The effectiveness of sedentary behaviour reduction workplace interventions on cardiometabolic risk markers: A systematic review

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Data Availability Statement

All data generated or analysed for this review are included in this published article and its Electronic Supplementary Material documents.

Compliance with Ethical Standards

Ethics approval and consent to participate. This work was approved by the University of Bedfordshire Institute for Sport and Physical Activity Research Ethics Committee (approval no. 2018ISPAR006).

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Conflict of interests

Marsha Brierley, Angel Chater, Lindsey Smith and Daniel Bailey declare that they have no conflict of interests with the content of this article.

Author contributions

Marsha Brierley, Lindsey Smith, Daniel Bailey and Angel Chater conceived and designed this review. Marsha Brierley performed the searches, analysed the data, interpreted the data, and wrote the initial manuscript draft. Lindsey Smith, Daniel Bailey and Angel Chater critically revised the manuscript. Marsha Brierley and Lindsey Smith independently screened titles, abstracts, and full texts. Marsha Brierley and Daniel Bailey conducted the quality assessment. Marsha Brierley and Angel Chater double coded the behaviour change techniques. All authors approved the final version of the paper.

Abstract

Background: Sedentary behaviour is a risk factor for type 2 diabetes and cardiovascular disease. **Objectives**: The aims of this study were to systematically review the effects of workplace sedentary behaviour reduction interventions on cardiometabolic risk markers (primary aim) and identify the active behaviour change techniques (BCTs) by which these interventions work (secondary aim). **Methods**: A systematic search of 11 databases for articles published up until 12th April 2019 yielded a total of 4255 unique titles with 29 articles being identified for inclusion. Interventions were rated as very promising, quite promising, or non-promising based on their effects on cardiometabolic risk markers compared with baseline and/or a control group. Interventions were coded for BCTs used. To assess the relative effectiveness of BCTs, a promise ratio was calculated as the frequency of a BCT appearing in all promising interventions divided by its frequency of appearance in all non-promising interventions. **Results**: A narrative synthesis included 29 published studies of varying study design and comprised of 30 interventions. Risk of bias was high for blinding and allocation concealment, moderate for random sequence generation, and low for outcome assessment. Nine interventions were very promising, eleven were quite promising, ten were non-promising, and ten active control groups did not experience cardiometabolic changes. Significant sedentary behaviour reductions were present in all but five studies where cardiometabolic risk markers improved. The BCTs of social comparison, problem solving, demonstration of the behaviour, goal setting (behaviour), behaviour substitution, and habit reversal, demonstrated moderate to high promise ratios. **Conclusions**: Workplace interventions show promise for improving cardiometabolic risk markers. The BCTs with greatest promise of cardiometabolic risk marker improvements included social comparison, individual habits, and behaviour goals.

Key Points

1. Sedentary behaviour workplace interventions show promise for improving cardiometabolic risk health.
2. Results should be interpreted with caution as individual studies were at risk of allocation and performance bias.
3. The behaviour change techniques of social comparison, problem solving, demonstration of the behaviour, goal setting, behaviour substitution, and habit reversal were frequently observed in those studies that reported an improvement in cardiometabolic risk markers.

Registration

This systematic review was prospectively registered on PROSPERO (CRD42017072427).

1. Background

The nature of work has changed over the last 60 years with an increase in the number of sedentary service jobs (now representing 43% of all jobs) and a decrease in the number of jobs requiring moderate physical activity (20% of all jobs) [1]. Sedentary behaviour is defined as any waking behaviour with an energy expenditure of less than 1.5 metabolic equivalents (METs) while in a sitting, lying, or reclining position [2]. A wide body of evidence suggests that sedentary behaviour is an independent risk factor for a range of health outcomes such as cardiovascular disease, type 2 diabetes, some cancers, and premature mortality [3–6]. However, high levels of moderate-intensity physical activity (60 min/day) may negate the increased mortality risk associated with high levels of sitting [7]. Office workers spend upwards of 65% of their working hours sedentary [8–11] with almost half of this time accrued in prolonged bouts of sitting (≥ 20 minutes at a time) [10]. The office workplace thus represents a public health opportunity to intervene in a large population who engage in high amounts of sitting [12].

Expert statement guidelines have been published recommending that full time employees engage in standing or light intensity activity for half of their work day; that they break up their sitting time throughout the day at regular intervals; and that they avoid any prolonged static postures (sitting or standing) [12]. However, the authors acknowledged the limited epidemiological evidence and controlled laboratory trials that the recommendations are based on and stress the need for longer term workplace-based efficacy trials [12]. The guidelines also omit specific information pertaining to the cardiometabolic benefits from reducing prolonged sitting, such as the effects on specific biomarkers that indicate a person's risk for developing chronic disease.

Detrimental associations of prolonged objectively measured sedentary time have been found with waist circumference [3,13], clustered metabolic risk score [13], high density lipoprotein (HDL) cholesterol [3], triglycerides [3], and insulin [3]. Conversely, an increased number of breaks in daily sedentary time was favourably associated with body mass index (BMI), waist circumference, triglycerides and postprandial glucose levels [3,14]. These breaks were brief changes from sedentary to light intensity activity lasting longer than one minute and averaging about four minutes each. These associations were independent of total daily sedentary time and moderate-to-vigorous physical activity [3,14]. To further support these findings, there is experimental evidence to suggest that small reductions in sedentary time (e.g. by 28 minutes) when sitting is interrupted with short frequent bouts of standing, light- or moderate-intensity walking improves cardiometabolic risk markers over a single day [15–19]. Controlled free-living studies have also demonstrated positive cardiometabolic changes in response to reducing daily sitting time over four days [20–22]. Longer term interventions that promote reductions in sitting in the workplace by increasing standing, light intensity physical activity, or a combination of both can effectively reduce sitting time at work [23,24]. However, it remains unclear if these interventions also improve cardiometabolic risk markers.

Previous reviews of sedentary behaviour reduction workplace interventions have focused on behaviour outcomes (i.e. changes in sedentary behaviour) and have not considered the effects of such interventions on cardiometabolic risk markers [23–25]. Overall, workplace interventions have significantly reduced sitting time by 39.6 min per 8-hour workday (95% CI -51.7 to -27.5) according to a pooled meta-analysis of 21 intervention studies [24]. A variety of strategies were deployed in these interventions, but the most effective were single component environmental interventions (a pooled reduction of -72.8 min/8-h workday; 95% CI: -104.9, -40.6) and multi-component interventions that targeted environmental (e.g. sit-

stand desks), individual (e.g. prompt software) and organisational strategies (e.g. manager emails) (-88.8 min/8-h workday; 95% CI: -132.7, -44.0). However, there has been no review of the efficacy of specific behaviour change techniques (BCTs) used in sedentary behaviour workplace interventions for improving cardiometabolic health, which would help to appropriately inform future workplace interventions and policy.

The efficacy of sedentary behaviour workplace interventions to improve cardiometabolic risk markers is not clear. A systematic review of interventions to reduce sedentary behaviour or increase physical activity during productive work in predominantly office-based workers reported conflicting or insufficient evidence for an effect of active workstation, stair use or personalised behavioural (e.g. goal setting, self-monitoring) interventions on anthropometric, lipid and metabolic health profiles [26]. However, this study collectively reviewed interventions that aimed to increase physical activity and/or reduce sedentary time and the isolated effects of sedentary behaviour interventions separate from those that focused only on physical activity were thus not reported. A systematic review of interventions to reduce sedentary time in free-living adults found that physical activity-only interventions (n = 16) and lifestyle interventions simultaneously targeting sedentary behaviour, physical activity and diet (n = 22) significantly improved cardiometabolic risk markers, but that interventions explicitly targeting sedentary behaviour only (n = 3) did not report on these outcomes [27]. At present, no systematic review has examined the isolated effects of workplace sedentary behaviour interventions (i.e. not including studies that target physical activity only) on cardiometabolic risk markers. This is important to understand the potential effectiveness of sedentary behaviour interventions for improving the cardiometabolic health of office workers. Furthermore, due to the substantial increase in studies evaluating sedentary behaviour reduction interventions in recent years, it is appropriate to conduct a systematic

review of the effects of sedentary behaviour workplace interventions on cardiometabolic health based on the larger evidence base that is now available.

The active BCTs by which sedentary behaviour reduction workplace interventions work is not fully understood. By elucidating these 'observable, replicable and irreducible components' of behaviour change [28,29] used in such interventions, researchers may better understand how interventions influence those behavioural outcomes (i.e. sitting), which have the potential to improve employee health. As one main goal of reducing sedentary behaviour in the workplace is to reduce an employee's risk of developing chronic disease, it is important to identify the components of behaviour change interventions that affect behavioural outcomes in order to elicit cardiometabolic risk marker improvements. Michie et al. [30] developed a reliable, comprehensive and theory-based taxonomy of 93 hierarchically clustered BCTs which facilitates examination of behaviour change intervention components. These BCTs may be tallied and, through the use of frequency ratios, help identify those which appear more frequently in effective versus ineffective interventions [28,29]. Gardner et al. [29] used this ratio to identify the most commonly used BCTs to reduce sedentary behaviour in adults in various settings, including workplaces. Their systematic review identified 26 studies describing 38 sedentary behaviour change interventions, which were subsequently categorised as very promising, quite promising, or non-promising. In a sub-group analysis of workplace interventions (n = 20) Gardner et al. [29] found that the BCTs self-monitoring, restructuring the social environment, restructuring the physical environment, and adding objects to the environment appeared more frequently in promising interventions. However, the review did not evaluate the effects of the interventions or the BCTs within them on health outcomes. Furthermore, the review did not isolate the BCTs that were most promising for reducing sedentary behavior in the workplace specifically, which could be

distinctly different to those that are effective in other contexts, such as leisure time. The ultimate aim of any sedentary behaviour intervention would be to improve health and it is thus important that the active intervention ingredients that lead to health improvements are identified.

