −8.21; 84%)
Intervention aim‡			
SB Primary outcome	14	2258	−24.05 (−45.43 to −2.67; 73%)
SB Secondary outcome	22	3764	−23.17 (−40.02 to −6.32; 80%)

*statistically significant subgroup difference at p<0.01.
†statistically significant subgroup difference at p <0.05.
‡non-significant subgroup difference.
SB, sedentary behaviour.

three studies[53 76 78] and therefore assessed at high risk of bias related to the comparability of baseline groups. For the remaining studies, no formal assessment of the comparability of baseline groups was reported, and thus the risk of bias was 'unclear'.

Reporting bias

For half of the studies (26/51), access to a published study protocol or trial register was missing so that the risk of selective reporting was 'unclear'. However, nearly 50% (24/51) of the studies were at low risk of selective outcome reporting. One study did not report all outcomes as stated in the study protocol and thus was at high risk of selective reporting.[70]

Publication bias

Lifestyle interventions were the only category of interventions where at least 10 studies were available and thus suitable for assessment of publication bias using the funnel plot (see online supplementary figure S1). The asymmetric distribution of effect sizes might indicate a publication bias towards studies with beneficial effects for reducing SB. However, an asymmetric funnel plot might be a study size effect.

Effect of interventions

Primary outcomes

The primary outcomes reported were overall time spent in SB as minutes per day (n=49) or percentage of assessed time period (n=3), number of sitting breaks (n=3) and number of prolonged sitting events (n=3).

Online supplementary table S1 summarises the original trial authors' conclusions of study outcomes. Twenty studies indicated a beneficial effect of interventions for reducing SB in favour of the intervention group. Of these, 10 studies employed a lifestyle intervention,[29 33 34 37 38 42 51 52 54 74] six studies targeted increase in PA,[30 41 46 48 64 78] two studies were combined PA/SB interventions[32 68] and two studies were SB interventions.[40 63] Two studies reported a beneficial intervention effect in favour of the control group;[39 60] both studies were PA interventions. Control conditions were attention control[60] and an alternative exercise treatment.[39] Twenty-four studies suggested no evidence of a group difference in SB: 10 lifestyle interventions,[29 45 50 52 56 57 67 71 73 75] seven PA interventions,[35 36 49 55 58 66 72] six PA/SB interventions,[53 62 65 70 76 77] and one SB intervention.[44] Four studies—two lifestyle,[47 69] one PA/SBs,[43] one dietary intervention[61]—did not conclude on SB outcomes despite assessing SB.

A meta-analysis of 34 studies (5868 participants) suggested an overall reduction in sedentary time by mean differences (MD) of −22.34 min/day (95% CI −35.81 to −8.88, p=0.001, I^2=71%) in favour of the intervention group. Figure 3 shows effect sizes of individual studies and pooled results by intervention type. Findings indicated a beneficial effect of interventions specifically targeting the reduction in SB as well as interventions employing a lifestyle intervention approach on reduced SB. Specific SB interventions (n=2, 62 participants) yielded an MD of −41.76 min/day (95% CI −78.92 to −4.60, p=0.003, I^2=65%) and lifestyle

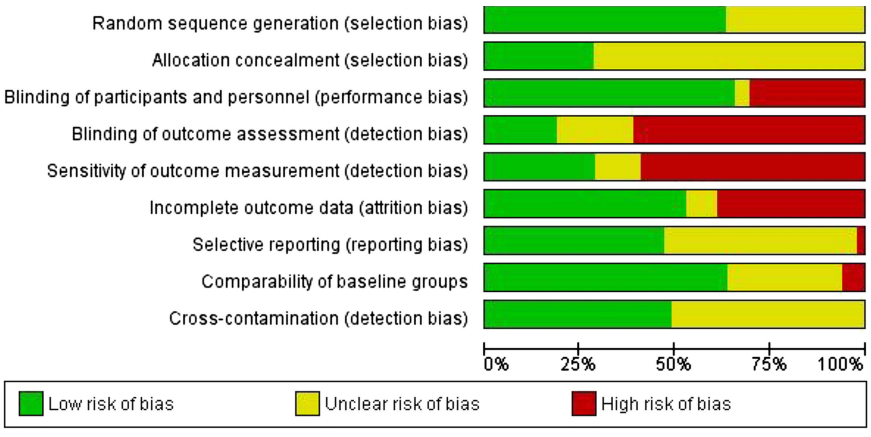

Figure 2 Risk of bias item presented as percentages across all studies.

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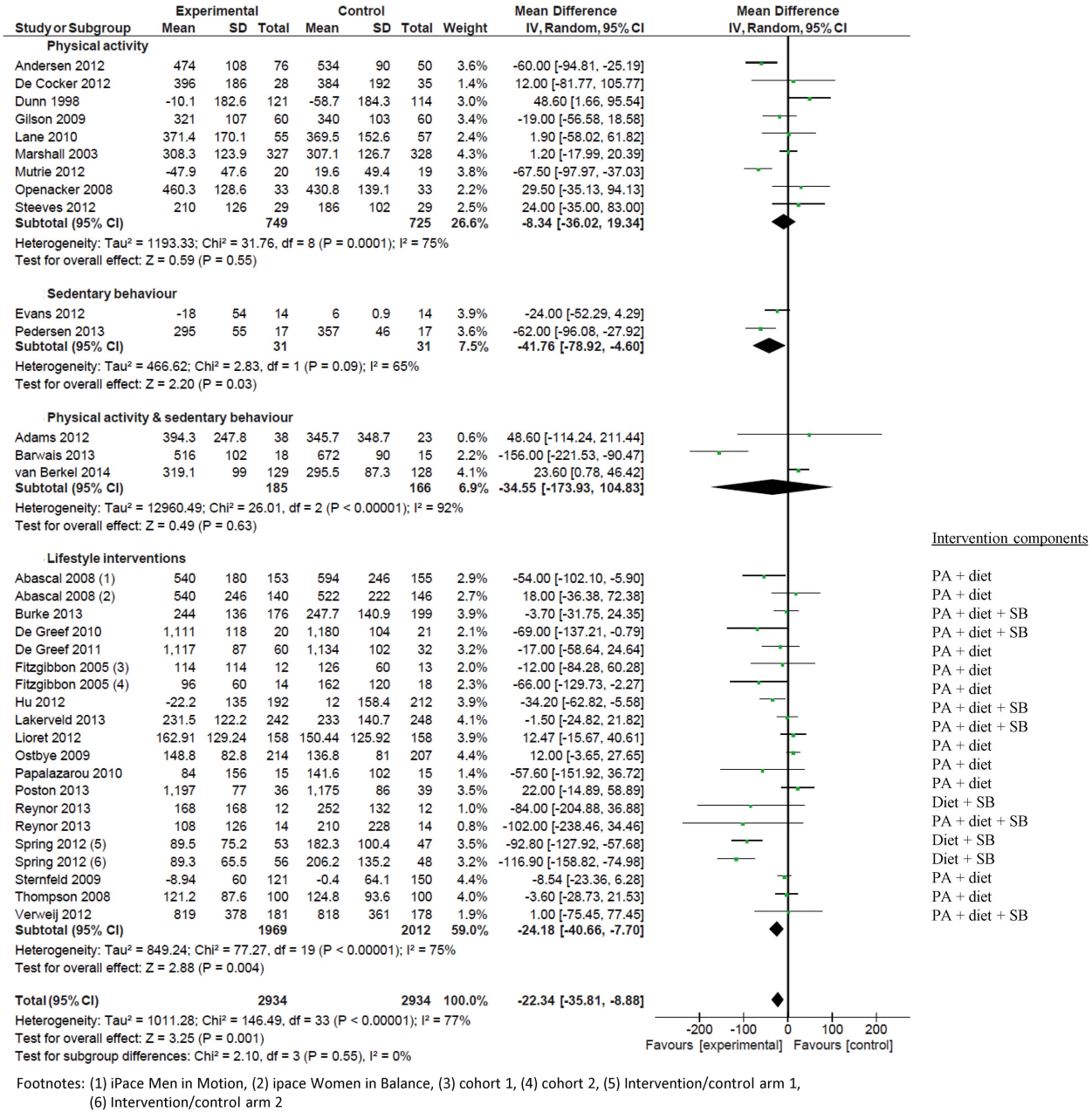

Footnotes: (1) iPace Men in Motion, (2) ipace Women in Balance, (3) cohort 1, (4) cohort 2, (5) Intervention/control arm 1, (6) Intervention/control arm 2

Figure 3 Forest plot of the intervention effect for reducing sitting time in minutes/day in adults by type of intervention. PA, physical activity; SB, sedentary behavior.

interventions (n=20, 3881 participants) an MD of −24.18 min/day (95% CI −40.66 to −7.70, p=0.004, I^2=75%). There was no evidence of a statistically significant effect of PA interventions or combined PA/SB interventions for reducing SB.

Pooled intervention effects on SB patterns indicated no statistically significant effect for both the number of sitting breaks per hour or the number of prolonged sitting events of more than 30 min.

As indicated by the large I^2 statistic, the level of statistical heterogeneity between studies was high. Subgroup analyses were conducted (defined a priori) to assess potential reasons for heterogeneity (table 1). A significant subgroup difference between assessed groups was detected for gender and intervention duration. Studies in men-only (n=2; 434 men), but not women-only (n=10; 1541 women), resulted in significant intervention effects for reduced SB of intervention group participants (MD −57.94 min/day, 95% CI −86.14 to −29.74 min/day, p<0.001). The combined effects of mixed gender studies (n=22; 3393 participants) also showed benefit in favour of the intervention group (MD −25.32 min/day, 95% CI −42.94 to −7.69 min/day, p=0.005). Interventions of up to 3 months resulted in a significant reduction in sedentary time by an MD of −47.51 min/day (95% CI −76.57 to −18.46 min/day, p=0.001, 14 studies, 1474 participants) in favour of the intervention group, whereas longer intervention durations of more than 3 months did not show beneficial intervention effects (table 1). Heterogeneity between studies could not be explained by follow-up duration, intervention setting, type of assessment tool and whether reducing SB was a primary or secondary aim of the study. However, subgroup analysis revealed that long-term effects of interventions were evident up to 12 months. The beneficial intervention effects attenuated at a follow-up duration

of more than 12 months. All intervention settings except workplaces resulted in a significant reduction in SB in favour of the intervention group. Objective assessment of SB using an inclinometer and subjective assessment using proxy measure questionnaires resulted in a detection of a beneficial intervention effect. The overall intervention effect was not influenced by whether SB was a primary or secondary outcome (table 1).

Sensitivity analyses (see online supplementary tables S2–S5) show that results on SB for different types of interventions were not affected by inclusion of cluster RCTs, studies at high risk of attrition and performance bias, and studies with usual care or alternative treatment as the control group.

Secondary outcomes

Studies reported intervention effects on fasting blood glucose concentration,[31 42 56] glycosylated haemoglobin levels,[37 42 69] triglyceride levels,[31 42 56 69] low-density lipoprotein levels,[31 42 56 69] total cholesterol,[37 42 56 69] high-density lipoprotein levels,[31 39 42 56 64 69] blood pressure,[32 38 43 57 59 65 70] BMI,[29 33 36 37 42 55 56 57 58 59 62 64 69 74] waist circumference,[31 42 55–59 62 64 69 74 76] percentage body fat[42 55 56 58 62 64] and mental health outcomes.[29 41 48 49 64 72] Some studies indicated a reduction in these secondary outcomes; however, studies were PA-only or lifestyle interventions and none of the studies were SB-only studies. Therefore, it is not possible to determine the intervention effect of reduced SB on cardiometabolic risk, body composition and mental health outcome. Specific SB studies did not assess the intervention effect on health outcomes. Meta-analysis results for each outcome are not reported here but are available from the authors.

Quality of evidence

Table 2 summarises the quality of evidence for reducing sedentary time by intervention type and duration. Owing to the intention of comparing different types of intervention with various control conditions, which was considered in the sensitivity analyses, the quality of evidence was not downgraded for indirectness or heterogeneity. Many plausible reasons for heterogeneity exist (eg, variation in population age, ethnicity, socioeconomic status).

Lifestyle interventions

The overall quality of evidence for lifestyle interventions was moderate with downgrading of the evidence by one level due to limitations in the design and implementation of the included studies.

PA/SB interventions

The overall quality of evidence of combined PA and SB interventions for reducing SB was moderate. The quality was downgraded by one level for high risk of bias in the majority of included studies.

PA interventions

Overall, the quality of PA intervention was moderate with the majority of studies having a high risk of detection and attrition bias.

SB interventions

The quality of evidence for reducing SB in adults was low based on the two studies available. The quality was downgraded twice for imprecision of results and high risk of performance bias. Participants and personnel were not blinded to the intervention intention.

DISCUSSION

Summary of main findings

There was clear evidence that it is possible to intervene to reduce SB in adults by 22 min/day in favour of the intervention group. Moderate to high-quality evidence on the efficacy of lifestyle interventions for reducing SB suggests that this may be a promising approach. Interventions focusing on SB only resulted in the greatest reduction in sedentary time (42 min/day); however, the quality of evidence was low and restricted to two studies only. Findings suggested that intervention durations up to 3 months and interventions targeting men and mixed genders can produce significant reductions in SB. There was no evidence that PA and combined PA/SB interventions reduced SB. Evidence of intervention effects on changes in patterns of accumulation of SB was limited. Encouragingly, intervention effects were evident up to 12 months. Interventions in any setting except the workplace resulted in a significant reduction in SB in favour of the intervention group.