Previous systematic reviews have identified the BCTs (active ingredients) that occur in interventions that effectively improve weight and BMI [28,31]. It would be beneficial to use such an approach to identify the BCTs in workplace interventions that improve cardiometabolic health via changes in sedentary behaviour. Furthermore, the number of BCTs used in an intervention could contribute to effectiveness [32] and should also be considered. In addition, intervention fidelity is important to consider when systematically reviewing evidence in order to provide context for the role that certain factors (e.g., study design, training of the provider, delivery by the provider, receipt of the intervention, and enactment of the behaviour [33]) play in intervention effectiveness [34]. This information can then be used to design evaluations of future interventions and to inform occupational health intervention strategies to reduce the risk of cardiometabolic disease. However, there are no reviews to date that have conducted such an evaluation in workplace sedentary behaviour interventions.

The primary aim of this study was, therefore, to systematically review the effects of workplace sedentary behaviour interventions on cardiometabolic risk markers in adult employees. A secondary aim was to identify and code the BCTs used in sedentary behaviour workplace interventions and establish which BCTs are used in interventions that effectively improve cardiometabolic risk markers. This will help inform the development of future sedentary behaviour workplace interventions to reduce the risk of cardiometabolic disease.

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2. Methods

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [35]. The review was prospectively registered on PROSPERO (CRD42017072427) and approved by the University of Bedfordshire Institute for Sport and Physical Activity Research Ethics Committee (2018ISPAR006).

2.1 Search procedure

A systematic search was performed to identify articles published up until 12th April 2019. Eleven databases were searched: PubMed, Web of Science, Medline, Cochrane Library, CINAHL, ScienceDirect, Directory of Open Access Journals, Scopus, PsycARTICLES, PsycINFO, and SPORTDiscus. A search string composed of terms relating to the workplace, sedentary behaviour, interventions, and cardiometabolic risk markers was used and adapted for the various databases (see Table 1 [36]). The search was limited to peer-reviewed journal articles published in English. There were no restrictions on publication date. Eligible articles were identified and their reference lists were hand searched for additional articles to be screened. Previous systematic reviews of sedentary behaviour interventions in the workplace [23–25,27,29,36–42] were also cross-checked for relevant studies.

2.2 Eligibility criteria

Studies were identified for inclusion based on the population, intervention, comparator, and outcome (PICO) method for eligibility.

2.2.1 Population

To be eligible for inclusion, studies had to include only adult participants ≥ 18 years who spent the majority of their time in desk-based or seated tasks in the workplace. No restrictions were placed on health or fitness status.

2.2.2 Intervention or exposure

Any workplace sedentary behaviour reduction intervention that evaluated effects on at least one cardiometabolic risk marker was eligible for inclusion. Studies that were of an acute nature (i.e. ≤48 h in duration) were excluded as the outcomes would not be comparable to interventions that evaluate chronic effects on cardiometabolic outcomes. If reducing sedentary behaviour was not a stated aim of the study (for example, if the study's focus was to reduce physical inactivity), but the nature of the intervention aimed to reduce sedentary time (e.g. installation of treadmill desks) and it reported on a sedentary behaviour outcome such as total sedentary time, sedentary bouts, number of breaks from sedentary time, number of sit-stand transitions, then the study was considered eligible for inclusion. Interventions that targeted physical activity or multiple behaviours (e.g., sedentary behaviour and physical activity; sedentary behaviour, physical activity and diet) were included if at some level they had a sedentary behaviour reduction component, or they measured sedentary behaviour outcomes.

2.2.3 Comparator

Any type of study design was considered and a control comparator was not necessary for inclusion in this review. Studies with or without the following controls were considered: no treatment control groups, waitlist control, normal practice (passive control), and active control (e.g., education handout). Study designs eligible for inclusion were: randomised controlled trials (with or without cross-over), cluster randomised controlled trials (with or

without cross-over), quasi-experimental design, cluster controlled trials, stepped wedge designs, pre/post intervention designs, pilot studies, and feasibility and acceptability studies.

2.2.4 Outcomes

To be eligible for inclusion, studies had to report on at least one of the following cardiometabolic risk marker outcomes: insulin (fasting, insulin sensitivity, or insulin resistance), glucose (fasting, continuous or postprandial), triglycerides, HDL cholesterol, low-density lipoprotein (LDL) cholesterol, total cholesterol, blood pressure, intima-media thickness, flow mediated dilation, and/or body composition measures (e.g. BMI, percent body fat, percent lean muscle mass, weight, waist circumference, waist-to-hip ratio).

2.2.5 Exclusion criteria

Studies were excluded if they recruited participants working < 0.5 full time equivalent hours; if it was an intervention for transport workers [23]; if it was a physical activity, lifestyle, mindfulness or other intervention with no sedentary behaviour reduction component; and if the intervention was not carried out in the workplace. Interventions in transport workers were excluded as they present unique barriers to reducing sedentary behaviour compared with office workers. This could thus be examined in a separate review so occupational health interventions can be more appropriately informed for each occupation group.

2.3 Screening procedure

Searches were conducted by MB. Results were downloaded into referencing software (Endnote X8, Clarivate Analytics, Philadelphia, PA, USA) where duplicates were automatically removed. The remaining results were transferred to a spreadsheet (Microsoft Excel 2010, Microsoft Corporation, Redmond, WA, USA) where additional duplicates were

removed and the remainder screened for eligibility by two independent reviewers (MB and LS). Titles were screened first, then abstracts, then the full text of remaining articles [43] (see Fig. 1). Discrepancies were resolved through discussion between the first and second reviewer where possible and further disagreements were resolved by consulting a third reviewer (DB).

2.4 Data extraction

Study design, methodological, and interventional characteristics of included studies were extracted (see Table 2). Cardiometabolic risk marker outcomes and total sedentary time at work outcomes (when reported) were also extracted.

Intervention details were entered onto the Template for Intervention Description and Replication (TIDieR) [44]. For the remaining data, an extraction file was independently and iteratively (MB) developed for information capture using Microsoft Excel software. Where necessary, further information regarding intervention components and delivery was obtained from trial registries (12 papers), linked articles (9 papers), and supplementary online material (10 papers) [29]. Contact was also made with three study authors where sex information [45,46], age [46], and full-time status of participants [47] were not fully reported. Data was independently extracted by one reviewer (MB) with a second reviewer (LS) independently extracting and coding data for 20% of included studies (n = 6). Percentage agreement was 99.9% with disagreement resolved through discussion.

2.5 Risk of bias assessment

Internal validity of individual studies was assessed using the Tool for Assessing Bias from the Cochrane Collaboration [48]. Each study was given a rating of ‘high’, ‘low’ or ‘unclear’

for up to seven items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and outcome-specific evaluations of risk of bias. Two separate researchers completed the risk of bias assessment (MB and LS). Percentage agreement and interrater agreement (kappa) [49] were calculated (0 - 0.20 = slight agreement, 0.20 - 0.40 = fair agreement, 0.40 - 0.60 = moderate agreement, 0.60 - 0.80 = substantial agreement, and >0.80 = nearly perfect agreement).

2.6 Synthesis of data

There was large heterogeneity across sedentary behaviour workplace interventions employed, study designs, and the cardiometabolic risk marker outcomes reported. Thus, a meta-analysis was not appropriate and a narrative review and classification system with respect to apparent potential to improve cardiometabolic risk was used.

2.6.1 Intervention effects on cardiometabolic risk markers

In order to facilitate BCT comparison with a past review focusing on the effects of sedentary behaviour interventions on sedentary behaviour outcomes [29], interventions were categorised as very promising, quite promising or non-promising with regards to significant cardiometabolic risk marker improvements. A very promising intervention must have reported a significant improvement ($p < 0.05$) for at least one cardiometabolic risk marker compared to baseline and a comparison arm at the last follow-up time point, which was post-intervention for all but five studies that reported follow-up time points from two weeks post intervention (21-week follow-up) [50], to nine months post-intervention (12-month follow-up) [51,52], to one year post-intervention (18-month follow-up) [53], to 14 months post-intervention (18-month follow-up) [54]. To be classed as quite promising, an intervention

must have reported significant improvement ($p < 0.05$) on at least one cardiometabolic risk marker compared to baseline or compared to a comparison arm. Non-promising interventions reported no improvement in any cardiometabolic risk marker outcome. As reported by Gardner et al. [29] this classification system ensures that interventions showing any promise of changing cardiometabolic risk were coded as such, and that interventions demonstrating the strongest evidence of promise were distinguished from interventions that showed lesser evidence.