This systematic review sought to evaluate the evidence of effects of interventions which included SB as an outcome measure on cardiometabolic risk factors, body composition and mental health outcomes. Studies reporting these outcomes were PA or lifestyle interventions, and thus it was unclear whether any intervention effect was due to reduction in SB. Furthermore, the majority of studies that assessed health-related outcomes did not show a reduction in SB. However, improvement of health outcomes due to reduction of SB has been demonstrated in laboratory-based studies[12] and a recently published community-based RCT.[79]

Comparison of the findings with the literature

Prince *et al*[23] published a systematic review on the effects of interventions for reducing SB in adults. Our findings are consistent with those of Prince *et al* in relation to the effect of PA/SB interventions and interventions focusing on SB only, despite there being no overlap of included studies in the latter. The SB studies on which Prince *et al* based their main conclusion were excluded from this review because they either did not report a valid SB outcome measure[80] or the intervention was not independent of the outcome (measuring TV viewing time while blocking TV function).[81] In contrast to Prince *et al*, we found no evidence of a beneficial effect on SB from interventions focused on increasing PA. This difference in findings may be explained by six studies in our review being classed as lifestyle interventions while Prince *et al* classed them as PA interventions and one study being classed as a PA/SB intervention while Prince *et al* classed it as a PA intervention. Authors of future reviews should use precise categories of intervention types to identify the potential of single or multicomponent interventions (eg, lifestyle intervention which, in addition to PA/SB, also included a dietary/nutrition component) to reduce SB.

Other systematic reviews have been conducted with a focus on the effect of workplace interventions for reducing sitting time.[82–84] Some findings are consistent[82] with the findings of this study on the effect of workplace interventions to reduce SB while others were not.[83 84] Inconsistency can be explained by differences in inclusion criteria, since the majority of studies included in these reviews were not RCTs and thus did not qualify for our review. However, further high-quality RCTs investigating the effect of workplace interventions on sitting time are currently being conducted and publication of new evidence will follow shortly.[85]

Implications for research and practice

Findings from lifestyle interventions and studies focusing on reducing SB are promising. While this is encouraging, SB are

Table 2 GRADE assessment of quality of evidence

Interventions for reducing sedentary behaviour			
Outcomes	**Illustrative comparative risks* (95% CI) Corresponding risk Interventions for reducing sedentary behaviour**	**Number of Participants (studies)**	**Quality of the evidence (GRADE)**
Effect of lifestyle interventions	The mean effect of lifestyle interventions in the intervention groups was 24.18 min/day lower (40.66 to 7.70 lower)	3981 (20 studies)	⊕⊕⊕⊖ moderate†
Intervention duration ≤3 months	The mean effect of lifestyle interventions—intervention duration ≤3 months in the intervention groups was 97.75 min/day lower (121.88 to 73.61 lower)	297 (5 studies)	⊕⊕⊕⊕ high
Intervention duration 3–6 months	The mean effect of lifestyle interventions—intervention duration 3–6 months in the intervention groups was 8.42 min/day lower (19.05 lower to 2.21 higher)	1664 (7 studies)	⊕⊕⊕⊖ moderate‡
Intervention duration >6 months	The mean effect of lifestyle interventions—intervention duration >6 months in the intervention groups was 3.99 min/day lower (21.93 lower to 13.96 higher)	2040 (8 studies)	⊕⊕⊕⊖ moderate†
Effect of physical activity/ sedentary behaviour interventions	The mean effect of physical activity/sedentary behaviour interventions in the intervention groups was 32.51 min/day lower (106.52 lower to 41.50 higher)	471 (4 studies)	⊕⊕⊕⊖ moderate†
Intervention duration ≤3 months	The mean effect of physical activity/sedentary behaviour interventions—intervention duration ≤3 months in the intervention groups was 54.69 min/day lower (166.60 lower to 57.22 higher)	214 (3 studies)	⊕⊖⊖⊖ very low§¶
Intervention duration 3–6 months	The mean effect of physical activity/sedentary behaviour interventions—intervention duration 3–6 months in the intervention groups was 23.60 min/day higher (0.78 higher to 46.42 higher)	257 (1 study)	⊕⊕⊕⊖ moderate**
Intervention duration >6 months	No evidence available	0 (0)	No evidence available
Effect of physical activity interventions	The mean effect of physical activity interventions in the intervention groups was 6.08 min/day lower (38.00 lower to 25.84 higher)	1354 (8 studies)	⊕⊕⊕⊖ moderate††
Intervention duration ≤3 months	The mean effect of physical activity interventions—intervention duration ≤3 months in the intervention groups was 10.43 min/day lower (49.85 lower to 28.98 higher)	935 (5 studies)	⊕⊕⊕⊖ moderate††
Intervention duration 3–6 months	The mean effect of physical activity interventions—intervention duration 3–6 months in the intervention groups was 21.52 min/day lower (103.55 lower to 60.51 higher)	184 (2 studies)	⊕⊕⊕⊖ moderate††
Intervention duration >6 months	The mean effect of physical activity interventions—intervention duration >6 months in the intervention groups was 48.60 min/day higher (1.66 to 95.54 higher)	235 (1 study)	⊕⊕⊕⊖ moderate‡‡
Effect of sedentary behaviour interventions	The mean effect of sedentary behaviour interventions in the intervention groups was 41.76 min/day lower (78.92 to 4.60 lower)	62 (2 studies)	⊕⊕⊖⊖ low§§
Intervention duration ≤3 months	The mean effect of sedentary behaviour interventions—intervention duration ≤3 months in the intervention groups was 41.76 min/day lower (78.92 to 4.60 lower)	62 (2 studies)	⊕⊕⊖⊖ low§§
Intervention duration 3–6 months	No evidence available	0 (0)	No evidence available
Intervention duration >6 months	No evidence available	0 (0)	No evidence available

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.
*The basis for the assumed risk (eg, the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% CI) is based on the assumed risk in the control group and the relative effect of the intervention (and its 95% CI).
†The majority of studies were of high risk of selection, performance or detection bias.
‡Half of the studies were of high risk for performance bias (no blinding of participants or personnel to the intervention intention).
§The wide CI indicates imprecision of results.
¶All studies were of high risk of performance bias and more than half showed high risk of attrition.
**The study was of high risk of selection bias.
††Studies were of high risk of detection or attrition bias.
‡‡The study was of high risk of detection bias.
§§The studies were of high risk of performance bias, that is, participants and personnel were not blinded.

health-related behaviours and part of a pathway to better health outcomes. More high-quality research is needed that includes clinical health outcome measures. However, the findings of this review should encourage clinicians and public health practitioners to provide advice on how to reduce total volume of sitting time and breaking up long periods of sitting. This advice should not diminish or replace advice on achieving the recommended levels of MVPA. It is somewhat surprising that interventions that targeted PA alone, or even PA and SB, appeared to be less effective in reducing SB. This suggests that attention needs to be paid to the ways in which SB are targeted in these interventions. For example, it may be important to improve knowledge about the independent health risks of SB and to highlight the risk of compensatory behaviour (eg, a feeling that you have earned the right to be sedentary because you went for a brisk walk earlier). Given the evidence that increased breaks in SB are associated with improved health status, consensus is needed on the most appropriate SB patterning descriptors to use which are

sensitive to intervention (eg, 'breaking rate' or time spent/number of longer sedentary events). New interventions should also be developed around technologies that allow people to monitor their SB in addition to their physical activity to support them in setting goals to reduce their SB and increase PA.

The majority of studies included in the meta-analyses assessed intervention effects using self-report. While self-report measures are pragmatic and may provide contextual information, they have limitations in terms of accuracy. Subgroup analysis revealed that objective assessment of SB using a posture measurement tool such as the *activ*PAL and subjective assessment using proxy measure questionnaires (captures context specific sitting time) resulted in the detection of a beneficial intervention effect. Assessment tools that measure posture might be more valid and reliable in measuring SB and thus detecting intervention effects compared to *estimation of SB* via *accelerometry* (eg, ActiGraph). Therefore, researchers and practitioners should use posture measurement tools and context specific measurement tools which may prompt a reliable cognitive recall of sedentary behaviour.

Heterogeneity between studies was only partly explained by differences of studies in gender and intervention duration. Further work is warranted to identify the 'active ingredients' of the successful interventions and to explore the specific behaviour change techniques employed as well as barriers and facilitators of SB interventions. General principles for development of interventions to reduce SB have been established drawing from behavioural research on physical activity.[86] Examples include evaluating interventions designed for very specific contexts (work environments at home) and using behaviour change theory and associated techniques[87] to systematically understand and change SB in different groups and settings.

Additionally, future studies should consider the influence of gender, given that some cohort studies suggested deleterious relationships of SB with health outcomes to be more pronounced in women than men. However, based on our review evidence, interventions with the potential to reduce SB showed limited effects when targeting women. Limited evidence was available on intervention effects on sedentary time in older adults.

Strengths and limitations

The systematic and transparent methods reported here reduce identification and selection bias. The inclusion criteria used for study designs (only RCTs) meant that the risk of bias was reduced. Overall, the robust methods used in this review ensure that the results and conclusions are likely to be as truly valid and replicable as possible. Subgroup and sensitivity analyses enabled a more nuanced understanding and interpretation of the results, as well as exploring the effect of potentially influential variables. Lastly, our exploration of the clinical outcomes was a strength, and led to the identification of research gaps which should be addressed in future RCTs.

One limitation was that no subgroup analysis for age was undertaken because there were too few studies in older adults.

CONCLUSION

There was evidence that it is possible to intervene to reduce SB in adults by around 22 min/day. Lifestyle interventions and those targeting SB only may be promising approaches, but more high-quality research is needed. More research is also needed to determine if SB interventions are sufficient to produce clinically meaningful and sustainable reductions in sedentary time. Further work is needed to identify the 'active' intervention components.

What are the new findings?

- Interventions targeting sedentary behaviour (SB) and lifestyle interventions can reduce sedentary time in adults.
- Interventions targeting an increase in physical activity and interventions combining an increase of physical activity with reducing sedentary behaviour did not reduce sedentary time in adults.
- We do not yet know if effective interventions for reducing sedentary behaviour result in clinically meaningful and sustained improvements in health outcomes.

How might it impact on clinical and public health practice in the near future?

- The findings of this study (together with the broader body of relevant evidence) do not point to specific recommendations on the degree of reduction in sitting time required to deliver significant health benefits. Nevertheless, the findings should encourage clinicians and public health practitioners to provide advice about reducing the total volume of sitting time and breaking up long periods of sitting by demonstrating that such advice can be effective. This advice should not diminish or replace advice on achieving recommended levels of physical activity.
- Interventions with a focus on physical activity should provide additional emphasis on the importance of and barriers to reducing SB. New technologies should be developed to allow self-monitoring and goal setting around SB as well as physical activity.
- Awareness will be raised on the topic of sedentary behaviour and its impact on health.
- Interventions that target sedentary behaviour will be developed and tested.
- Further research is needed to determine the clinical significance of changing patterns of sedentary behaviour.

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Contributors AM, NM, DHS, RJ and CF led the review on behalf of the EuroFIT consortium. AM, NM, DHS, CF and RJ conceived of the systematic review strategy. AM wrote the protocol and all authors refined and approved it. AM conducted the review and screened the initial results. AM, DHS, RJ, CF and NM appraised and extracted data from the primary studies and analysed the findings. AM drafted the manuscript and all authors contributed to the critical revision of the manuscript and approved the final revised version. NM is the guarantor.