In order to determine whether target behaviour played a role in cardiometabolic risk marker improvement, a chi-square test of goodness-of-fit was computed (alpha level set at $p < 0.05$) to determine if the prevalence of very, quite or non-promising interventions was dependent on the primary behaviour being changed (sedentary behaviour; physical activity; sedentary behaviour and physical activity; or sedentary behaviour, physical activity and diet).

2.6.2 Sedentary behaviour outcomes

Sedentary behaviour outcomes for each study were recorded and presented narratively to contextualise the interpretation of cardiometabolic risk marker and BCT outcomes.

2.6.3 Behaviour change techniques

The BCT taxonomy (v1) [30] was used to code the sedentary behaviour workplace interventions. The coders (MC and AC) were familiar with the BCT Taxonomy and both had been trained through the BCT Taxonomy online training, with the senior coder (AC) trained through the original BCT Taxonomy project [55]. Both coders have been involved in previous systematic reviews applying the BCT Taxonomy [28,56]. All interventions (including active control comparison groups receiving BCTs) were independently coded for

356 BCTs by MB and AC using the main article for each intervention as well as all related
357 (published) material including additional articles describing the same study, protocol papers,
358 clinical trial registries, and supplemental material [28,29,56]. Percentage agreement and
359 interrater agreement (kappa) [49] were calculated. Disagreements were resolved through
360 discussion between the two coders. Data collection methods, which could also have been
361 deemed BCTs (e.g., accelerometers), were coded separately unless they were explicitly
362 reported in the paper to have been used with the intention to change behaviour. A total of 30
363 interventions and ten active controls were coded. Inter-rater agreement was 99.6% and inter-
364 rater reliability was very high (kappa = 0.97).
365
366 Frequency data for BCTs across all interventions (promising and non-promising) was
367 computed. A one-way ANOVA was conducted to compare the number of BCTs used in very
368 promising, quite promising, and non-promising interventions (when excluding active controls
369 and when including active controls). A t-test was conducted to compare the number of BCTs
370 used in all (very and quite) promising interventions versus non-promising interventions
371 (when excluding active controls and when including active controls).
372
373 2.6.4 Promise ratios
374 The promise ratio gives an indication of the contribution of specific BCTs towards
375 intervention effectiveness [28,29]. The promise ratio was calculated as the frequency of all
376 (very or quite) promising interventions in which a BCT was present divided by the frequency
377 of its appearance in non-promising interventions (active controls included). A second ratio
378 was calculated without the BCTs from active controls. A promise ratio of ≥ 2.0 was
379 considered to be an effective BCT [29].
380
381

3. Results

3.1 Article selection

Database searching returned 5019 results. After removing duplicates and screening for inclusion criteria, 69 articles were full-text screened. Twenty-seven articles were identified as eligible for inclusion plus two articles identified from hand searches after checking the references of included papers. A total of 29 articles describing 30 interventions were included in this review (see Fig. 1).

3.1.1 Study characteristics

All studies were in office settings such as university offices (n = 9), private companies (n = 9), public sector offices (n = 4), health care settings (n = 3), a mixture of private and state run companies (n=1), a mixture of university and private companies (n=1), a mixture of healthcare settings and private companies (n=1), and various unspecified employers (n=1). (see Table 3). Studies were conducted in 13 different countries: Australia, Canada, Denmark, Greenland, Japan, the Netherlands, Singapore, South Africa, Spain, Sweden, Taiwan, the UK and the USA. Intervention length varied from two weeks to 13 months (mode = 12 weeks). Five studies reported follow-up data ranging from two weeks [50], to nine months [51,52], to one year [53], to 14 months post-intervention [54].

3.1.2 Sample characteristics

A total of 2,544 participants were included with the median number of participants across studies being 40 (interquartile range = 28, range 12-523) (see Table 3). Women (n = 1611) represented 63% of participants. For the majority of studies, an apparently healthy population was recruited. A third of studies (n = 9) specifically recruited overweight/obese participants. Reported occupations of participants included: clerical work, customer service, administrative work, IT help-desk work, knowledge-based work, and screen-based work [57].

Fifteen studies reported explicit sedentary behaviour inclusion criteria for participants, which included definitions of sedentary behaviour at work being based on physical activity levels (<3000 MET min/week [50]), job role ("office workers with sedentary occupations that involve sitting most of the time" [52]), self-reported daily sitting ("self-reported sitting ≥75% of workday" [58]), and environmentally-defined behaviour (office workers "who used a nonadjustable work surface and desktop computer " [59]).

3.1.3 Methodological characteristics

Interventions targeted a range of levels from the socio-ecological model [60], which includes addressing behaviour change at the individual, organisational or environmental level (see Table 3). Nearly half of included interventions (n = 14) targeted two or more levels [45–47,50–54,58,61–65]. Twenty-four interventions [45–47,51–54,58,59,61–75] incorporated some element of environmental change (e.g., active workstations, activity-permissive buildings). Eighteen interventions [45–47,50–54,58,61–65,76–79] had an individual/educational element (e.g., newsletters, behavioural support strategies) and seven interventions [47,50–52,54,62,65] contained an organisational/social element (e.g., team champions, management support). A theoretical framework was explicitly stated in 33% of interventions (n = 10) (see Electronic Supplementary Table S1) [47,51–53,61,62,64,65,78,80].

According to their stated aim, interventions reported targeting one or more health behaviours including sedentary behaviour [46,51,54,59,61–68,70,71,74,78]; physical activity [45,58,75]; sedentary behaviour and physical activity [50,52,69,72,73,76,77,79]; or sedentary behaviour, physical activity and diet [47,53].

433

434 3.1.4 Fidelity

435 Fidelity to the intervention was not consistently planned across interventions with only 43%
436 reporting it (n = 13 of 30) (see item 11 in Electronic Supplementary Table S1). Most
437 treatment groups (80%, n = 24) provided intervention tailoring (see item 9 in Electronic
438 Supplementary Table S1). Common adaptations were counselling topics, use of personalised
439 goal setting, self-selected activities, self-determined frequency of engagement, and
440 personalised communications. Though fidelity assessments may have been planned, only
441 37% of interventions (n = 11) reported on them (see item 12 in Electronic Supplementary
442 Table S1).

443

444 3.2 Risk of bias

445 Risk of bias for individual studies is presented in Table 4. Percentage agreement between
446 reviewers (MB, LS) was 90% (kappa = 0.73). Over two thirds of studies (69%, n = 20) were
447 at low risk for random sequence generation bias, although nearly half (41%, n = 12) did not
448 have allocation concealment (i.e. researchers were not blinded to group allocation). The
449 majority of studies (72%, n = 21) were at high risk of performance bias. Cardiometabolic risk
450 marker outcome bias was assessed as mostly low risk (93% of studies, n = 27) since they
451 were objective measures and lack of blinding is unlikely to have biased results. Two thirds of
452 studies (67%, n = 20) were assessed as low risk of bias for incomplete outcome data. The
453 remaining third of studies (34%, n = 10) were assessed as high risk of bias for incomplete
454 outcome data due to withdrawals and dropouts. Reporting bias was low risk as all studies
455 (100%, n = 29) reported on findings stated in their methodologies or provided details on
456 where to find related published material elsewhere.

457

458 In general, because of the naturalistic settings in which these studies took place, the overall
459 risk of bias among individual studies was moderate (see Table 4). Despite the use of cluster
460 randomisation techniques and allocation blinding, baseline imbalances were a high source of
461 bias in five studies [45,59,62,63,78]. Contamination during the intervention due to spillover
462 effects may have biased findings in six studies [63,67,68,70,71,77]. External validity was
463 assessed as high risk in four studies [50,54,61,66], largely because these involved university
464 faculty and staff educated to a high degree level, thereby limiting the application of findings
465 to the population at large. Effect of season was stated as a potential confounder in Gorman et
466 al. [61] and Koepp et al. [73]. Other issues such as funding source (e.g., Miyachi et al. [76],
467 which was partly funded by the participating organisation) and fluctuating adherence levels
468 during the active intervention [69,79] may have biased results.
469
470 3.3 Intervention effects on cardiometabolic risk markers
471 Twenty interventions (67%) significantly improved at least one cardiometabolic risk marker
472 compared to a comparison arm or baseline. Significant cardiometabolic risk marker effects
473 varied widely across studies (Fig. 2).
474
475 Seven interventions reported reduced blood pressure [52,64–66,70,73,79] and three reduced
476 mean arterial pressure (MAP) [64,77,79]. No interventions reported improvements in flow
477 mediated dilation or carotid intima-media thickness. Six interventions reported improved
478 blood glucose levels: three improved fasting glucose [46,57 (short breaks intervention),60],
479 two improved fasting insulin [54,81], one improved glycosylated haemoglobin (HbA1c) [72],
480 and one improved homeostatic modelling assessment version 2 for insulin sensitivity
481 (HOMA2-%S) [51]. No interventions improved HOMA2-%B for insulin output or insulin
482 resistance (HOMA-IR). For lipid levels, one intervention improved LDL cholesterol [54],

two interventions increased HDL cholesterol [59,73], but no interventions reduced total cholesterol, very low density lipoprotein (VLDL) cholesterol, non-LDL, triglycerides, or ratios of LDL/HDL nor total cholesterol/HDL. One intervention reported an improved clustered cardiometabolic risk score [51]. Eleven interventions reported improved body composition outcomes, which included four interventions that decreased weight/body mass [45,52,54,73], one intervention that reduced BMI [45], seven interventions that reduced waist circumference [50,52,64,66,72,73,76], one intervention that reduced hip circumference [72], four interventions that increased fat-free mass/total lean mass [45,64,67,75], one intervention that reduced body fat percentage [67], and one intervention that reduced total fat mass [75]. No interventions decreased truncal fat mass or waist-to-hip ratio.

3.4 Cardiometabolic risk marker outcomes by promise category

The prevalence of very, quite and non-promising interventions did not differ dependent on the primary target behaviour.

3.4.1 Very promising interventions

There were nine very promising interventions [50,52,54,59,64,67,71,75,77] with significant cardiometabolic risk marker improvements compared to both baseline and a comparison arm (see Fig. 2).

3.4.2 Quite promising interventions

Eleven quite promising interventions [45,51,62,65,66,68,70,72,73,76,79] were associated with significant cardiometabolic risk marker improvements compared to baseline or a comparison arm (see Fig. 2).

3.4.3 Non-promising interventions

Ten non-promising interventions [46,47,53,58,61–63,69,74,78] did not result in improvements in cardiometabolic risk markers.

3.4.4 Active controls

Of the ten active control conditions [46,47,50–54,58,63,77], none reported any improvement in cardiometabolic risk markers; however, Healy et al. [51] found that the (active) control group experienced a significant worsening of clustered cardiometabolic risk scores, fasting glucose levels, and HOMA2-%S levels compared to baseline.

3.5 Sedentary behaviour outcomes

Of the 20 interventions which showed an improvement in at least one cardiometabolic risk marker [45,50–52,54,59,62,64–68,70–73,75–77,79], fifteen (75%) also reported significantly reducing ($p < 0.05$) sedentary behaviour [45,50–52,54,59,62,64–68,71–73]. The remaining five did not report on sedentary behaviour change.

Of the ten interventions which showed no improvements for cardiometabolic risk markers [46,47,53,58,61–63,69,74,78], six interventions significantly reduced sedentary behaviour [46,47,53,63,69,74]. The remaining four interventions [58,61,62,78] did not observe a change in sedentary behaviour. Of the ten active control conditions [46,47,50–54,58,63,77], none had sedentary behaviour changes.

3.6 Behaviour change techniques

3.6.1 All Interventions

A total of 35 BCTs were present across the 30 interventions and ten active control conditions, not including data collection BCTs (see Table 5 and Electronic Supplementary Tables 2 and 3). Very promising interventions used an average of 12.1 ± 4.6 BCTs, quite promising interventions used 13.2 ± 7.4 BCTs, non-promising interventions used 12.1 ± 6.5 BCTs, and active controls used 4.3 ± 3.4 BCTs. There was no difference between the number of BCTs used in non-promising (excluding active controls), quite promising and very promising interventions. There was also no difference in BCTs when active controls and non-promising interventions were combined (9.7 ± 7.2) versus quite promising and very promising interventions.

There was no difference in the number of BCTs used in all promising (very and quite; 12.7 ± 6.1 BCTs) versus non-promising interventions (excluding active controls), nor in all promising versus non-promising interventions plus active controls. Across all interventions (not including active controls) the BCTs of habit formation and behavioural practice/rehearsal appeared most frequently in 26 interventions each (87% of all interventions). Twenty-four interventions (80%) featured restructuring the physical environment, 23 interventions (77%) featured behaviour substitution and habit reversal, 22 interventions (73%) featured goal setting and instructions on how to perform the behaviour, 20 interventions (67%) featured adding objects to the environment, and 18 interventions (60%) featured action planning and prompts/cues.

3.6.2 Promising interventions

There were eleven BCTs unique to all (very and quite) promising interventions: social support (practical), behavioural experiments, information about others' approval, remove aversive stimulus, generalisation of target behaviour, social incentive, restructuring the social

environment, material incentive (behaviour), remove punishment, focus on past success, and identification of self as role model (See Table 6).

3.6.3 Non-promising interventions

The following six BCTs were unique to non-promising interventions: self-monitoring of outcomes of behaviour, salience of consequences, pros and cons, self-reward, framing/reframing, and verbal persuasion about capability (see Electronic Supplementary Table S2).

3.6.4 Unintended behaviour change techniques (used for data collection)

The results for unintentional BCTs coded from the data collection methodology are presented in Table 7. Monitoring of behaviour without feedback (sitting), monitoring of outcomes of behaviour without feedback (e.g., calories, weight, etc.), and biofeedback were present in 86% of interventions as this was used to gain data for the main outcomes of interest. Also commonly present (59% of interventions) was self-monitoring of behaviour, while only 17% of interventions involved participants self-monitoring outcomes of behaviour as part of data collection procedures. Feedback on behaviour (28%) and feedback on outcomes of behaviour (24%) were present in about a third of interventions.

3.7 Promise ratios

The following BCTs held the highest promise ratios: social comparison (promise ratio = 6.0), problem solving (2.7), demonstration of the behaviour (2.5), goal setting (2.3), behaviour substitution (2.0), and habit reversal (2.0). These promise ratios remained robust even when excluding active controls (see Table 6), although eleven additional BCTs emerged with moderate ratios (2.5-2.0): information about health consequences, monitoring of behaviour

582 by others without feedback, habit formation, behavioural practice/rehearsal, self-monitoring
583 of behaviour, restructuring the physical environment, action planning, feedback on
584 outcome(s) of behaviour, prompts/cues, feedback on behaviour, and social support
585 (unspecified).
586
587

4. Discussion

The main findings of this review were that, in general, sedentary behaviour workplace interventions showed promise for improving cardiometabolic risk markers, although there was no consistency in which cardiometabolic risk markers showed improvement across interventions. Significant sedentary behaviour improvements were present in all studies where cardiometabolic risk markers improved apart from five studies where sedentary time was not measured as an outcome. This is in line with previous reviews [23,24], which have shown that sedentary behaviour workplace interventions are able to significantly reduce sedentary behaviour. The present review adds to the literature by identifying that reductions in sedentary behaviour in office workers have promise for improving cardiometabolic health.

The minimum change in sedentary behaviour to yield cardiometabolic benefits is unknown [82] and a dose-response relationship is yet to be established [64]. Frequency, duration and intensity of breaks in sedentary time may be important factors in addition to reductions in the total volume of sedentary time. Interventions that replace sedentary time with passive standing, a predominantly static activity requiring ≤ 2.0 METs [2], may require greater volumes of standing or longer intervention timeframes before cardiometabolic benefits are realised [51], whereas replacing sedentary time with similar volumes of light or moderate activity may result in greater benefits [83,84]. In the present review, it was not possible to evaluate how cardiometabolic risk markers responded according to the sedentary behaviour intervention dose as the description of the interventions was not sufficiently detailed or consistent across studies. For example, there was a lack of detail and consistency for describing the frequency of contact with the research team and health coaches, the frequency and duration of breaks from sitting when using prompt software, and recommendations for how frequent and for what duration active workstations should be used. Further studies are

613 required to identify if a dose-response relationship exists between sedentary behaviour and
614 cardiometabolic risk changes and the role of frequency, intensity, mode and duration of
615 activity used to replace sedentary time in determining health outcome changes. Future studies
616 should also ensure that the dose of the intervention is sufficiently described to enable
617 evaluation of intervention dose in the context of cardiometabolic health changes.
618
619 Sedentary behaviour workplace intervention effects on cardiometabolic health may take
620 longer than the frequently employed 12-week intervention length seen in this review to elicit
621 detectable chronic changes in cardiometabolic risk markers. This may be due to differences in
622 the specific measures taken and the type of measure (e.g. fasting or postprandial) [64]. In the
623 present review, blood glucose, insulin, and lipid profiles were measured in the fasted state.
624 Short term (up to one day) laboratory-based trials have consistently reported attenuations in
625 postprandial glucose, insulin and triglycerides in response to breaking up prolonged sitting
626 [85]. It is therefore of interest to examine long term adaptations to postprandial outcomes in
627 response to sedentary behaviour interventions as these outcomes may be more sensitive to
628 changes in sedentary behaviour.
629
630 In the present review, the BCTs concerning habits, goal setting, and social support were
631 present more often in promising interventions than non-promising interventions. Specifically,
632 social comparison, problem solving, demonstration of the behaviour, goal setting
633 (behaviour), behaviour substitution, and habit reversal, were more than twice as likely to be
634 present in promising than non-promising interventions. Supporting the notion of sitting as
635 habit, the BCTs of habit substitution and habit reversal demonstrated moderate promise
636 ratios. Previous investigations [86,87] into employee perceptions of sedentary behaviour in
637 the workplace have shown that sitting is often performed out of habit. Thus, it makes sense