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REFERENCES

1 Barnes J, Behrens TK, Benden ME, *et al*. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours." *Appl Physiol Nutr Metab-Physiol Appliquee Nutr Et Metabolisme* 2012;37:540–2.
2 Owen N, Salmon J, Koohsari MJ, *et al*. Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention. *Br J Sports Med* 2014;48:174–7.
3 de Rezende LF, Rodrigues Lopes M, Rey-López JP, *et al*. Sedentary behavior and health outcomes: an overview of systematic reviews. *PLoS ONE* 2014;9:e105620.
4 Dempsey PC, Owen N, Biddle SJ, *et al*. Managing sedentary behavior to reduce the risk of diabetes and cardiovascular disease. *Curr Diab Rep* 2014;14:1–11.
5 Dunstan DW, Howard B, Healy GN, *et al*. Too much sitting—a health hazard. *Diabetes Res Clin Pract* 2012;97:368–76.
6 Katzmarzyk PT, Church TS, Craig CL, *et al*. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc* 2009;41:998–1005.
7 Matthews CE, George SM, Moore SC, *et al*. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *Am J Clin Nutr* 2012;95:437–45.
8 Seguin R, Buchner DM, Liu J, *et al*. Sedentary behavior and mortality in older women: the Women's Health Initiative. *Am J Prev Med* 2014;46:122–35.
9 Van der Ploeg HP, Chey T, Korda RJ, *et al*. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med* 2012;172:494–500.
10 Healy GN, Dunstan DW, Salmon J, *et al*. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care* 2008;31:661–6.
11 Bailey DP, Locke CD. Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. *J Sci Med Sport* 2014;pii: S1440-2440(14)00051-6 .
12 Peddie MC, Bone JL, Rehrer NJ, *et al*. Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *Am J Clin Nutr* 2013;98:358–66.
13 Dunstan DW, Kingwell BA, Larsen R, *et al*. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care* 2012;35:976–83.
14 Proper KI, Singh AS, van Mechelen W, *et al*. Sedentary behaviors and health outcomes among adults a systematic review of prospective studies. *Am J Prev Med* 2011;40:174–82.
15 Rezende LF, Rey-Lopez J, Matsudo VK, *et al*. Sedentary behavior and health outcomes among older adults: a systematic review. *BMC Public Health* 2014;14:333.
16 Chau JY, Grunseit AC, Chey T, *et al*. Daily sitting time and all-cause mortality: a meta-analysis. *PLoS ONE* 2013;8:e80000.
17 Thorp AA, Owen N, Neuhaus M, *et al*. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. *Am J Prev Med* 2011;41:207–15.
18 Wilmot E, Edwardson C, Achana F, *et al*. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia* 2012;55:2895–905.
19 Healy GN, Clark BK, Winkler EA, *et al*. Measurement of adults' sedentary time in population-based studies. *Am J Prev Med* 2011;41:216–27.
20 Harvey J, Chastin S, Skelton D. Prevalence of sedentary behavior in older adults: a systematic review. *Int J Environ Res Public Health* 2013;10:6645–61.
21 Rhodes RE, Mark RS, Temmel CP. Adult sedentary behavior: a systematic review. *Am J Prev Med* 2012;42:e3–28.
22 Biddle SJ, Petrolini I, Pearson N. Interventions designed to reduce sedentary behaviours in young people: a review of reviews. *Br J Sports Med* 2014;48:182–6.
23 Prince SA, Saunders TJ, Gresty K, *et al*. A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: a systematic review and meta-analysis of controlled trials. *Obes Rev* 2014;15:905–19.
24 Martin A, Saunders D, Jepson R, *et al*. Interventions to influence sedentary behaviour in adults: systematic review and meta-analysis. http://www.crd.york.ac.uk/PROSPERO_REBRANDING/display_record.asp?ID=CRD42014007064: PROSPERO International prospective register of systematic reviews, 2014.
25 Higgins JPT, Green S. eds. *Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]*. The Cochrane Collaboration, 2011.
26 GRADEpro [program]. 3.2 for Windows version, 2008.
27 Review Manager [program]. *5.2 version*. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012.
28 Aadahl M, Linneberg A, Witte D, *et al*. Reduction of sitting time in sedentary men and women. A randomized controlled trial (Sedentary Intervention Trial). *J Sci Med Sport* 2012;15:S302–−303.
29 Abascal LB. The effect of depression and adherence in a dietary and physical activity intervention for overweight and obese adults. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2008;69(4-B):2614.
30 Allen NA, Fain JA, Braun B, *et al*. Continuous glucose monitoring counseling improves physical activity behaviors of individuals with type 2 diabetes: a randomized clinical trial. *Diabetes Res Clin Pract* 2008;80:371–9.
31 Andersen E, Burton NW, Anderssen SA. Physical activity levels six months after a randomised controlled physical activity intervention for Pakistani immigrant men living in Norway. *Int J Behav Nutr Phys Act* 2012;9:47.
32 Barwais FA, Cuddihy TF, Tomson LM. Physical activity, sedentary behavior and total wellness changes among sedentary adults: a 4-week randomized controlled trial. *Health Qual Life Outcomes* 2013;11:183.
33 Burke L, Lee AH, Jancey J, *et al*. Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomized controlled trial. *Int J Behav Nutr Phys Act* 2013;10:14.
34 Carlson JA, Sallis JF, Ramirez ER, *et al*. Physical activity and dietary behavior change in Internet-based weight loss interventions: comparing two multiple-behavior change indices. *Prev Med* 2012;54:50–4.
35 Chin A Paw MJ, van Poppel MN, *et al*. Effects of resistance and functional-skills training on habitual activity and constipation among older adults living in long-term care facilities: a randomized controlled trial. *BMC Geriatr* 2006;6:9. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/914/CN-00566914/frame.html
36 De Cocker K, Spittaels H, Cardon G, *et al*. Web-based, computer-tailored, pedometer-based physical activity advice: development, dissemination through general practice, acceptability, and preliminary efficacy in a randomized controlled trial. *J Med Internet Res* 2012;14:e53.
37 De Greef K, Deforche B, Tudor-Locke C, *et al*. A cognitive-behavioural pedometer-based group intervention on physical activity and sedentary behaviour in individuals with type 2 diabetes. *Health Educ Res* 2010;25:724–36.
38 De Greef KP, Deforche BI, Ruige JB, *et al*. The effects of a pedometer-based behavioral modification program with telephone support on physical activity and sedentary behavior in type 2 diabetes patients. *Patient Educ Couns* 2011;84:275–9.
39 Dunn AL, Marcus BH, Kampert JB, *et al*. Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: a randomized trial. *JAMA* 1999;281:327–34.
40 Evans RE, Fawole HO, Sheriff SA, *et al*. Point-of-choice prompts to reduce sitting time at work: a randomized trial. *Am J Prev Med* 2012;43:293–7.
41 Fitzsimons CF, Baker G, Gray SR, *et al*. Does physical activity counselling enhance the effects of a pedometer-based intervention over the long-term: 12-month findings from the Walking for Wellbeing in the west study. *BMC Public Health* 2012;12:206.
42 Hu G, Tian H, Zhang F, *et al*. Tianjin Gestational Diabetes Mellitus Prevention Program: study design, methods, and 1-year interim report on the feasibility of lifestyle intervention program. *Diabetes Res Clin Pract* 2012;98:508–17.
43 Jago R, Sebire SJ, Turner KM, *et al*. Feasibility trial evaluation of a physical activity and screen-viewing course for parents of 6 to 8 year-old children: teamplay. *Int J Behav Nutr Phys Act.* 2013;10:31. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/090/CN-00864090/frame.html
44 Judice PB, Matias CN, Santos DA, *et al*. Caffeine intake, short bouts of physical activity, and energy expenditure: a double-blind randomized crossover trial. *PLoS ONE* 2013;8:e68936.
45 Lakerveld J, Bot SDM, Van der Ploeg HP, *et al*. The effects of a lifestyle intervention on leisure-time sedentary behaviors in adults at risk: the Hoorn Prevention Study, a randomized controlled trial. *Prev Med* 2013;57:351–6.
46 Marshall AL, Leslie ER, Bauman AE, *et al*. Print versus website physical activity programs: a randomized trial. *Am J Prev Med* 2003;25:88–94.
47 McGuire MT, Jeffery RW, French SA, *et al*. The relationship between restraint and weight and weight-related behaviors among individuals in a community weight gain prevention trial. *Int J Obes Relat Metab Disord* 2001;25:574–80.
48 Mutrie N, Doolin O, Fitzsimons CF, *et al*. Increasing older adults' walking through primary care: results of a pilot randomized controlled trial. *Fam Pract* 2012;29:633–42.
49 Opdenacker J, Boen F. Effectiveness of face-to-face versus telephone support in increasing physical activity and mental health among university employees. *J Phys Act Health* 2008;5:830–43.
50 Ostbye T, Krause KM, Lovelady CA, *et al*. Active Mothers Postpartum: a randomized controlled weight-loss intervention trial. *Am J Prev Med* 2009;37:173–80.
51 Papalazarou A, Yannakoulia M, Kavouras SA, *et al*. Lifestyle intervention favorably affects weight loss and maintenance following obesity surgery. *Obesity* 2010;18:1348–53.
52 Raynor HA, Steeves EA, Bassett DR Jr, *et al*. Reducing TV watching during adult obesity treatment: two pilot randomized controlled trials. *Behav Ther* 2013;44:674–85.
53 Slootmaker SM, Chinapaw MJM, Schuit AJ, *et al*. Feasibility and effectiveness of online physical activity advice based on a personal activity monitor: randomized controlled trial. *J Med Internet Res* 2009;11:e27.
54 Spring B, Schneider K, McFadden HG, *et al*. Multiple behavior changes in diet and activity: a randomized controlled trial using mobile technology. *Arch Intern Med* 2012;172:789–96.
55 Steeves JA, Bassett DR, Fitzhugh EC, *et al*. Can sedentary behavior be made more active? A randomized pilot study of TV commercial stepping versus walking. *Int J Behav Nutr Phys Act* 2012;9:95.

56 Thompson JL, Allen P, Helitzer DL, *et al*. Reducing diabetes risk in American Indian women. *Am J Prev Med* 2008;34:192–201.
57 Fitzgibbon ML, Stolley MR, Schiffer L, *et al*. A combined breast health/weight loss intervention for Black women. *Prev Med* 2005;40:373–83. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/377/CN-00511377/frame.html
58 Hansen AW, Grønbæk M, Helge JW, *et al*. Effect of a web-based intervention to promote physical activity and improve health among physically inactive adults: a population-based randomized controlled trial. *J Med Internet Res* 2012;14:e145. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/871/CN-00841871/frame.html
59 Katzmarzyk PT, Champagne CM, Tudor-Locke C, *et al*. A short-term physical activity randomized trial in the lower Mississippi delta. *PLoS ONE* 2011;6:e26667.
60 Lane A, Murphy N, Bauman A, *et al*. Randomized controlled trial to increase physical activity among insufficiently active women following their participation in a mass event. *Health Educ J* 2010;69:287–96.
61 López-Fontana CM, Sánchez-Villegas A, Martínez-Gonzalez MA, *et al*. Daily physical activity and macronutrient distribution of low-calorie diets jointly affect body fat reduction in obese women. *Appl Physiol Nutr Metab* 2009;34:595–602. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/007/CN-00722007/frame.html
62 Kallings LV, Sierra Johnson J, Fisher RM, *et al*. Beneficial effects of individualized physical activity on prescription on body composition and cardiometabolic risk factors: results from a randomized controlled trial. *Eur J Cardiovasc Prev Rehabil* 2009;16:80–4.
63 Pedersen SJ, Cooley PD, Mainsbridge C. An e-health intervention designed to increase workday energy expenditure by reducing prolonged occupational sitting habits. *Work* 2014;49:289–95.
64 Baker G, Gray SR, Wright A, *et al*; Scottish Physical Activity Research Collaboration (SPARColl). The effect of a pedometer-based community walking intervention "Walking for Wellbeing in the West" on physical activity levels and health outcomes: a 12-week randomized controlled trial. *Int J Behav Nutr Phys Act* 2008;5:44.
65 Gilson ND, Puig-Ribera A, McKenna J, *et al*. Do walking strategies to increase physical activity reduce reported sitting in workplaces: a randomized control trial. *Int J Behav Nutr Phys Act* 2009;6:43.
66 Morrison R, Reilly JJ, Penpraze V, *et al*. Children, parents and pets exercising together (CPET): exploratory randomised controlled trial. *BMC Public Health* 2013;13:1096.
67 Poston L, Briley AL, Barr S, *et al*. Developing a complex intervention for diet and activity behaviour change in obese pregnant women (the UPBEAT trial); assessment of behavioural change and process evaluation in a pilot randomised controlled trial. *BMC Pregnancy Childbirth* 2013;13:148.
68 Robertson MM, Ciriello VM, Garabet AM. Office ergonomics training and a sit-stand workstation: effects on musculoskeletal and visual symptoms and performance of office workers. *Appl Ergon* 2013;44:73–85.
69 Canuto K, Cargo M, Li M, *et al*. Pragmatic randomised trial of a 12-week exercise and nutrition program for Aboriginal and Torres Strait Islander women: clinical results immediate post and 3 months follow-up. *BMC Public Health* 2012;12:933.
70 van Berkel J, Boot CR, Proper KI, *et al*. Effectiveness of a worksite mindfulness-based multi-component intervention on lifestyle behaviors. *Int J Behav Nutr Phys Act* 2014;11:9.
71 Lioret S, Campbell KJ, Crawford D, *et al*. A parent focused child obesity prevention intervention improves some mother obesity risk behaviors: the Melbourne infant program. *Int J Behav Nutr Phys Act* 2012;9:100.
72 Rosenberg DE. Outcomes of a multilevel walking intervention for older adults living in retirement communities. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2011;71(8-B):5143.
73 Sternfeld B, Block C, Quesenberry CP Jr, *et al*. Improving diet and physical activity with ALIVE: a worksite randomized trial. *Am J Prev Med* 2009;36:475–83.
74 Verweij LM, Proper KI, Weel ANH, *et al*. The application of an occupational health guideline reduces sedentary behaviour and increases fruit intake at work: results from an RCT. *Occup Environ Med* 2012;69:500–7.
75 Anand SS, Davis AD, Ahmed R, *et al*; SHARE-AP ACTION Investigators. A family-based intervention to promote healthy lifestyles in an aboriginal community in Canada. *Can J Public Health* 2007;98:447–52.http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/774/CN-00668774/frame.html
76 Adams MM. On our feet: feasibility trial of an intervention to reduce sedentary behavior and increase physical activity. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2013;73:(10-B(E)):No Pagination Specified.
77 Parry S, Straker L, Gilson ND, *et al*. Participatory workplace interventions can reduce sedentary time for office workers—a randomised controlled trial. *PLoS ONE* 2013;8:e78957.
78 Andersen E, Høstmark AT, Anderssen SA. Effect of a physical activity intervention on the metabolic syndrome in Pakistani immigrant men: a randomized controlled trial. *J Immigr Minor Health* 2012;14:738–46. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/646/CN-00848646/frame.html
79 Aadahl M, Linneberg A, Møller TC, *et al*. Motivational counseling to reduce sitting time. *Am J Prev Med* 2014;47:576–86.
80 Carr LJ, Karvinen K, Peavler M, *et al*. Multicomponent intervention to reduce daily sedentary time: a randomised controlled trial. *BMJ Open* 2013;3:e003261.
81 Otten JJ, Jones KE, Littenberg B, *et al*. Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomized controlled trial. *Arch Intern Med* 2009;169:2109–15.
82 Chau JY, der Ploeg HP, van Uffelen JG, *et al*. Are workplace interventions to reduce sitting effective? A systematic review. *Prev Med* 2010;51:352–6.
83 Neuhaus M, Eakin EG, Straker L, *et al*. Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations. *Obes Rev* 2014;15:822–38.
84 Torbeyns T, Bailey S, Bos I, *et al*. Active workstations to fight sedentary behaviour. *Sports Med* 2014;44:1261–73.
85 Shrestha N, Ijaz S, Kukkonen-Harjula Katriina T, *et al*. Workplace interventions for reducing sitting at work. *Cochrane Database Syst Rev* 2015;1:CD010912. http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD010912/abstract
86 Owen N, Sugiyama T, Eakin EE, *et al*. Adults' sedentary behavior: determinants and interventions. *Am J Prev Med* 2011;41:189–96.
87 Michie S, Johnston M. Theories and techniques of behaviour change: developing a cumulative science of behaviour change. *Health Psychol Rev* 2012;6:1–6.

Interventions with potential to reduce sedentary time in adults – systematic review and meta-analysis

Online only supplementary material

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1 **Table 1: Characteristics and authors' conclusions of intervention effect of included studies**

Study ID, Country, Funding source	Participant characteristics	Study design	Intervention	Intervention setting	Intervention duration	Control condition	Attrition rates	SB primary outcome	Author's conclusion
Abascal 2008a USA National Cancer Institute	N: I=153, C=155, Mean age across groups: 43.9 ± 8.0y Gender: all males	RCT	"iPace Men in Motion": Use of **a pedometer, web-based activities** which included learning about and applying new behavioral skills, and reading **diet and physical activity topics**. Encouragement to log on weekly to report weight and progress on goals (at least 10,000 steps (5-7 d/wk) and participating in strength training two times per week).	Home based	12 months	Waiting list: Access to an alternate website and encouragement to log on monthly. The control website contained general health information of interest to men but not likely to lead to changes in diet or physical activity behaviors.	I = 32%, C = 29%, Total = 30%	no - BMI change	Decreased sedentary behaviour in favour of the intervention group
Abascal 2008b USA National Cancer Institute	N: I=140, C=146 Mean age across groups: 41.2 ± 8.7y Gender: all females	RCT	"iPace Women in Balance": Initial web-based assessment**, health behavior counseling** follow-up intervention via the **web**, and periodic **phone and email interaction with a health counselor**. Target behaviors for the intervention included **increasing physical activity (30-60 minute goal), fruit and vegetable intake, fiber intake, and decreasing dietary fat.**	General practise/ home	12 months	Usual-care: Consisted of previously scheduled provider visits without health behavior counseling and a standard set of materials summarizing diet and activity recommendations	I= 32%, C = 25%, total = 29%	no - diet and PA behaviour change	No significant intervention effects on sedentary behaviour
Adams 2012 USA Funding source not reported	N: I=40, C=24 Mean age: 58.47±12.55y Gender: all female	cluster RCT (cluster size: I=4, C=3)	"On our Feet": **face-to-face interactions and email messages**. The content was intended to **increase self-efficacy for reducing sedentary behaviour and for increasing light physical activity** by highlighting mastery experiences related to both behaviors.	community	6 weeks	waiting list	I= 14%, C= 14%, Total = 18%	yes	No significant intervention effects on sedentary behaviour
Allen 2008 USA Funding source not reported	N: I=27, C=25 Mean age across groups: 57y Gender: male+female,	RCT	**Provision of an activity monitor** at week 1. Participants received 90 min of **individualized education and physical activity counselling**. This counselling protocol was designed to change efficacy beliefs about physical activity	home/community	8 weeks	Alternative treatment: The control group received 90 min of individualized diabetes education based on major components from the International Diabetes Center curriculum	Not reported	no - PA and self-efficacy behavior	Decreased combined sedentary behavior and light physical activity in favor of the intervention

	proportions not obtainable								group.
Anand 2007 Australia Funding source not reported	N (include children): I=88, C=86 Mean age: I= 41y, C= 37y Gender: not reported for adults	cluster RCT (cluster size: I=29, C= 28)	"SHARE-AP ACTION": The intervention consisted of a **regular home visit** by Aboriginal health counsellors who were trained to assess and set **dietary and physical activity goals** for each household member.	home based	6 months	Usual care: families received Canada's Food Guide to Healthy Eating and Canada's Physical Activity Guide to Healthy Active Living.		no - lower Ei, more PA	No significant intervention effects on sedentary behavior on cluster level.
Andersen 2012 Norway Norwegian Extra Foundation for Health and Norwegian School of Sport Sciences, Department of Sport Medicine	N 6-months: I=76, C=50; N 12-months: I=59, C=38 Mean age: I=35.7 ±6.1y, C=39.7 ±9.2y Gender: all male	RCT	"Physical Activity and Minority Health": The programme included **structured group exercise sessions** led by an exercise physiologist twice a week, two **group lectures**, one **individual counselling session, written material and a phone call.**	community	6 months	Waiting list: organised exercise (once a week for four months), one group lecture and written material after the end of the intervention.	16%/35%	No - increase of PA	Decreased sedentary behaviour in favour of the intervention group
Baker 2010 UK Scottish Government	N: I=39, C=40 Mean age: I= 47.3 ±9.3y, C= 51.2 ±7.9y Gender across groups: 20% men, 80% women	RCT	"Walking for Well-being in the West": **Physical activity consultation** and **pedometer-based walking program**. The **consultations** were focused on promoting increases in walking. The overall goal was to increase mean daily step-count by 3,000 accumulated steps above baseline value on 5 days/week.	community	12 weeks	Waiting list: asked to maintain their normal walking levels	INT = 18%, CON = 20%	no - increase of walking	Decreased sedentary behaviour in favour of the intervention group

Barwais 2013 Australia Funding source not reported	N: I=18, C=15 Mean age across groups: 27 ± 4y Gender across groups: 67% men, 33% women	RCT	Interaction with an **online personal activity monitor**. The device was designed to motivate a **reduction in sedentary behavior and increase physical activity** in the activities of daily living. Data subsequently provide the user with a visualization of daily activity patterns.	home based	4 weeks	No treatment: instructed to follow the normal, daily lifestyle patterns.	0%	yes	Decreased sedentary behaviour in favour of the intervention group
Burke 2013 Australia Australian National Health and Medical Research Council grant	N: I=375, C=199 Mean age: I= 65.8±3.0y, C= 65.8 ±3.2y Gender: I=53%men, 47% women, C=51% men, 49% women	RCT	"Physical Activity and Nutrition for Seniors": specially designed **booklet** that provided participants with information and **promoted dietary and physical activity goal setting**. Supplementary materials were an exercise chart, calendar, bi-monthly newsletters, resistance bands and pedometers. Trained group guides provided support for participants.	home based	6 months	no treatment	INT = 29%, CON = 13%	yes - (PA and nutrition behaviour)	Decreased sedentary behaviour in favour of the intervention group
Canuto 2012 Australia Australian National Health and Medical Research Council grant	N: I=51, C=49 Mean age: I=39.8y C= 40.7y Gender: all females	RCT	Women's Fitness Program: structures 45-60min group aerobic and resistance exercise 2x/week, provision of pedometers and encouragement to reach 10,000 steps/week, 4 group nutrition and healthy lifestyle workshops	community	12 weeks	Waiting list	Not available for primary outcome	yes	Results on secondary outcomes available only
Carlson 2012 USA Funding source not reported	N: I=163, C=189 Mean age: I=44.3± 7.9y, C=42.2 ±8.7y Gender: I = 47.2% men, 52.8% women, C=48.1% men,	RCT	An interactive **web-based program** to help participants set goals relative to their initial status on each of the behavioral targets. Goals: **increasing fruit and vegetable intake** to 5–9+servings/day; **decreasing total fat** to 30% of total calorie **consumption; increasing PA to 30–60 min/day 5–7 days/week; increasing steps/day measured by pedometer to ≥10,000 (men only); and participating in**	home based	12 months	Waiting list (women), attention control (men): In the men's study, the control condition had access to a website that contained general health information topics (e.g., information on sun exposure protection and worksite injury prevention).	INT = 32%, CON = 23%	no - weight loss through dietary and physical activity changes	Decreased sedentary behaviour in favour of the intervention group

	51.9% women		**strength training** twice/ week targeting at least two body areas (upper-body, lower-body and core; men only).						
Chin A Paw 2006 The Netherlands Dutch Health Research Council, 'Stichting Ouderen in Beweging West-Friesland', Regional Health Care Insurance Company Univé, TechnoGym Benelux B.V. and Nijha Lochem B.V.	N: I1=40, I2=41, I3= 45, C=31 Mean age: I1=81.0±5.8yI 2=82.1±4.9yI3 =80.9±6.3yC= 81.3±4.4y Gender: I1=27% men, 73% women, I2= 20% men, 80% women, I3=16% men, 84% women, C=16% men, 84% women	RCT	Arm 1: The **resistance training program** was performed twice a week in groups. Resistance increased until two sets of 8–12 repetitions were possible. Resistance was to be increased after the participant could complete two sets of 12 repetitions for two consecutive sessions. Arm 2: The **functional-skills training program** was performed twice a week during six months in groups consisting of 5–10 min of warm-up activities, 30–35 min of skills training in game-like and cooperative activities and cool-down period (5–10 min) Arm 3: C**ombination group** performed once weekly the resistance training and once weekly the allround functional-skills training protocol.	home based	6 months	Attention control: Group discussions about topics of interest to older people such as history of the 20th century, music, relaxation etc.. Sessions were organized two days of the week during six months for 45–60 min in groups of 7–15 participants, supervised by a professional creative therapist.	resistance training 30%, functional-skills training 27%, combined training 21% and control group 39%. 8 participants discontinued the intervention because they found the exercise program too intensive.	no -effect on habitual PA and constipation	No significant intervention effects on sedentary behaviour
De Cocker 2012 Belgium Research Foundation Flanders, National Health and Medical Research Council of Australia' and National Heart Foundation of Australia	N: I=45 (28 sitting), C=47 (35 sitting) Mean age: I=46.6±10.9yC =47.7±11.4y Gender: I= 38% men, 62% women, C=45% men, 55% women	RCT	**Pedometer** intervention supplemented with **computer-tailored step advice**.	home based	3 months	Alternative treatment: pedometer provision	INT = 29%, CON = 22%	no - acceptability, step count	No significant intervention effects on sedentary behaviour

De Greef 2010 Belgium Funding source not reported	N: I=21,C=20 Mean age: I=61.3±6.3y, C=61.3±6.9y Gender: I=62%, 38% women, C=75% men, 25% women	RCT	**Lifestyle intervention (dietary and physical activity)** that consisted of five **cognitive-behavioural group sessions** of 90 min. In addition participants received a **pedometer** and a pedometer diary as motivational tools.	Community/home	12 weeks	Usual care: one single-group education on the effects of PA on diabetes care.	Week 13 (immediate post-intervention): was 9.7% (two persons in each group); Week 52 (follow up): the average dropout was 12.2% (one more participant from the IG lost interest)	yes	Decreased sedentary behaviour in favour of the intervention group
De Greef 2011 Belgium Funding source not reported	N: I=60, C=32 Mean age for both groups: 62±9y Gender for both groups: 69% men, 31% women	RCT	Consisted of a **face-to-face session, a pedometer and telephone support**. 30 min face-to-face sessions started with a motivational interview phase. The psychologist together with the participants made an **individualized lifestyle plan**. After this session patients started the telephone support program given by the psychologist.	Hostpital /home based	24 weeks	Usual care	two patients in each group dropped out	yes	Decreased sedentary behaviour in favour of the intervention group
Dunn 1998 USA National Institute of Health	N: I=121, C=114 Mean age: I=45.9±6.8y, C=46.2±6.5y Gender: I= 50% men, 50% women, C= 49.1% men, 50.9% women	RCT	"Project Active": Lifestyle **physical activity** programme: Encouragement to engage in daily 30 min MVPA, behaviour change methods (e.g. problem solving) applied in group sessions	Community (Fitness centre)	24 months	Alternative treatment: structured exercise programme	INT = 18%, CON = 22%	no- increase in Physical Activity Energy Expenditure	Decreased sedentary beahviour in favour of the control group
Evans 2012 UK Funding source not reported	N: I=14, C=14 Mean age: I=49±8y, C= 39±10y Gender:	RCT	**Education programme** (see control group) and **Point of Choice PC** software: advice window that reminded participants to take a break appeared on the monitor for 1 minute every 30 minutes from	work place	5 days	Alternative treatment: 30 min. **education programme on sedentary behaviour** and breaking prolonged sitting time, information leaflet		Yes	Decreased duration and number of sitting events in favour of the intervention

	I= 29%men, 71% women, C= 29%men, 71% women		the time the PC was started. The window could not be minimized or moved, but participants could work in any opened windows around it.						group.
Fitzgibbon 2005 USA National Cancer Institute and Postdoctoral Research Supplement for Underrepresented Minorities	N: $I_{Cohort\ 1}$ =12, $I_{Cohort\ 2}$ =14, $C_{Cohort\ 1}$ = 13, $C_{Cohort\ 2}$ = 18 Mean age for both groups in each cohort: Cohort 1 = 44.4±7.9y, Cohort 2 = 45.1±6.9y Gender: all female	RCT	The first 90-min weekly meeting was divided into a 45-min interactive **didactic component** and a 45-min exercise component **(structured aerobics and walking**). The second weekly meeting consisted of a 45-min **exercise session.**	community	20 weeks	Attention control: received weekly newsletters by mail. These newsletters focused on general health topics such as first aid, smoking cessation, and screening for cancers other than breast cancer.	Cohort 1 = 17%, Cohort 2 = 5%	No - The intervention was designed to decrease weight, decrease dietary fat intake, increase physical activity, and increase BSE proficiency	No significant intervention effects on sedentary behaviour
Fitzsimons 2012 UK Scottish Government	N: I=39, C=40 Mean age: I = 47.3±9.3y, C= 51.2±7.9y Gender: I= 21% men, 79% women, C=20% en, 80% women	RCT	"Walking for Well-being in the West": Following the 12 week walking programme (Baker 2010), participants received a second **individual physical activity consultation** focusing on relapse prevention strategies, encouragement and maintenance of activity. At 24 weeks participants received a **written physical activity advice leaflet** and at 36 weeks remote support in the form of a **short telephone consultation**.	community based	12 months	Alternative treatment: individualised 12 week walking programme five minutes of brief advice and a pedometer		No - increased walking	Decreased sedentary behaviour in favour of the intervention group
Gilson 2009 UK, Australia Funding source not reported	N: I1 = 60, I2 = 59, C=60 Mean age: I1=42.1±9.2y I2= 41.0±9.7y C= 40.8±11.4y Gender: I1=25% men,	RCT	**Pedometer** use and weekly **group emails** as a motivational and self-regulatory tool, participants with > 10,000 daily steps at pre-intervention were encouraged to maintain this level of workday walking and add additional steps where possible. Arm 1: directed to achieve step	workplace - white-collar university employees	10 weeks	Waiting list: Control group participants were asked to maintain their normal behavior over a ten-week period	missing data: 16%	yes - through increased walking/less sitting	No significant intervention effects on sedentary behaviour.