638 that techniques to establish new sitting reduction habits are a prominent feature of promising
639 sedentary workplace interventions. Behavioural habits also have cultural significance [88] as
640 they shape expectations around shared workplace norms [87,89,90]. Consistent with our
641 findings, automatic motivation may be best influenced through environmental strategies and
642 prompts to break up and reduce sitting time by substituting and reversing prolonged sitting
643 habits [91]. These findings may thus help to inform the design of interventions to reduce
644 sedentary behaviour and improve cardiometabolic health in office workers.
645
646 BCTs addressing the social context may also be supportive of cardiometabolic health
647 improvement in sedentary behaviour workplace interventions. Unique to promising
648 interventions only (and appearing in two or more interventions) were: information about
649 others' approval, social incentive, restructuring the social environment, identification of self
650 as role model, and generalisation of the target behaviour. This, along with social comparison,
651 which was six times more likely to be present in a promising versus a non-promising
652 intervention, indicates that support from workplace colleagues, managers, and the
653 organisation, may be beneficial for improving cardiometabolic risk markers in sedentary
654 workplace interventions. Social support in various forms thus appear to be important for
655 changes to sedentary behaviour in the workplace and multi-component interventions should
656 consider including these aforementioned BCTs.
657
658 This review identified that unintentional BCTs may have been administered through data
659 collection methods. However, it is important to note that both the control and intervention
660 groups in each study underwent the same procedures for data collection, thereby receiving the
661 same unintentional BCTs. As most data collection results were not provided to the
662 participants (only 28% and 24% of interventions received feedback on behaviour or feedback

on outcomes of behaviour, respectively) it is assumed that data collection methods were implemented to observe and record behaviour, and not intended to change behaviour. That said, there is evidence to suggest that measurement effects on sedentary behaviour can occur. In a study of 153 participants aged 40-75 years, cardiovascular assessments and the International Physical Activity Questionnaire administered at regular time points over 12 months rendered behaviour changes negligible between a letter-based tailored counselling intervention and a no-treatment control group [92]. There was, however, a significant decrease in sedentary time across both intervention and control groups from months six to 12, suggesting that data collection methods may result from repeated assessments. Importantly, none of the control groups in this review improved any cardiometabolic risk markers or sedentary time outcomes, which indicates that data collection methods did not influence behaviour or outcomes of behaviour. It remains possible that intervention effects may be underestimated if data collection methods introduce systemic bias to the study design or that, conversely, effects may be overestimated due to the addition of unintentional BCTs [92]. This may explain inconsistencies in cardiometabolic changes in response to sedentary behaviour interventions.

Another factor that may explain inconsistencies in cardiometabolic risk markers affected by interventions was sample size. Only two of the included studies [51,53] were adequately powered a priori to detect cardiometabolic risk marker changes, which were generally secondary outcomes. Healy et al. [51] initially reported in their protocol paper [93] that their anticipated sample size would allow detection of minimum differences of interest in a range of risk markers. However, after study completion the actual sample size restricted adequate power to cholesterol and body composition measures only. Verweij et al. [94] reported an a priori design to detect change in waist circumference at longest follow-up timepoint (18

688 months). Both Healy et al. [51] and Chia et al. [70] reported post-hoc power calculations
689 indicating that adequate power was reached for specific risk markers, although the thresholds
690 for adequate power were not consistent between the two studies and the minimum detectable
691 differences were not reported by Chia et al. [70]. Although lack of power is a limitation of
692 nearly all of the studies included in the current review, the significant cardiometabolic
693 changes observed in many of the studies with relatively small sample sizes is noteworthy,
694 given that changes in a larger number of outcomes may be detected with larger sample sizes.
695 Future studies should therefore ensure that sample sizes are sufficiently powered to detect
696 cardiometabolic risk marker changes in response to sedentary behaviour interventions.
697
698 Participants in the included studies were apparently healthy but were often overweight and/or
699 physically inactive. Inactive and highly sedentary workers are a group who may benefit
700 greatly from reducing sedentary time [7,95]. Dempsey et al. [96] in their review of the
701 experimental evidence for breaking up or replacing sitting suggested that those with poor
702 metabolic health, such as those with obesity or type 2 diabetes, experience greater glycaemic
703 improvements than healthy individuals. However, studies have yet to determine the
704 population groups that may benefit most from workplace interventions and this should be
705 investigated to help target public health and workplace policy more appropriately.
706
707 4.1 Limitations at study and outcome level
708 In order to gather as much information as possible on cardiometabolic risk marker responses,
709 there were no inclusion restrictions on study design, which means there may be an increased
710 risk of bias. Eighteen studies had a randomised design element, but the remaining eleven
711 studies were comprised of pilot interventions, quasi-experimental designs, convenience
712 sampling, naturalistic design, and pre-post testing. Six of the nine very promising

713 interventions were RCTs, four of the eleven quite promising interventions were RCTs, and
714 nine of the ten non-promising interventions were RCTs. In comparison, Chu et al. [24] found
715 consistent evidence for improved behavioural outcomes (workplace sitting reduction) in their
716 systematic review of RCTs. This would suggest that intervention effectiveness may be related
717 to study design, however, there may be additional factors to consider for cardiometabolic risk
718 marker change. This review has assessed one such study design factor, intervention behaviour
719 change components, as set out in the BCT taxonomy [30]. It is recommended that future
720 interventions are evaluated in RCT designs to provide stronger conclusions with regards to
721 the effectiveness of sedentary behaviour workplace interventions for improving
722 cardiometabolic health.
723
724 Methodological quality was moderate overall with a high risk of bias regarding allocation
725 concealment, performance bias, and small sample sizes. A lack of randomised controlled
726 trials as well as concealment and blinding are well-known issues in the field of sedentary
727 behaviour intervention research [23,24]. In workplace interventions it is not often practical to
728 blind participants and personnel to treatment group because behaviour change interventions
729 rely on knowledge and understanding by the participant and some intervention techniques
730 like motivational counselling make it impossible to blind personnel delivering the sessions. If
731 these issues continue to persist in sedentary behaviour studies, then intervention reporting
732 frameworks such as TIDieR would at least allow for greater transparency in delivery mode
733 and methods, as well as content [44].
734
735 Conflicting operational definitions concerning participant inclusion criteria were apparent in
736 the included studies, with sedentary behaviour levels and full-time status being two of the
737 most inconsistently defined terms. There was a lack of consistency with regard to sedentary

738 behaviour eligibility criteria. This might lead to the underestimation of intervention
739 effectiveness since those with the most sedentary time are more likely to gain the most
740 benefit from reducing their sitting time. The way full-time status was operationally defined
741 was likewise inconsistent. This was described either in percentage work hours, full time
742 equivalent hours worked, or simply as full-time employees. For those studies with specific
743 criteria such as ≥ 0.6 full time equivalent work hours (e.g., Healy et al. [51]), some had low
744 inclusion thresholds or may have only specified part-time hours as exclusion criteria. No
745 mention of these issues has been included in past sedentary behaviour workplace intervention
746 reviews [23–25]. These variations lead to increased heterogeneity of the results and caution
747 must be thus exercised when generalising the findings of this review.
748
749 4.2 Limitations at review level
750 A decision was made to include all workplace interventions regardless of primary behaviour
751 aim (e.g., sedentary behaviour-only; physical activity-only; joint sedentary behaviour and
752 physical activity; or sedentary behaviour, physical activity and diet) in anticipation of there
753 being few sedentary behaviour-only interventions reporting cardiometabolic risk marker
754 outcomes [27]. Previous reviews have highlighted that being clear about the target behaviour
755 for participants, subsequent messages, and supporting BCTs, impacts on intervention
756 effectiveness [27]. However, this review found that interventions with a sedentary behaviour-
757 only focus were no more promising for cardiometabolic risk marker improvement than those
758 with a joint sedentary behaviour and physical activity focus. For the 17 interventions in this
759 review that had sedentary behaviour-only as the stated target behaviour, 65% (n = 11)
760 improved at least one cardiometabolic risk marker. Of these, eight were RCTs. It may be that
761 targeting sedentary behaviour is related to improved cardiometabolic risk profiles and

762 researchers should thus be clear and explicit about the behaviour to be changed when
763 designing and reporting interventions in order to further evaluate the evidence base.
764
765 A potential limitation of all reviews in this field is the possibility of publication bias. Nine out
766 of the 10 non-promising interventions in this review were RCTs, which might suggest that
767 non-promising interventions found in non-randomised controlled trials have not been
768 published. The Open Science Movement [97] is a global strategy targeted at making all
769 scientific research data accessible to all, which will help to reduce the occurrence of
770 publication bias. There was large heterogeneity with respect to sedentary behaviour
771 interventions employed and cardiometabolic outcomes measured in this review. These
772 limitations should be addressed in future RCTs to permit meta-analyses that would allow
773 definitive conclusions to be drawn on sedentary behaviour intervention effectiveness.
774
775 Another potential limitation of this review is the crude approach to examining the
776 contribution of BCTs to intervention effectiveness via a "promise ratio". A meta-regression
777 approach [32] to determine associations between BCTs and effective interventions could be
778 preferred but this was not possible in the current review due to the inconsistency in outcome
779 measures reported across studies. Coding for the BCTs in promising interventions identified
780 several issues that limit the generalisability of the findings. It was only possible to code for
781 items if they were described by the authors. This may lead to the inadvertent omission of
782 techniques that are not fully described. It has been suggested that authors and journals offer
783 supplemental materials such as intervention manuals [98] or TIDieR supplements [99] in
784 order to provide precise, accurate reporting of intervention content. This would improve the
785 replicability of each intervention and the generalisability of the findings. Finally, a limitation
786 of the BCT taxonomy is that it risks not extracting important contextual information. For

example, social comparison, when attention is drawn to others' performance to allow comparison with the person's own performance, may refer to competition or more of a group learning environment, and labelling all instances under one heading may actually lead to less clarity about the intervention components. Therefore, it is important that researchers report on contextual information alongside the named BCTs to give greater understanding of what works and why.

4.3 Strengths

This study has several strengths, including a thorough search strategy and adherence to Cochrane [48] and PRISMA guidelines [35] for the reporting of systematic reviews. The study was strengthened by having two independent reviewers at all stages of the review process, including screening and study selection, data extraction, risk of bias assessment and BCT coding. This review has explored a topical issue (sedentary behaviour) identified by the World Health Organization [100] as a distinct and growing concern that would benefit from a systems-based approach as part of a global action plan for policymakers.

Another strength of this review was that in addressing the issue of incomplete BCT coding, coding was combined from all related (published) material including the main article, additional articles describing the same study, protocol papers, clinical trial registries, and supplementary material [27,29,56]. It was thus possible to capture information such as email newsletter content that would otherwise have been missed. Furthermore, by coding active control conditions and including them in promise ratio analyses [27,29], it is more certain that the promising BCTs that emerged were indeed associated with intervention effects.

5. Conclusions

The majority of workplace sedentary behaviour reduction interventions reviewed demonstrated a significant improvement for at least one cardiometabolic risk marker. However, inherent bias in study designs means that it was not possible to draw strong conclusions. Future studies of workplace sedentary behaviour interventions should employ an RCT design, ensure sample sizes are sufficiently powered to detect change in cardiometabolic risk markers, and include longer follow-ups to assess long-term adaptations. In addition, improved intervention reporting through the use of TIDieR would strengthen the evidence base in this field. For stakeholders of sedentary workplace interventions, this review has positive implications for cardiometabolic health in adult office workers. The BCTs of social comparison, problem solving, demonstration of the behaviour, goal setting (behaviour), behaviour substitution, and habit reversal, appeared more frequently throughout promising interventions and should be considered for future intervention development.

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1130 7. Tables
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1132 **Table 1.** Search terms were combined in the following manner for title and abstract search in
1133 PubMed and adapted to remaining databases: 1 and (2a and 2b) and 3 (adapted from Neuhaus
1134 et al. [36]).

1. Work setting	2a. Sedentary behaviour	2b. Intervention	3. Cardiometabolic risk markers
Workplace OR Worksite OR Work place OR Work site OR Work location OR Work setting OR Place of work OR Employer* OR Employee* OR Worker* OR Office work* OR Office* OR Call centre* OR Call center* OR Computer use* OR Occupation OR Job* OR Desk OR workstation	Sedentary behaviour OR sedentary behavior OR sitting OR Low energy expenditure OR Inactiv* OR Standing OR Sit-stand OR Seated	RCT OR Trial* OR Intervention* OR Program* OR Study OR Studies OR Random*	Cardiometabolic OR Cardiovascular OR Metabolic OR metabolic syndrome OR Hyperglycaemia OR Glycaemia OR Hyperglycemia OR Glycemia OR Lipid* OR cholesterol OR Triglyceride* OR Triacylglycerol OR Lipoprotein* OR Insulin OR glucose OR Blood Pressure OR Intima-Media Thickness OR Flow Mediated Dilation OR Waist OR Weight OR Body mass index OR BMI OR Body fat OR Body composition OR Anthropometric OR Overweight OR Obesity OR Fat

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Table 2. Data extracted from eligible studies.

Characteristics	Details
General information	Author names, publication year, funding source, country, linked papers, supplementary material, clinical trial registration, conflicts of interest
Population	Number of participants, sex, age, health status, attrition rates
Intervention	Study design; intervention aim; theory base; number of intervention groups; workplace setting; details of control group; sedentary behaviour eligibility criteria; intervention duration; time to longest follow-up; materials; procedures; provider information; mode of delivery; frequency of sessions, delivery schedule, intensity/dose; tailoring; modifications; planned and actual adherence/fidelity measures [44]; payments to participants
Outcomes	Cardiometabolic risk markers and workplace sedentary time
Risk of bias	Data on randomisation, allocation concealment, blinding (participants and personnel), blinding (outcome assessment), incomplete outcome data, selection reporting, or other bias
Results	Quantitative data for cardiometabolic risk marker and sedentary time outcomes

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1143 **Table 3**. Study characteristics, cardiometabolic risk marker results and significant sedentary
1144 behaviour outcomes (from baseline to longest timepoint reported).
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Study Country	Study design	Participants (n/sex); age (y) [mean ± SD, or range]; group; health status	Intervention	Active intervention duration (longest follow-up)	Cardio-metabolic risk marker effects	Sedentary behaviour effects
Alkhajah et al. [59] Australia	Quasi-experimental 2-arm, non-randomised design	29F 3M All: 20-65 I: 33.5 ± 8.7 C: 39.9 ± 7.2 Healthy	I: Sit-stand desks C: Normal work practices	3 mo (no follow-up)	↔BMI ↔Fat-free mass ↔Fat mass ↔HC ↑HDL ↔Plasma glucose ↔Total cholesterol ↔Trigly-cerides ↔WC ↔WT	Total workplace sedentary time reduction of -137 min/day (95% CI: 179, 95) p< 0.001, versus comparison group. -125min/day (95% CI: 150, 99) p<0.05, intervention group pre-post.
Bergman et al. [47] Sweden	Stratified RCT	44F 36M All: NR I: 52.4 ± 6.8 C: 50.3 ± 6.7 Overweight or obese	I: Treadmill desk installed under their normal sit-stand desk, 4 booster emails C: Normal work practices (using a sit-stand desk)	13 mo (no follow-up)	↔WT ↔BMI ↔WC ↔HC ↔SBP ↔DBP ↔RHR ↔Fat mass ↔Lean mass ↔HbA1c ↔Fasting glucose ↔Fasting insulin ↔Trigly-cerides ↔Total cholesterol	The intervention group decreased their workplace sitting time [-4 mins (95% CI: 21,13)] compared to control [35 mins (95% CI: 19,52)], p < 0.0001.
Bouchard et al. [65] Canada	Pre-post design	20F 2M All: 51.2 ± 10.4 I & C: N/A Any health status	I: Shared treadmill desk, pedometer No control group	3 mo (no follow-up)	↔BMI ↓DBP ↔RHR ↓SBP ↔WT	20.1% reduction in workday sedentary time from baseline, [1267 min (95% CI: 1189, 1286)], to intervention end [1013 min (95% CI: 908, 1053)]. d=2.19, p=0.007, pre-post.
Carr et al. [66] United States	RCT	36F 4M All: 44.7 ± 9.6 I: 42.6 ± 8.9 C: 47.6 ± 9.9 Healthy, inactive, overweight (must be all 3)	I: Desk pedal device, website C: Waitlist control,	12 wk (no follow-up)	↔BMI ↔DBP ↔HDL ↔LDL ↓SBP (Intervention	Total daily sedentary time reduction of −58.7 min/day (95% CI: −118.4, 0.99), p<0.01, compared to control.

			normal work practices		group pre-post) ↔Total cholesterol ↔Trigly-cerides ↓WC (compared to control, but not compared to baseline) ↔WT	
Carr et al. [58] United States	2-group RCT	38F 16M All: NR I (HP/HP): 45.2 ± 10.9 AC (HPO): 45 ± 10.7 Healthy, overweight/ obese	I: (HP/HP) ergonomics consultation, elliptical pedal device, iPod/app, emails, GENEactiv ankle accelerometer, pedal goal sheet AC: (HPO) ergonomics consultation, e-mails	16 wk (no follow-up)	↔BMI ↔DBP ↔Fat mass ↔Lean mass ↔RHR ↔SBP ↔WC ↔WT	No intervention effect for % of work time spent sedentary.
Chia et al. [70] Singapore	2-group crossover RCT	11F 10M All: 48 ± 12.4 I (S-C): NR C (O-C): NR Healthy	I: Seat-cycle (S-C) C: Normal work conditions with an office chair (O-C)	4 wk (no follow-up)	↔Body mass ↔BMI ↔DBP ↔RHR ↓SBP (Intervention group pre-post) ↔Waist-to-hip ratio	Sedentary time not reported as outcome. Participants spent on average 5.79±1.51 hours sitting in the office (0900-1700hrs) and used the seat-cycle for an average of 22.8 minutes daily at work.
Danquah et al. [67] Denmark & Green-land	Cluster RCT	210F 107M All: 46 ± 10 I: 46 ± 10 C: 45 ± 11 Healthy	I: Lecture, workshop, emails, text messages, high meeting tables, walking routes provided, posters, leaflets, webpage, postcard and sticky notes for goals, manager ambassadors C: Normal work practices	3 mo (no follow-up)	↓BF% ↔BMI ↔WC ↔WT ↑Fat-free mass ↔Fat mass	-48 min/8-h workday (95% CI: -62, -34), $p < 0.001$, reduction in sedentary time compared to control. Time accumulated in prolonged sitting periods was reduced by 16 min/8-h workday at 3 mo (95% CI: -31,-0.66; $p = 0.04$).