	75% women, I2= 20% men, 80% women, C = 18% men, 82% women		goal through **brisk, sustained, route-based walking during work** breaks campus walks supported by maps, times (10-to-45 minutes) and step count. Arm 2: asked to engage in **incidental walking and accumulate step counts during working tasks** (e.g. walking and talking to colleagues)						
Hansen 2012 Denmark TrygFonden	N: I=4435, C=4509 Mean age: I= 50.7±13.6y C=50.4±13.7y Gender: I=35% men, 65% women, C= 35% men, 65% women	RCT	Automated **web-based physical activity intervention**: The website was structured as three major parts: (1) a personal page, which included individually tailored PA advice and a personal profile, (2) a page with training programs and general recommendations, and (3) a forum and discussion page for questions from participants.	home based, web based	3 months?	no treatment	43.80% participation rate. Attrition rates in the 3-month questionnaire were I=42%; C=33%. Attrition rate at 6 months follow-up: I=41%, C=33%	no - increased PA	No intervention effects on sedentary behaviour
Hu 2012 China European Foundation for the Study of Diabetes (EFSD), Chinese Diabetes Society (CDS), Lilly Programme for Collaborative Research between China and Europe, Tianjin Public Health Bureau	N: I=192, C=212 Mean age: I= 32.3±3.5y, C=32.4±3.6y Gender: All females	RCT	A 2-week ''run-in'' period with 2 classes on general principles of **lifestyle intervention for the prevention of type 2 diabetes and obesity**. **Dietary intervention**: one-on-one meetings with a dietitian and provision of daily menu for 5 days. The **physical activity** goal is to gradually increase the physical activity from 15 to 30 min/day over the first 4 weeks. The level of physical activity increased to at least 30 min/day, 7 days/week over the whole trial.	home	1 year, year 2 maintenance period	Usual care: Education regarding general principles of healthy lifestyle that benefits type 2 diabetes and obesity prevention, and information about the current evidence showing that the lifestyle intervention is effective in women at high risk for type 2 diabetes.	I=67%, C=64%	no - gestational diabetes prevention	Decreased sedentary behaviour in favour of the intervention group

Jago 2013 UK British Heart Foundation	1st follow-up: INT = 23; 2nd follow-up: INT = 22 Mean age: not reported Gender: I=100% women, C=97.5% women, 2.5% men	RCT	"Teamplay": **parenting program,** The content drew heavily on key issues that affected **parental PA and SV behaviors**. A Teamplay leader manual was produced which gave detailed session plans for the 8-week course in order to ensure consistency of delivery across groups and the meeting of learning objectives.	community	8 weeks, + 2 months follow up	no treatment: provided with written materials summarizing the intervention content at the end of the study	1st follow up: I= 8%, C=35%; 2nd follow-up: I=12%, C=52%	yes	Both groups reduced weekday TV viewing time. Group differences not assessed.
Judice 2013 Portugal Portuguese Institute of Hydration and Health	N:I=10, C=11? Mean across groups: 24.3 ± 4.5y Gender: all male	RCT (cross-over)	5 mg of caffeine per kg of body mass per day was administered. The dose of caffeine was divided into two equal parts (2.5 mg kg-1) to be orally consumed through capsules in the morning and after lunch.		4 days	placebo controlled : maltodextrin as placebo, dose (5 m kg-1day-1) and number of placebo capsules, of the same color as the caffeine capsules, containing maltodextrin were provided for the placebo condition.		yes	No intervention effects on sedentary behaviour
Kallings 2009 Schweden Swedish National Institute of Public Health, The Swedish Heart and Lung Foundation, Swedish National Centre for Research in Sports, Tornspiran Foundation, Karolinska Institutet Founds and	N: I=47, C=54 Mean age in both groups: 68y Gender: I=43% men, 57% women, C=43% men, 57% women	RCT	"Physical Activity on Prescription (PAP)": 30 minutes of **patient centred counselling and individualized written prescription of PAP**. Participants in the intervention group were encouraged **to reduce their time spent in sedentary behaviour**.	GP practice	6 months	Alternative treatment: low-intensity intervention, with one page of written general information about the importance of PA for health.	INT = 13%, CON = 7%	yes	No group differences in sedentary behaviour

Capio Foundation.									
Katzmarzyk 2011 USA ARS/USDA cooperative agreement, Louisiana Public Facilities Authority Endowed Chair in Nutrition.	N: I=20, C=23 Mean age: I=52.7±8.8y, C=50.3±7.7y Gender: I= 20.0% men, 89% women, C= 13.0% men, 87% women	RCT	**Education +pedometer**: **physical activity** brochure (for description see control group) and pedometer. Walking with an interventionist for approximately 10 minutes to build self-efficacy for **walking at MVPA** and to observe how quickly steps accrued. Specific strategies discussed and encouragement to **increase steps/day** by an amount that would approximate USDA guidelines for the prevention of weight gain.	home	1 week	Alternative treatment: brochure detailing the importance of physical activity for maintaining health, the physical activity guidelines, and strategies to **increase physical activity** levels	INT = 23%, CON = 18%	no - increase in MVPA	No intervention effects on sedentary behaviour
Lakerveld 2013 The Netherlands Netherlands Organization for Health Research and Development	N at 6 months: I =267, C=269, N at 1 year: I=249, C=253, N 2 years: I=242,C=249 Mean age: I= 43.6± 5.1y, C=43.4± 5.5y Gender: I=43% men, 57% women, C= 59% men, 41% women	RCT	"Hoorn Prevention Study": In a maximum of six individual 30-min **counseling sessions, followed by 3-monthly sessions by phone**, an innovative combination of motivational interviewing and problem solving treatment were used. The participants were free to **choose which lifestyle component**(s) (smoking, physical activity or diet) they wanted to change.	GP practice	6 months	Alternative treatment: health brochure with information and guidelines with regard to healthy physical activity levels, a healthy diet and smoking cessation.	6month: INT = 15%, CON = 13%, 1 year: INT = 21%, CON = 18%, 2 years: INT = 23%, CON = 19%	yes	No intervention effects on sedentary behaviour. Stratified analyses for educational attainment revealed a small and temporary between-group difference in favour of the intervention group, in those who finished secondary school.

Lane 2010 Ireland Funding source not reported	N: I=55,C=57 Age: 84% were aged between 21y and 49y Gender: all female	RCT	The intervention consisted of two **print booklet**s, specific to initial and later stages of motivational readiness. The booklets contained information and strategies designed to alter self-efficacy, social support, outcome expectancy and barriers to **physical activity**.	home	6 weeks	Attention control: Healthy eating and nutrition booklet developed by the Irish Heart Foundation, An Bord Bia and the Health Promotion Unit.	INT = 35%, CON = 37%	no - PA and self-efficay behaviour	Reduced sitting time in favour of the control group
Lioret 2012 Australia Funding source not reported	N: I=179,C=178 Mean age: I=32.5±4.2y, C=32.0±4.4y Gender: all female	cluster RCT cluster size = 14 local governm ent areas	"Melbourne InFANT Program": focused on **parenting skills and behaviors that aimed to promote the development of healthy eating and physical activity behaviors** in infants, along with **reduced sedentary behaviors**. This dietician-delivered intervention comprised six 2-hour sessions delivered quarterly during the regular meeting time of the first-time parents' group. Intervention materials incorporated six key messages within a DVD and written handouts.	home based	18 months	Usual care/attention control: newsletters regarding generic issues in child health	INT = 10%, CON = 8%	yes	No significant intervention effect on sedentary behaviour
Lopez-Fontana 2009 Spain Navarra Government, CIBERobn, and the Special Research Line of Nutrition, Obesity and Health of the University of Navarra, Friend's	N: I=19, C=21 Mean age: I=34.2±6.2y, C=34.5±7.9y Gender: all female	RCT	**Low-CHO–high-fat diet**:. Each volunteer receiveda plan detailing the food distribution, quantities of each food, weekly meal menu, quantity of oil permitted per day, recipes and cooking techniques, and specific suggestions.		10 weeks (Sedentary behaviour assessment after 5 weeks)	Alternative treatment: **high-carbohydrate–low-fat diet**. Each volunteer received a plan detailing the food distribution, quantities of each food, weekly meal menu, quantity of oil permitted per day,recipes and cooking techniques	0% in each group	no - weight change/loss	No post-intervention group differences in sedentary behaviour reported

Association of the University of Navarra									
Marshall 2003 Australia National Heart Foundation of Australia	N: I=327, C=328 Mean age: I= 43±10y, C=43±11y Gender: I=50% men, 50% women, C=47% men, 53% women	RCT	**PA program delivered via an interactive stage-targeted website and e-mail**. The "Active Living" website was based on the content of the "Active Living" booklets. The website included interactive and animated features, stage-based quizzes with feedback on responses, as well as personalized sections on goal setting, activity planning, determining target heart rates, and a PA readiness questionnaire.	home based	8 weeks	Alternative treatment: Physical activity program delivered via print. The print intervention included the previously tested "Active Living" booklets, additional behavioral reinforcement letters were sent to participants every 2 weeks	INT = 24%, CON = 20%	no - increase in PA	Reduced weekday sitting time in favour of the intervention group
McGuire 2001 USA Funding source not reported	N: I1=306, I2 =305, C=613 Mean age across groups: 35.2±6.3y Gender across all groups: 21% men, 79% women	RCT	Arm 1: **Education only** group which received monthly newsletters that **emphasized self-weighing, increased servings of fruits and vegetables, decreased servings of high-fat foods, and walking**. The monthly newsletters were mailed to participants for the 3y of the intervention. Arm 2: **Education plus lottery incentive group**. This group received the same monthly newsletters as the education-only group but, in addition, they were entered into a lottery drawing for $100 if they returned their adherence postcard.	community	3 yrs	no treatment	Not reported	no - weight gain prevention	No group effects reported
Morrison 2013 UK Henry Dryerre Scholarship,	N: I=16, C=12 Mean age for groups: 44.8 y Gender for	RCT	Children, parents and the pet dog being physically active together by providing **information on dog walking routes and promoting various forms of active play with the dog both indoors and outdoors**. Intervention families received	family	10 weeks	no treatment	INT = 6%, Con = 0%	No - feasibility, increase the frequency, intensity, and duration of dog-walking/playing with the family	No significant intervention effect on sedentary behaviour

administered by the Carnegie Trust for the Universities of Scotland. Medical Research Council Population Health Scientist Fellowship	both groups: 18% men, 82% women,		one home visit in week 0 (at baseline following outcome measures) from a qualified animal behaviourist and two further home visits in weeks 1 and 6 from a PA research assistant. In addition, intervention families received telephone calls (weeks 2 and 8) and text messages (weeks 4 and 10) to review goal progress, address questions and provide encouragement.					dog	
Mutrie 2012 UK Chief Scientist Office [CSO] Scotland NHS Research and Development from Greater Glasgow and Clyde and the Scottish Primary Care Research Network.	N: I=20, C=19 Mean age: I=71.6±6.0y, C=70.0±4.3y Gender: I= 35% men, 65% women, C= 29% men, 71% women	RCT	Two 30-minute **physical activity consultations** were delivered individually to each participant by a practice nurse. The consultations followed recommended guidelines. The initial consultation aimed to **increase walking participation**. A 12-week individualized graduated walking programme in the form of a specially designed booklet and pedometer was given to participants.	GP practice	12 weeks	Waiting list: asked to continue normal PA for the first 12 weeks	INT = 0%, CON 1st follow-up = 10%, 2nd follow-up = 19%	No - feasibility and increased walking	Decrease of sedentary behaviour in favour of the intervention group
Opdenacker 2008 Belgium Funding source not reported	N: I=33, C=33 Mean age: I=38.8±11.4, C=39.9±9.9 Gender: Men+ women, proportion not reported	RCT	For both groups, the coaching program started with a **face-to-face** intake **session**. During this session the coach designed an **individualized physical activity program** in accordance with the preferences and habits of the participant. **The main goal was to attain the recommended ACSM/CDC amount of physical activity**. The coach further provided a **brochure that included information**, tips, and	workplace - University: professors, academic assistans, technical assistants	3 months	Alternative treatment: coach designed an individualized physical activity program in accordance with the preferences and habits of the participant in a face-to-face session. The coach further provided the employee with a 20-page colorful brochure that included information, tips, and examples on how to	both groups 27%	no - effect on PA and mental health	Reduced sitting time in both groups with no significant group differences