Dunning et al. [78]South Africa	Repeated measures RCT	12F 9M All: 27.5 ± 5.7 I: NR C: NR Healthy	I: Text message prompts to interrupt sitting C: Normal work practices	10 wk (no follow-up)	↔WT ↔BMI ↔BF% ↔SBP ↔DBP ↔Fasting glucose ↔Fasting insulin ↔HOMA-IR ↔Trigly-cerides ↔Total cholesterol ↔HDL ↔LDL	No intervention effect for amount of work time spent sitting.
Garland et al. [63] United States	Cluster RCT	27F 40M All: NR I: NR AC: NR Apparently healthy	I: Education session, ergonomics training, sit-stand desks AC: Normal work practices and education session	12 mo (no follow-up)	↔BMI	The intervention group's sitting time was 16 percent less ($p<0.05$) than baseline at 12 mo, but no between group differences were found.
Gorman et al. [61] Canada	Pre-post design	18F 6M All: 34.5 ± 8.1 I & C: N/A Any health status	I: Activity permissive building: activity-encouraging spaces and stairways, active commuting facilities, sit-stand desks (faculty only) & café-style meeting rooms with standing tables, centralised supplies/ printing, office layout to encourage stair use No control group	4 mo average; 3-6 mo range (no follow-up)	↔BF% ↔HDL ↔Insulin ↔Plasma glucose ↔Trigly-cerides ↔WT	No change in sitting time.
Graves et al. [71] United Kingdom	2-arm, parallel group, individual RCT	37F 10M All: 38.6 ± 9.5 I: 38.8 ± 9.8 C: 38.4 ± 9.3 Healthy	I: Sit-stand desks, ecological momentary assessment diary. C: Normal work practices	8 wk (no follow-up)	↔BMI ↔Body mass ↔cIMT ↔DBP ↔FMD ↔Plasma glucose ↔SBP	Significant decrease in sitting time [−80.2 min/8-h workday (95% CI: −129.0, −31.4); p = 0.002], compared to control.

					↓Total cholesterol ↔Trigly-cerides	
Healy et al. [68] Australia	Conven-ience clusters; 2-arm (non-randomised)	24F 19M All: 43.2 ± 10.3 I: 42.4 ± 10.6 C: 42.9 ± 10.3 Healthy, ambulatory, no pre-existing musculoskeletal disorders	I: Team champion & management support; sit-stand workstations; health coaching, goal setting, tracking, focus groups C: Normal work practices	4 wk (no follow-up)	↔DBP ↔Fat-free mass ↔Fat mass ↔HC ↔HDL ↔Insulin ↔LDL ↓Plasma glucose (Intervention group pre-post) ↔SBP ↔Total cholesterol ↔Trigly-cerides ↔WC ↔WT	Intervention group significantly reduced workplace sitting time compared to control [−125 (95% CI: −161, −89) min/8-h workday; $p < 0.001$]. Reduction in prolonged sitting time compared to control [−73 (95% CI: −108, −40) min/8-h workday; $p < 0.001$].
Healy et al. [51] Australia	2-arm cluster RCT	158F 73M All: 45.6 ± 9.4 I: 44.6 ± 9.1 AC: 47 ± 9.7 Healthy, obese/over-weight, self-report diagnosed diabetes (11.7%)	I: Team champion & management support; sit-stand workstations; health coaching, goal setting, tracking, focus groups AC: Normal work practices but received written feedback on activity & biomarkers at 3 & 12 mo.	3 mo (12 mo)	↔BF% ↔BMI ↓Clustered CM risk score ↔DBP ↔Fat-free mass ↔Fat mass ↔HC ↔HDL ↔ HOMA2-%B ↓HOMA2-%S ↔Insulin ↔LDL ↓Plasma glucose ↔SBP ↔Total cholesterol ↔Trigly-cerides ↔WC ↔WT NOTE: Long-term significant intervention effects were due to control group worsening.	Significant reduction in sitting time [-99.1 min/ 8-hr workday (95% CI: -116.3, -81.8); $p < 0.001$] compared to control. Participants sat for significantly shorter periods at a time than controls [-4.4 min/8-hr workday (95% CI: -7.0, -1.8); $p < 0.001$]. Prolonged sitting time at work was lower compared to controls [-72.6 min/8-hr workday (95% CI: -93.8, -51.4); $p < 0.001$].

John et al. [72] United States	Pre-post design	7F 5M All: 46.2 ± 9.2 I & C: N/A Overweight/ obese	I: Treadmill workstation No control group	9 mo (no follow-up)	↔BF% ↔BMI ↔DBP ↔Fat-free mass ↔Fat mass ↓HbA1c ↓HC ↔HDL ↔Insulin ↔LDL ↔Plasma glucose ↔RHR ↔SBP ↔Total cholesterol ↔Trigly-cerides ↔Truncal fat mass ↔VLDL ↓WC ↔WT	Significant decrease in median time spent sedentary (sitting/lying) over the entire day [1238 (interquartile range: 128) min/day to 1150 (interquartile range: 87) min/day, $p < 0.05$], pre-post.
Koepp et al. [73] United States	Prospect-ive trial, pre-post design	25F 11M All: 42 ± 9.9 I & C: N/A Any health status	I: Sit-stand individual treadmill desk No control group	12 mo (no follow-up)	↔BF% ↔BMI ↔DBP ↔HbA1c ↓HDL ↔Insulin ↔Fat mass ↔Fat-free mass ↔LDL ↔Plasma glucose ↓SBP ↔Total cholesterol ↔Trigly-cerides ↓WC ↓WT	Significant decrease in daily sedentary time by -43 (SD: 67) min/day ($p < 0.001$) from baseline to 12 mo; $p < 0.001$.
Lin et al. [52] Taiwan	Quasi-experi-mental pretest-posttest compar-ison group design	52F 47M All: 49.5 ± NR I: 52.1 ± 6.57 AC: 46.8 ± 9.75 Any health status	I: Focus group, research liaisons, competitive teams, education via monthly management support emails, remuneration for participation, pedometer challenge, environmental prompts, motivational tools, walking route & resources	12 wk (12 mo)	↔BMI ↔DBP ↔HDL ↓Insulin ↔LDL ↔Plasma glucose ↔SBP ↔Total cholesterol ↔Trigly-cer-ides ↓WC ↓WT	For OSPAQ outcomes, no differences were observed between the two groups at follow-up. The intervention group showed significant improvements in occupational sitting from baseline [7.79 hours/day (standard error: 6.70)] to 12 months [7.41 hours/day (standard error: 6.70)], $p < 0.041$.

			AC: Normal work practices and monthly newsletters			
MacEwen et al. [74] Canada	RCT	23F 5M All: NR I: 43.2 ± 9.7, C: 48.9 ± 11.4, Workers with abdominal obesity, excluding those on glucose-lowering medication	I: Sit-stand desks C: Normal work practices	3 mo (no follow-up)	↔WT ↔BMI ↔WC ↔BF% ↔SBP ↔DBP ↔Triglycerides ↔Total cholesterol ↔LDL ↔Non-LDL ↔HDL ↔LDL/HDL ↔Fasting glucose ↔HbA1c	Intervention group reduced workday sitting time (344 ± 107 to 186 ± 101 min/day) and increased workday standing time (154 ± 108 to 301 ± 101 min/day) (all $p < .05$) compared to control.
Mailey et al. [62] United States	Parallel group randomised trial	49F 0M All: 38.71 ± 8.19 I_1 (SB): 38.50 ± 8.67 I_2 (LB): 38.92 ± 7.88 Healthy, overweight/obese	I_1: SB coaching phone call, list of computer/apps to break sedentary time, orientation session, planning worksheet, emails, break log I_2: LB coaching phone call, list of computer/apps to break sedentary time, orientation session, planning worksheet, emails, break log	8 wk (no follow-up)	↔BMI ↔DBP ↓Plasma glucose (SB group compared to baseline) ↔SBP ↔Total cholesterol ↔Triglycerides ↔WC ↔WT	Significant group by time interaction for average minutes of sedentary time during the workday [$p = 0.05$, $\eta^2 = 0.11$]. Sedentary time during the workday decreased significantly in the SB group (−35.6 min, $d = -0.75$, $p = 0.03$) but did not change in the LB group (+4.5 min, $d = 0.12$).