			examples on how to become more physically active. In the face-to-face group, these 4 support contacts were in person.			become more physically active. Further support was given by telephone			
Ostbye 2009 USA National Institute of Diabetes and Digestive and Kidney Diseases	N: I=214, C=207 Mean age: I=30.6±5.8y C=31.2± 5.3y Gender: all female	RCT	Eight **healthy eating** sessions (Mom's Time Out [MTO] classes); ten **physical-activity group sessions** (ACTIVMOMS classes); and six **telephone-counseling sessions** (20 minutes). They were also provided with a **study notebook** with exercises, recipes, and other intervention-related information; and a pedometer. Given the intervention's **strong emphasis on walking**, a sport stroller was provided to encourage walking for exercise outside of class and after the end of the intervention.	Commun ity	9 months	Usual care: received biweekly newsletters with general tips for postpartum mothers	INT = 18%, CON = 23%	no - postpartum weight management	No significant intervention effects for reducing sedentary behaviour
Papalazarou 2010 Greece Funding source not reported	N: I=15, C=15 Mean age: I=32.7±1.6y, C=33.4±2.0y Gender: all female	RCT	Instruction to follow a liquid diet of very low calorie content for 4 weeks. Following this period, soft and solid foods were gradually introduced to the diet of both groups. Additional 40min of indivudual couseling: Aim of the intervention was to help patients to overcome barriers and regulate their body weight by **adopting healthier eating habits and a less sedentary lifestyle.**	Dietetics Departm ent	3 years	Usual care: Instructed to follow a liquid diet of very low calorie content for 4 weeks. Following this period, soft and solid foods were gradually introduced to the diet of both group. During these assessment sessions general information was provided on adopting healthier eating and physical habits.	Not reported	no - weight loss and maintenance, dietary and PA behaviour	Decreased TV viewing time in favour of the intervention group
Parry 2013 Australia Funding source not reported	N: I1=19, I2=14,C=29 Mean age across the groups: 43.5y Gender across the groups: 19% men, 81% women	cluster RCT	<u>Arm 1:</u> 'active office work' intervention - access to a single '**Active Workstation**' which consisted of an electronically height **adjustable desk with integrated treadmill** or a treadmill plus a stationary cycle ergometer. It was recommended that the Active Workstation be used for short periods several times a day, starting at 10 minutes and building up to 30 minutes per session.	work place - office workers (clerical, data entry and call centre workers) from 3 governm ent	12 weeks	Alternative treatment /attention control: 'office ergonomics' intervention which focused on computer workstation setup, 'active' sitting (moving whilst in the chair) and breaking up computer tasks	INT 1 = 61%, INT 2 = 53%, Con = 46%	yes	Both groups reduced sitting time and increased sitting breaks without significant groups differences

			Arm 2: traditional physical activity' intervention - focused on strategies to **promote light to moderate activity in breaks between productive work** times and **increasing the use of active transport** before and after work. Participants were all provided with a **pedometer** to use as a motivational tool	organisations					
Pederson 2013 Australia Funding source not reported	N: I=17, C=17 Mean age: I=41.5± 12.4y, C=43.9± 9.7y Gender across groups: 24% men, 76% women	RCT	15-minute **educational session** on the negative health effects associated with **prolonged sitting**, general instructions on performing appropriate **workplace physical activity** (20 minutes), and an information session on using the Exertime software (30 minutes). This software was designed to **prompt employees to periodically break long periods of sitting** by standing up to engage in a short period of physical activity during their work hours. The prompting intervention automatically deactivated employees' computer screens every 45 minutes and the end-users were unable to exit the program or ignore the prompt.	work place - desk-based Tasmania Police 174 employees from across several metropolitan sectors	13 weeks	Alternative treatment /waiting list: 15-minute educational session on the negative health effects associated with prolonged sitting, general instructions on performing appropriate workplace physical activity (20 minutes), and an information session on using the Exertime software (30 minutes). No e-health software loaded on their computers for a 13 week period.	INT = 0%, CON = 0%	yes	Decreased sitting behaviour at work in favour of the intervention group
Poston 2013 UK National Institute for Health Research, Guys and St.Thomas' Charity, Chief Scientist Office, Tommy's Charity	N: I= 56, C=54 Mean age: I=30.4±5.7y, C=30.7±4.9y Gender: all female	RCT	Participants attended a one to-one appointment where women were provided with a participant **handbook**, **a pedometer,** a log book for weekly SMART goals and related behaviours (steps, PA and diet) and a **DVD** of a specially devised **pregnancy exercise regime** and were invited to **weekly group sessions** for 8 consecutive weeks from approximately 19 weeks' gestation. All women attended routine antenatal care appointments and received	hospital and community children's centre	28 weeks	Usual care: routine antenatal visits	Actigraph data: INT = 62%, CON = 56%	no - changes in diet and physical activity behaviours	No significant intervention effect on sedentary behaviour

			advice regarding diet and physical activity (PA) in accordance with local policies, which draw on UK NICE guidelines.						
Reynor 2013a USA Feasibility grant from the University of Tennessee Obesity Research Center	N: I=12, C=12 Mean age: I= 53.3±8.0y C=51.7±10.0y Gender: I=10% men, 90% women C=20% men, 80% women	RCT	**Energy restriction + TV decrease**: Participants were instructed to consume a standard energy- and fat-restricted diet. Intervention consisted of 8, 60-minute **group meetings**. Participants were **instructed to gradually reduce their TV watching time to 10 hours per week.**	research centre/home	8 weeks	Alternative treatment: Energy restriction and instruction to gradually increase MVPA to at least 40 minutes per day, 5 days per week. Participants were encouraged to do brisk walking and accumulate time spent in MVPA. 8 group meetings	I = 25%, C = 17%	yes	No significant intervention effect for TV viewing time
Reynor 2013b USA Feasibility grant from the University of Tennessee Obesity Research Center	N: I=14, C=14 Mean age: I= 54.9±7.4y C=53.3±9.1y Gender: I=27% men, 73% women C=27% men, 73% women	RCT	**Energy restriction + TV decrease + PA increase**: Intervention consisted of 8, 60-minute group meetings. Participants were instructed to consume a standard energy- and fat-restricted diet, to reduce TV watching to 10 hours/week and to gradually increase MVPA to at least 40 minutes per day, 5 days/week. Participants were encouraged to do brisk walking and accumulate time spent in MVPA. Participants were given a **pedometer**. **Home visits** occurred so that the code that the participants used to watch TV on the TV Allowances was set to limit TV watching accordingly to meet target.	research centre/home	8 weeks	Alternative treatment: Energy restriction and instruction to gradually increase MVPA to at least 40 minutes per day, 5 days/week. Participants were encouraged to do brisk walking and accumulate time spent in MVPA. Provision of a pedometer.	I= 36%, C = 14%	yes	Reduced TV viewing time in favour of the intervention group

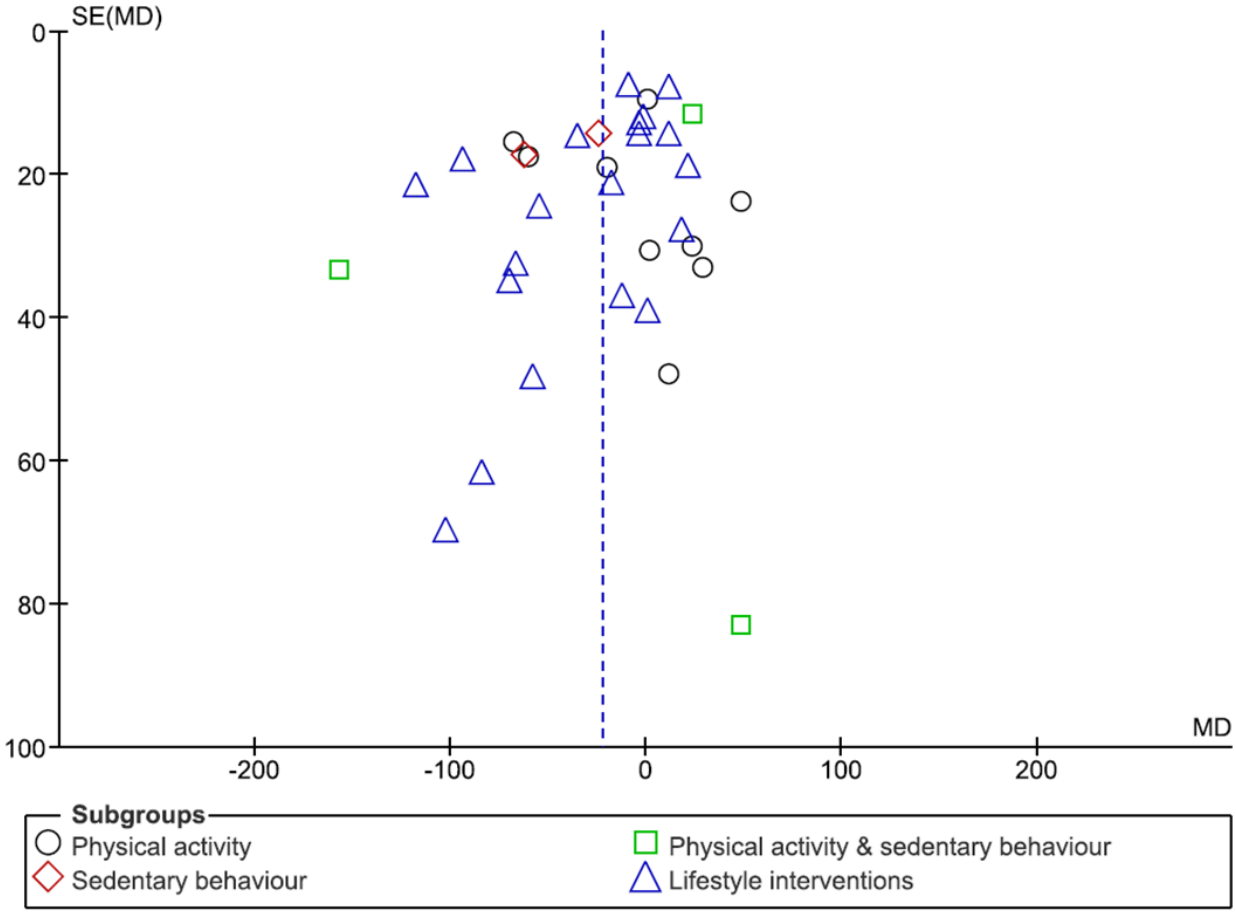
Robertson 2013 USA Funding source not reported	N: I=11, C=11 Mean age: I=43.2± 10.4y C=46.2±12.5y Gender: all female	RCT	Ergonomics training: **sit-stand workstation. 1,5 h group coaching** and **mandatory experiential practice period**, where participants were asked to stand once for 5 min in the middle of the 50min session, and three days later to stand once for 20 min in the middle of the 50 min session. Reminders were also presented once every three days in the morning and they contained three helpful tips regarding office ergonomics principles.	workplace	4 weeks	Alternative treatment: Sit-stand workstation with separate adjustments for the monitor and main table work surface. Group received no coaching, ergonomics reminders, or mandatory sit/stand periods.	Not reported	no - musculo-skeletal discomfort	Reduced sitting time at work in favour of the intervention group
Rosenberg 2010 USA Funding source not reported	N: I=46, C=41 Mean age across the groups: 84.1y (range: 69-98y) Gender across the groups: 34% men, 66% women	cluster RCT; (ICC for sedentary behaviour = 0)	Provision of **pedometer,** Information provided in **print materials** included: safe walking tips, benefits of walking, overcoming barriers to walking, and summaries of recommendations for walking with health conditions. **Group meetings** lasted approximately 30 minutes and included a check-in with residents to share any relevant walking stories from the previous week, a brief didactic on the weekly topic, and time for residents to problem-solve difficulties as a group. To deliver individualized feedback and assistance, brief (5-10 minutes) biweekly **individual telephone counseling**. Provision of walking maps.	Retirement community	12 weeks	Alternative treatment: handouts on goal-setting so participants could set their own step goals.	I=22%, C=32%	No - increased walking	No intervention effect on sedentary behaviour
Slootmaker 2009 The Netherlands The Netherlands Organization for Health Research and	N 3 months: I = 46, C=42; N 8 months: I= 38, C=38 Mean age: I=32.5±3.4y, C=31.2±3.5y Gender: I=39% men,	RCT	The intervention group received the **Personal Activity Monitor** (PAM) and was provided with **Web-based tailored physical activity advice** (PAM COACH). Based on the user's uploaded PAM score for the first week, the PAM COACH assigns a lower goal that increases daily until the PAM goal score is reached at the end of the intervention period.	work place - office workers	3 months	Alternative treatment: single written information brochure with brief general PA recommendations and health benefits of PA.	3 months: I= 6%, C=2%; 8 months: I=25%, C=18%	yes	No intervention effect on sedentary behaviour

Development	61% women, C= 41% men, 59% women		The uploaded PAM scores are automatically accompanied by tailored physical activity advice and motivational tips for increasing physical activity.						
Spring 2012 USA Three different National Institutes of Health grants	N: I= 53, I2= 44, C1=47, C2=48 Mean age: I1=30.8±10.8y I2=35.0±12.1y C1=31.9±9.7y C2=33.4±10.8 y Gender: I1=23% men, 77% women I2=25% men, 75%women C1=17%men, 83% women C2=29% men, 71% women	RCT	Make better choices: (behvioural choice theory) ARM 1 - ↓Fat ↓Sedentary behaviour: decrease saturated fat consumption to < 8% per day and decrease targeted sedentary leisure activity to < 90 minutes/day; ARM 2 - ↑Fruits & Vegetables (FV) ↓Sedentary behaviour: increase FV consumption to > 5/day and decrease sedentary leisure activity to < 90 min/day. For the first week of treatment, daily goals were set midway between the baseline behavior and the ultimate daily goal. Beginning the second treatment week, full goals were set for the 2 targeted behaviors. During the 3 treatment weeks, participants uploaded data daily (PDA) **and communicated as needed with their coaches via telephone or e-mail**, per preference, to overcome challenges.	home based	3 weeks	Alternative treatment: ARM 1 - decrease saturated fat to < 8%/day and increase physical activity to > 60 min/day ARM 2 - increase fruit and vegetable consumption to >5/day and increase moderate-vigorous physical activity to >60 minutes/day	I1 = 25%, I2 = 0%, C1= 4%, C2 = 0%	no - general health behaviour change	Significant reduction of sedentary behaviour in intervention arm 2 compared to other intervention groups
Steeves 2012 USA Plus One Active Research Grant on Wellness from the American College of Sports Medicine Foundation	N: I=29, C=29 Mean age: I=53.8±6.8y C=50.2±9.8y Gender: I=20% men, 80% women, C=32% men, 68% women	RCT	Instructed to **stand and "briskly" step in place, or "briskly" walk continuously around the room**/ house for the duration of each commercial break **during at least 90 min of TV programming at least 5 d/wk**. Participants were instructed to step in place at a "moderate pace" (e.g., 100–120 steps per minute), Participants reviewed appropriate stepping-in-place or walking around the room pace and technique during each the first 3 face-to-face meetings.	home based	6 months	Alternative treatment: Walking group. Participants were instructed to **walk "briskly" for at least 30 min at least 5 d/wk**. Participants built up to walking 30 min/d over the first 3 weeks; increasing duration from 10 min/d in week 1, to 20 min/d in week 2, to 30 min/d for the remainder of this study. Participants were instructed to walk for 30	I=21%, C=17%	no - feasibility, increase of PA	Both groups decreased TV viewing time with no significant group differences.

						min continuously or break their walking up into bouts of at least 10 min.			
Sternfeld 2009 USA Centre for Disease Control	N: I=351, C=436 Mean age: I=44.8±10.0y, C=43.5±11.0y Gender: I=27% men, 73% women C=25% men, 75% women	cluster RCT cluster size= 192 departments of a health care delivery system	"ALIVE": delivered by **e-mail designed to increase both the consumption of fruits and vegetables and physical activity** and to decrease the consumption of saturated fats, trans fats, and added sugars. Participants choose to work on one of three paths (increasing physical activity; increasing fruits and vegetables [fruits/ vegetables]; or decreasing fats and sugars [fats/sugars]); the messages they subsequently receive are specific to the chosen path. The participant chooses one or two of those goals for the week; once a selection is made, a personal home page opens with tips for achieving the selected goal(s), along with other modules.	work site - the nation's oldest and largest nonprofit, integrated healthcare-delivery system	16 weeks	no treatment	16 weeks: I=34%, C=27%; 4 months: I=49%, C=41%	no	No intervention effect on sedentary behaviour
Thompson 2008 USA Funding source not reported	N: I=100, C=100 Mean age: I=29.6±6.6y C=28.9±6.7y Gender: All female	RCT	The final intervention consisted of five **discussion-format group sessions** (one per month for five months). Sessions lasted 2 to 2.5 hours and included learning to read food labels, strategies for choosing healthier foods when eating out or snacking, taste-testing of healthy meals, and dissemination of inexpensive recipes for at-home preparation of foods to increase vegetable and fruit intake and decrease saturated fats. Weather permitting, the facilitator led a **15-minute outdoor walk** at the beginning of each session.	community	18 months	Attention control : participants received mailings of a Native health magazine	Across groups: 6 months : 18% ; 12 months: 23%; 18 months: 32%	no - diabetes prevention, diet + increased physical activity	Both groups decreased TV viewing time. No significant group difference.

van Berkel 2014 The Netherlands Nuts Ohra Foundation	N: I=129, C=128 Mean age: I=46.0±9.4y C= 45.1±9.6y Gender: I= 37% men, 63% women, C=29% men, 71% women	RCT	The Mindful VIP intervention comprised 8 weeks of in company **mindfulness training** with **homework exercises, followed by 8 sessions of e–coaching**. The weekly mindfulness training sessions took 90 minutes and were held in a room at the worksite in a group setting. The homework exercises comprised a variety of meditation and informal exercises such as breathing exercises when starting up the computer, and grocery shopping mindfully and took approximately 30 min/day on 5 days/week. Materials for this training consisted of 2 cd's with guided meditation exercises and a booklet with examples of workplace situations, background and (workplace) exercises. Lunch walking routes, and a buddy-system were offered as supportive tools.	work site - employees from two Dutch research institutes	6 months	no treatment	6 months: I=6%, C=11%, 12 months: I=6%, C=13%	yes	No intervention effect on sedentary behaviour
Verweij 2012 The Netherlands The Netherlands Organisation for Health Research and Development	N: I=210, C=206 Mean age: I= 46±8y, C=48±9y Gender: I=62%men, 38% women C=65% men, 35% women	cluster RCT cluster size = 16 practices of occupational physicians	Guideline based care: Prevention at the environmental level (advice for the employer), (b) prevention at the individual level (advice for the employee) and (c) evaluation and maintenance of a) + b). Physician led **behaviour change councelling to promote employees' healthy lifestyle** in five 20-30 min counselling sessions. In the first counselling session, employees could choose which target behaviour they would like to discuss (increasing physical activity, decreasing sedentary behaviour, increasing fruit consumption or reducing the energy intake derived from snacks). Employees were **provided with a toolkit containing a waist**	work site - Employees of Occupational Physicians	6 months	Usual care: health risk appraisal with anthropometric measurements and a subsequent health advice	I = 23%, C = 17%	yes	Reduced sedentary behaviour at work in favour of the intervention group but not during leisure time

			circumference measure tape, a pedometer, leaflets on physical activity and nutrition from the Dutch Heart Foundations and the Netherlands Nutrition Centre						



Supplement figure 1: Funnel plot of the intervention effect for reducing sitting time in minutes/day in adults by type of intervention

Sensitivity analyses for effect of interventions with the potential to reduce sedentary behaviour in adults

Sensitivity analyses were used to test the influence of study characteristics on the robustness of the review results. The effect of the following characteristics was explored: 'high risk' of performance and attrition bias (Tables 2 and 3), cluster designs (Table 4), usual care or alternative treatment control groups (Table 5). The tables show the pooled intervention effects when studies meeting the above characteristics were excluded from the analyses.

Table 2: Sensitivity analysis for studies of 'high' risk of performance bias

Outcome or Subgroup	n Studies	n Participants	Statistical Method	Effect Estimate [min/day]
All interventions	20	3818	Mean Difference (IV, Random, 95% CI)	-17.38 [-35.55, 0.80]
Physical activity	9	1729	Mean Difference (IV, Random, 95% CI)	-6.60 [-33.27, 20.07]
Sedentary behaviour	0	0	Mean Difference (IV, Random, 95% CI)	Not estimable
Physical activity & sedentary behaviour	1	257	Mean Difference (IV, Random, 95% CI)	23.60 [0.78, 46.42]
Lifestyle interventions	10	1832	Mean Difference (IV, Random, 95% CI)	-35.48 [-65.26, -5.69]

Table 3: Sensitivity analysis for studies of 'high' risk of attrition bias

Outcome or Subgroup	n Studies	n Participants	Statistical Method	Effect Estimate [min/day]
All interventions	21	3054	Mean Difference (IV, Random, 95% CI)	-28.32 [-47.06, -9.58]
Physical activity	5	1050	Mean Difference (IV, Random, 95% CI)	-0.16 [-42.91, 42.59]
Sedentary behaviour	2	62	Mean Difference (IV, Random, 95% CI)	-41.76 [-78.92, -4.60]
Physical activity & sedentary behaviour	2	290	Mean Difference (IV, Random, 95% CI)	-63.46 [-239.39, 112.46]
Lifestyle interventions	12	1652	Mean Difference (IV, Random, 95% CI)	-34.22 [-59.12, -9.31]

Table 4: Sensitivity analysis for cluster RCTs

Outcome or Subgroup	n Studies	n Participants	Statistical Method	Effect Estimate [min/day]
All interventions	30	4861	Mean Difference (IV, Random, 95% CI)	-25.91 [-41.29, -10.53]
Physical activity	10	1849	Mean Difference (IV, Random, 95% CI)	-8.45 [-32.16, 15.26]
Sedentary behaviour	2	62	Mean Difference (IV, Random, 95% CI)	-41.76 [-78.92, -4.60]
Physical activity & sedentary behaviour	2	290	Mean Difference (IV, Random, 95% CI)	-63.46 [-239.39, 112.46]
Lifestyle interventions	16	2660	Mean Difference (IV, Random, 95% CI)	-33.55 [-55.90, -11.20]

Table 5: Sensitivity analysis for studies with usual care and alternative treatment as control condition

Outcome or Subgroup	n Studies	n Participants	Statistical Method	Effect Estimate [min/day]
All interventions	12	1898	Mean Difference (IV, Random, 95% CI)	-30.17 [-51.79, -8.54]
Physical activity	5	772	Mean Difference (IV, Random, 95% CI)	-32.14 [-61.49, -2.80]
Sedentary behaviour	0	0	Mean Difference (IV, Random, 95% CI)	Not estimable
Physical activity & sedentary behaviour	2	290	Mean Difference (IV, Random, 95% CI)	-63.46 [-239.39, 112.46]
Lifestyle interventions	5	836	Mean Difference (IV, Random, 95% CI)	-17.62 [-36.94, 1.70]

References

REFERENCES

1. Barnes J, Behrens TK, Benden ME, et al. Letter to the Editor: Standardized use of the terms" sedentary" and" sedentary behaviours". Applied Physiology Nutrition and Metabolism-Physiologie Appliquee Nutrition Et Metabolisme 2012;**37**(3):540-42.
2. Owen N, Salmon J, Koohsari MJ, et al. Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention. Br J Sports Med 2014;**48**(3):174-7.
3. de Rezende LFM, Lopes MR, Rey-López JP, et al. Sedentary Behavior and Health Outcomes: An Overview of Systematic Reviews. PloS one 2014;**9**(8):e105620.
4. Dempsey PC, Owen N, Biddle SJ, et al. Managing sedentary behavior to reduce the risk of diabetes and cardiovascular disease. Current diabetes reports 2014;**14**(9):1-11.
5. Dunstan DW, Howard B, Healy GN, et al. Too much sitting--a health hazard. Diabetes research and clinical practice 2012;**97**(3):368-76.
6. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
7. Matthews CE, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. The American journal of clinical nutrition 2012:ajcn. 019620.
8. Seguin R, Buchner DM, Liu J, et al. Sedentary behavior and mortality in older women: the Women's Health Initiative. Am J Prev Med 2014;**46**(2):122-35.
9. Van der Ploeg HP, Chey T, Korda RJ, et al. Sitting time and all-cause mortality risk in 222 497 Australian adults. Archives of internal medicine 2012;**172**(6):494-500.
10. Healy GN, Dunstan DW, Salmon J, et al. Breaks in Sedentary Time: Beneficial associations with metabolic risk. Diabetes Care 2008;**31**(4):661-66.
11. Bailey DP, Locke CD. Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. Journal of science and medicine in sport / Sports Medicine Australia 2014.
12. Peddie MC, Bone JL, Rehrer NJ, et al. Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. The American Journal of Clinical Nutrition 2013.
13. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. Diabetes Care 2012;**35**(5):976-83.
14. Proper KI, Singh AS, van Mechelen W, et al. Sedentary Behaviors and Health Outcomes Among Adults A Systematic Review of Prospective Studies. American Journal of Preventive Medicine 2011;**40**(2):174-82.
15. Rezende LF, Rey-Lopez J, Matsudo VK, et al. Sedentary behavior and health outcomes among older adults: a systematic review. BMC Public Health 2014;**14**(1):333.
16. Chau JY, Grunseit AC, Chey T, et al. Daily sitting time and all-cause mortality: a meta-analysis. PloS one 2013;**8**(11):e80000.
17. Thorp AA, Owen N, Neuhaus M, et al. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. American journal of preventive medicine 2011;**41**(2):207-15.

18. Wilmot E, Edwardson C, Achana F, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia 2012;**55**:2895-905.
19. Healy GN, Clark BK, Winkler EAH, et al. Measurement of Adults' Sedentary Time in Population-Based Studies. American Journal of Preventive Medicine 2011;**41**(2):216-27.
20. Harvey J, Chastin S, Skelton D. Prevalence of Sedentary Behavior in Older Adults: A Systematic Review. International Journal of Environmental Research and Public Health 2013;**10**(12):6645-61.
21. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior: A Systematic Review. American journal of preventive medicine 2012;**42**(3):e3-e28.
22. Biddle SJ, Petrolini I, Pearson N. Interventions designed to reduce sedentary behaviours in young people: a review of reviews. British journal of sports medicine 2014;**48**(3):182-86.
23. Prince SA, Saunders TJ, Gresty K, et al. A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: a systematic review and meta-analysis of controlled trials. Obesity Reviews 2014;**15**(11):905-19.
24. Martin A, Saunders D, Jepson R, et al. Interventions to influence sedentary behaviour in adults: systematic review and meta-analysis. http://www.crd.york.ac.uk/PROSPERO_REBRANDING/display_record.asp?ID=CRD42014007064: PROSPERO International prospective register of systematic reviews, 2014.
25. Higgins JPT, Green S, editors. *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]*: The Cochrane Collaboration., 2011.
26. GRADEpro [program]. 3.2 for Windows version, 2008.
27. Review Manager [program]. 5.2 version. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012.
28. Aadahl M, Linneberg A, Witte D, et al. Reduction of sitting time in sedentary men and women. A randomized controlled trial (Sedentary Intervention Trial). Journal of Science and Medicine in Sport Conference: Be Active 2012;**15**(pp S302).
29. Abascal LB. The effect of depression and adherence in a dietary and physical activity intervention for overweight and obese adults. Dissertation Abstracts International: Section B: The Sciences and Engineering 2008;**69**(4-B):2614.
30. Allen NA, Fain JA, Braun B, et al. Continuous glucose monitoring counseling improves physical activity behaviors of individuals with type 2 diabetes: A randomized clinical trial. Diabetes Research & Clinical Practice 2008;**80**(3):371-9.
31. Andersen E, Burton NW, Anderssen SA. Physical activity levels six months after a randomised controlled physical activity intervention for Pakistani immigrant men living in Norway. International Journal of Behavioral Nutrition & Physical Activity 2012;**9**:47.
32. Barwais FA, Cuddihy TF, Tomson LM. Physical activity, sedentary behavior and total wellness changes among sedentary adults: A 4-week randomized controlled trial. Health and Quality of Life Outcomes 2013;**11**(1).
33. Burke L, Lee AH, Jancey J, et al. Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomized

controlled trial. International Journal of Behavioral Nutrition & Physical Activity 2013;**10**:14.
34. Carlson JA, Sallis JF, Ramirez ER, et al. Physical activity and dietary behavior change in Internet-based weight loss interventions: comparing two multiple-behavior change indices. Preventive Medicine 2012;**54**(1):50-4.
35. Chin APMJ, Poppel MN, Mechelen W. Effects of resistance and functional-skills training on habitual activity and constipation among older adults living in long-term care facilities: a randomized controlled trial. BMC Geriatrics 2006. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/914/CN-00566914/frame.html.
36. De Cocker K, Spittaels H, Cardon G, et al. Web-based, computer-tailored, pedometer-based physical activity advice: development, dissemination through general practice, acceptability, and preliminary efficacy in a randomized controlled trial. Journal of Medical Internet Research 2012;**14**(2):e53.
37. De Greef K, Deforche B, Tudor-Locke C, et al. A cognitive-behavioural pedometer-based group intervention on physical activity and sedentary behaviour in individuals with type 2 diabetes. Health Education Research 2010(5):724-36.
38. De Greef KP, Deforche BI, Ruige JB, et al. The effects of a pedometer-based behavioral modification program with telephone support on physical activity and sedentary behavior in type 2 diabetes patients. Patient Education & Counseling 2011;**84**(2):275-9.
39. Dunn AL, Marcus BH, Kampert JB, et al. Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: a randomized trial. JAMA 1999;**281**(4):327-34.
40. Evans RE, Fawole HO, Sheriff SA, et al. Point-of-choice prompts to reduce sitting time at work: a randomized trial. American Journal of Preventive Medicine 2012;**43**(3):293-7.
41. Fitzsimons CF, Baker G, Gray SR, et al. Does physical activity counselling enhance the effects of a pedometer-based intervention over the long-term: 12-month findings from the Walking for Wellbeing in the west study. BMC Public Health 2012;**12**:206.
42. Hu G, Tian H, Zhang F, et al. Tianjin Gestational Diabetes Mellitus Prevention Program: study design, methods, and 1-year interim report on the feasibility of lifestyle intervention program. Diabetes Research & Clinical Practice 2012;**98**(3):508-17.
43. Jago R, Sebire SJ, Turner KM, et al. Feasibility trial evaluation of a physical activity and screen-viewing course for parents of 6 to 8 year-old children: Teamplay. The International Journal of Behavioral Nutrition and Physical Activity 2013. http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/090/CN-00864090/frame.html.
44. Judice PB, Matias CN, Santos DA, et al. Caffeine Intake, Short Bouts of Physical Activity, and Energy Expenditure: A Double-Blind Randomized Crossover Trial. PLoS ONE 2013;**8**(7).
45. Lakerveld J, Bot SDM, Van der Ploeg HP, et al. The effects of a lifestyle intervention on leisure-time sedentary behaviors in adults at risk: The Hoorn Prevention Study, a randomized controlled trial. Preventive Medicine 2013;**57**(4):351-56.

46. Marshall AL, Leslie ER, Bauman AE, et al. Print versus website physical activity programs: a randomized trial. American Journal of Preventive Medicine 2003;**25**(2):88-94.
47. McGuire MT, Jeffery RW, French SA, et al. The relationship between restraint and weight and weight-related behaviors among individuals in a community weight gain prevention trial. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 2001;**25**(4):574-80.
48. Mutrie N, Doolin O, Fitzsimons CF, et al. Increasing older adults' walking through primary care: results of a pilot randomized controlled trial. Family Practice 2012;**29**(6):633-42.
49. Opdenacker J, Boen F. Effectiveness of face-to-face versus telephone support in increasing physical activity and mental health among university employees. Journal of Physical Activity & Health 2008;**5**(6):830-43.
50. Ostbye T, Krause KM, Lovelady CA, et al. Active Mothers Postpartum: a randomized controlled weight-loss intervention trial. American Journal of Preventive Medicine 2009;**37**(3):173-80.
51. Papalazarou A, Yannakoulia M, Kavouras SA, et al. Lifestyle intervention favorably affects weight loss and maintenance following obesity surgery. Obesity 2010;**18**(7):1348-53.
52. Raynor HA, Steeves EA, Bassett DR, Jr., et al. Reducing TV watching during adult obesity treatment: Two pilot randomized controlled trials. Behavior Therapy 2013;**44**(4):674-85.
53. Slootmaker SM, Chinapaw MJM, Schuit AJ, et al. Feasibility and effectiveness of online physical activity advice based on a personal activity monitor: randomized controlled trial. Journal of Medical Internet Research 2009;**11**(3):e27.
54. Spring B, Schneider K, McFadden HG, et al. Multiple behavior changes in diet and activity: a randomized controlled trial using mobile technology. Archives of Internal Medicine 2012;**172**(10):789-96.
55. Steeves JA, Bassett DR, Fitzhugh EC, et al. Can sedentary behavior be made more active? A randomized pilot study of TV commercial stepping versus walking. International Journal of Behavioral Nutrition & Physical Activity 2012;**9**:95.
56. Thompson JL, Allen P, Helitzer DL, et al. Reducing diabetes risk in American Indian women. American Journal of Preventive Medicine 2008;**34**(3):192-201.
57. Fitzgibbon ML, Stolley MR, Schiffer L, et al. A combined breast health/weight loss intervention for Black women. Preventive Medicine 2005; (4). http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/377/CN-00511377/frame.html.
58. Hansen AW, Grønbæk M, Helge JW, et al. Effect of a Web-based intervention to promote physical activity and improve health among physically inactive adults: a population-based randomized controlled trial. Journal of Medical Internet Research 2012; (5). http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/871/CN-00841871/frame.html.
59. Katzmarzyk PT, Champagne CM, Tudor-Locke C, et al. A short-term physical activity randomized trial in the lower mississippi delta. PLoS ONE 2011;**6**(10).

60. Lane A, Murphy N, Bauman A, et al. Randomized controlled trial to increase physical activity among insufficiently active women following their participation in a mass event. Health Education Journal 2010;**69**(3):287-96.
61. López-Fontana CM, Sánchez-Villegas A, Martínez-Gonzalez MA, et al. Daily physical activity and macronutrient distribution of low-calorie diets jointly affect body fat reduction in obese women. Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme 2009; (4). http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/007/CN-00722007/frame.html.
62. Kallings LV, Sierra Johnson J, Fisher RM, et al. Beneficial effects of individualized physical activity on prescription on body composition and cardiometabolic risk factors: results from a randomized controlled trial. European journal of cardiovascular prevention and rehabilitation : official journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology 2009;**16**(1):80-84.
63. Pedersen SJ, Cooley PD, Mainsbridge C. An e-health intervention designed to increase workday energy expenditure by reducing prolonged occupational sitting habits. Work: A Journal of Prevention, Assessment and Rehabilitation 2013.
64. Baker G, Gray SR, Wright A, et al. The effect of a pedometer-based community walking intervention. International Journal of Behavioral Nutrition and Physical Activity 2008;**5**(1):44.
65. Gilson ND, Puig-Ribera A, McKenna J, et al. Do walking strategies to increase physical activity reduce reported sitting in workplaces: a randomized control trial. Int J Behav Nutr Phys Act 2009;**6**:43.
66. Morrison R, Reilly JJ, Penpraze V, et al. Children, parents and pets exercising together (CPET): exploratory randomised controlled trial. BMC public health 2013;**13**(1):1096.
67. Poston L, Briley AL, Barr S, et al. Developing a complex intervention for diet and activity behaviour change in obese pregnant women (the UPBEAT trial); assessment of behavioural change and process evaluation in a pilot randomised controlled trial. BMC pregnancy and childbirth 2013;**13**(1):148.
68. Robertson MM, Ciriello VM, Garabet AM. Office ergonomics training and a sit-stand workstation: Effects on musculoskeletal and visual symptoms and performance of office workers. Applied ergonomics 2013;**44**(1):73-85.
69. Canuto K, Cargo M, Li M, et al. Pragmatic randomised trial of a 12-week exercise and nutrition program for Aboriginal and Torres Strait Islander women: clinical results immediate post and 3 months follow-up. BMC public health 2012;**12**(1):933.
70. van Berkel J, Boot CR, Proper KI, et al. Effectiveness of a worksite mindfulness-based multi-component intervention on lifestyle behaviors. International Journal of Behavioral Nutrition and Physical Activity 2014;**11**(1):9.
71. Lioret S, Campbell KJ, Crawford D, et al. A parent focused child obesity prevention intervention improves some mother obesity risk behaviors: the Melbourne infant program. International Journal of Behavioral Nutrition & Physical Activity 2012;**9**:100.

72. Rosenberg DE. Outcomes of a multilevel walking intervention for older adults living in retirement communities. Dissertation Abstracts International: Section B: The Sciences and Engineering 2011;**71**(8-B):5143.
73. Sternfeld B, Block C, Quesenberry CP, Jr., et al. Improving diet and physical activity with ALIVE: a worksite randomized trial. American Journal of Preventive Medicine 2009;**36**(6):475-83.
74. Verweij LM, Proper KI, Weel ANH, et al. The application of an occupational health guideline reduces sedentary behaviour and increases fruit intake at work: results from an RCT. Occupational & Environmental Medicine 2012;**69**(7):500-7.
75. Anand SS, Davis AD, Ahmed R, et al. A family-based intervention to promote healthy lifestyles in an aboriginal community in Canada. Canadian journal of public health = Revue canadienne de santé publique 2007; (6). http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/774/CN-00668774/frame.html.
76. Adams MM. On our feet: Feasibility trial of an intervention to reduce sedentary behavior and increase physical activity. Dissertation Abstracts International: Section B: The Sciences and Engineering 2013;**73**(10-B(E)):No Pagination Specified.
77. Parry S, Straker L, Gilson ND, et al. Participatory Workplace Interventions Can Reduce Sedentary Time for Office Workers—A Randomised Controlled Trial. PloS one 2013;**8**(11):e78957.
78. Andersen E, Høstmark AT, Anderssen SA. Effect of a physical activity intervention on the metabolic syndrome in Pakistani immigrant men: a randomized controlled trial. Journal of immigrant and minority health / Center for Minority Public Health 2012; (5). http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/646/CN-00848646/frame.html.
79. Peddie MC, Bone JL, Rehrer NJ, et al. Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. American Journal of Clinical Nutrition 2013;**98**(2):358-66.
80. Aadahl M, Linneberg A, Møller TC, et al. Motivational Counseling to Reduce Sitting Time. American Journal of Preventive Medicine 2014;**47**(5):576-86.
81. Carr LJ, Karvinen K, Peavler M, et al. Multicomponent intervention to reduce daily sedentary time: A randomised controlled trial. BMJ Open 2013;**3**(10).
82. Otten JJ, Jones KE, Littenberg B, et al. Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomized controlled trial. Archives of Internal Medicine 2009;**169**(22):2109-15.
83. Chau JY, der Ploeg HPv, van Uffelen JG, et al. Are workplace interventions to reduce sitting effective? A systematic review. Preventive medicine 2010;**51**(5):352-56.
84. Neuhaus M, Eakin EG, Straker L, et al. Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations. Obesity Reviews 2014;**15**(10):822-38.
85. Torbeyns T, Bailey S, Bos I, et al. Active Workstations to Fight Sedentary Behaviour. Sports Medicine 2014:1-13.
86. Shrestha N, Ijaz S, Kukkonen-Harjula Katriina T, et al. Workplace interventions for reducing sitting at work. Cochrane Database of Systematic Reviews 2014; (1). http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD010912/abstract.

87. Owen N, Sugiyama T, Eakin EE, et al. Adults' sedentary behavior: determinants and interventions. American journal of preventive medicine 2011;**41**(2):189-96.
88. Michie S, Johnston M. Theories and techniques of behaviour change: Developing a cumulative science of behaviour change. Health Psychology Review 2012;**6**(1):1-6.