Mains-bridge et al. [77] Australia	RCT	24F 5M All: NR I: 36.73 ± 12.38 AC: 42.28 ± 9.59 Healthy	I: Education session, Exertime, phone interviews AC: Education session, normal work practices	13 wk (no follow-up)	↔DBP ↓MAP ↔SBP	Sitting time not measured as an outcome. Intervention participants broke up their workplace sitting on average 6.28±3.59 times per day.
Mains-bridge et al. [79] Australia	Interrupted time series cohort	195F 33M All: N/A I: 45.1 ± 10.5 C: N/A No health restrictions (included those with clinically elevated blood pressure)	I: Education session, e-health software (Exertime) to interrupt sitting with non-exercise physical activity, data collection reminder emails every 13 weeks No control group	12 mo (no follow-up)	↔WT ↔BMI ↔SBP ↓DBP ↓MAP	Sitting time not measured as an outcome. Intervention participants broke up their workplace sitting on average 5.5±2.0 times/workday in the first 3 months which decreased to 4.2±2.5 times per day by month 12 (P<0.05 for all time points compared with 3 months).
Malaeb et al. [75] United States	Prospective cohort within-subjects crossover design	17F 2M All: 47.2 I(PROMPT):NR C(CON):NR Apparently healthy (controlled chronic illness allowed)	I: Treadmill desk C: Normal work conditions	2 wk (no follow-up)	↔WT ↔BMI ↓Fat mass ↑Lean mass ↔BF%	Sitting time not measured as an outcome. Participants had to achieve ≥1,500 minutes of treadmill usage per 2-week period (i.e., 2.5 hours/working day) by self-report to be included in final analysis.
Mantzari et al. [46] United Kingdom	Feasibility RCT	11F 9M All:40.6 ± 13.3 I:39.6 ± 16.1, AC:41.6 ± 10.6 Apparently healthy	I: Sit-stand desks, demonstration, leaflet AC: Usual routine, verbal information on health consequences, tips to reduce prolonged sitting	3 mo (no follow-up)	↔SBP ↔DBP ↔RHR ↔WC ↔HC ↔WT ↔BMI ↔BF% ↔HbA1c ↔Total cholesterol ↔HDL ↔LDL ↔Trigly-cerides NOTE: Blood-related outcomes were	Reduced sitting time at work [-94 min/8-h workday (95% CI: −170.7, −17.7)] compared to control.

					assessed in 10 participants in total (5 in the intervention and 5 in the control group).	
Maylor et al. [64] United Kingdom	Two-arm cluster RCT	51F 38M I: All: 43.4 ± 2.5 I: 43.0 ± 3.7 C: 43.7 ± 4.0 Apparently healthy	I: Educational Presentation and Brainstorming Session; step challenge; Health Check Report and Individual Meetings; goodie bag with leaflet, facts sheet, information card, sticky notes reminders, prompt card; computer prompts, weekly 5-10min telephone support, work environment modifications (e.g. move bins further away) C: Normal work routine	8 wk (no follow-up)	↔WT ↔BMI ↓WC ↔BF% ↑Fat-free mass ↓SBP ↔DBP ↓MAP ↔Total cholesterol ↔HDL ↔Total cholesterol/ HDL	Reduction in workplace prolonged sitting time (-39 min/shift) at follow-up in favour of the intervention group (P<0.001). No change in total workplace sitting time.
Miyachi et al. [76] Japan	Random-ised crossover trial	22F 10M All: 44.2 ± 8.6 I (Group A): 44.4 ± 6.9 I (Group B): 44.0 ± 10.2 Any health status	I: Standing hot desks, diary log of standing work (groups A & B)	6 wk (no follow-up)	↔BMI ↓WC ↔WT	Sitting time not measured as an outcome. Group A and B replaced occupational sitting with standing 9.9 ± 0.9 and 9.6 ± 1.7 hrs/week, respectively.
Puig-Ribera et al. [50] Spain	Cluster, quasi-experi-mental pretest-posttest compar-ison group design	171F 93M All: 42 ± 10 I: NR C: NR Healthy but low-moderate PA levels (0 to 3,000 MET·min·wk^{-1})	I: Walk at Work automated internet-delivered intervention pedometer, paper diary C: Normal work practices	19 wk (8 wk ramping phase, 9-19 main-tenance phase) (21 wk)	↔BMI ↔DBP ↔WC ↔WT ↔SBP	A significant 2 (group) × 2 (programme phases) interaction was found for self-reported occupational sitting (p = 0.046) (including follow-up). Significant differences between groups were found for changes in self-reported occupational sitting time [-22 (SD: 11) min/day; p < 0.005] with occupational sitting time decreasing from 446.4 (SD: 126.7) min/day to 422.9 (SD: 123.4) min/day at the maintenance phase. There was no difference in sitting time between intervention and control groups at two months follow-up.

Schuna et al. [69] United States	2-arm RCT	40F 1M All: 40.1 ± 10.1 I: 40.0 ± 9.5 C: 40.3 ± 10.9 Overweight/ obese workers but otherwise apparently healthy	I: Treadmill workstation, electronic survey to record use/speed, behavioural support strategies (email, phone, face-to-face) C: Normal work practices	3 mo (no follow-up)	↔BF% ↔BMI ↔Body mass	Compared to the control group, the intervention group decreased sedentary time (-3.6 min/h, p = 0.047) during working hours. The intervention group reduced sedentary time by -2.4 min/h (95% CI: -5.0, 0.2) compared to baseline (p value not reported), with no decrease in control group sedentary time.
Tucker et al. [45] United States	Repeated measures design	40F 0M All: NR I (ET): 43.0 ± 12.4 I (DT): 42.2 ± 12.0 Apparently healthy (controlled chronic illness allowed)	I: Participants selected from a menu of options to reduce sedentary time at work by 30mins/day: treadmill workstation, Wii video game system, 'WellMe in 3' video clips (showing 3min exercises), stair climbing, walking meetings. two-way text messages (1-2/day) (ET and DT groups).	6 mo (no follow-up)	↔BF% ↓BMI ↔Fat mass ↓Total lean mass ↓WT NOTE: Results are for combined ET & DT results at 6 mo compared to baseline	Percentage time in sedentary activity decreased by - 3.3% (SD: 4.6, p < 0.01) for the early texting group. No changes for the delayed texting group. When the groups were combined, percentage time change in sedentary activity from baseline (90.4% ± 5.2) to 6 mo (88.0% ± 6.6) was significant (p = 0.01). NOTE: It was not stated whether sedentary activity measures were for at work times only or the entire day.
Verweij et al. [53] Netherlands	RCT parallel group, single blinded	193F 330M All: 47 ± 8 I: 46 ± 8 AC: 48 ± 9 Healthy, obese/over-weight, does not meet PA guidelines (had to meet all 3 conditions)	I: Motivational interviewing, toolkit (measuring tape, pedometer, leaflets on physical activity and nutrition, behaviour diary), obesogenic environment checklist AC: Care as usual; health risk appraisal, anthropometric measurements, health advice.	6 mo (18 mo)	↔BMI ↔DBP ↔SBP ↔Total cholesterol ↔WC ↔WT	The intervention had a significant effect on self-reported sedentary behaviour weekday work days compared to control [β: -28 min/day (95% CI: -2, -54), p < 0.05. NOTE: The occupational sitting questionnaire used had not yet been tested for validity.

Zhu et al. [54] United States	Two-arm, natural experiment (non RCT)	27F 9M All: 39.1 ± 11.3 I: 41.3 ± 11.6 AC: 34.8 ± 9.9 Apparently healthy	I: Personal sit-stand workstations, common area treadmill desks, initial management email letter of support, flyers, weekly 'stand & move' e-newsletters for 4 months. AC: weekly 'energize your workday' e-newsletters for 4 months.	4 mo (18 mo)	↓WT ↓Insulin ↓total cholesterol ↓LDL ↔HDL ↔BMI ↔SBP ↔DBP ↔Plasma glucose ↔Trigly-cerides	Total sitting time reduced 52.6±68.3 min/8-h workday; d = -0.77), total standing time increased (17.7±54.8 min/8-h workday, d = 0.32), prolonged sitting (≥30 min/8 h workday) reduced (data NR) compared to control.

Abbreviations: AC = active control group, AUC =area under the curve, BF% = body fat percentage, BMI = body mass index, C = control group, cIMT =carotid intima-media thickness, CM = cardiometabolic, DBP = diastolic blood pressure, DT = delayed texting, ET = early texting, F = female, FMD = flow mediated dilation, HbA1c = glycosylated haemoglobin, HC = hip circumference, HDL = high density lipoprotein cholesterol, HOMA2 = homeostatic modelling assessment version 2 (-%B for insulin output and -%S for insulin sensitivity), HP/HP = health protection/health promotion, HPO = health protection only, I = intervention group, LB = long break, LDL = low density lipoprotein cholesterol, M = male, MAP = mean arterial pressure, MET = metabolic equivalent of task, N/A = not applicable, NR = not reported, O-C = office chair, OSPAQ = Occupational Sitting and Physical Activity Questionnaire [101], PA = physical activity, RCT = randomised controlled trial, RHR = resting heart rate, SB = short break, SBP = systolic blood pressure, S-C = seat-cycle, VLDL = very low density lipoprotein cholesterol, WC = waist circumference, WT = weight, ↔ no change, ↓ significant decrease, ↑ significant increase.

Table 4. Risk of bias assessment of individual studies.

Study	Random sequence	Allocation concealment	Blinding of participants	Blinding of outcomes	Incomplete outcome data	Selective reporting	Other
Alkhajah et al. [59]	High	High	Unclear	Unclear	Low	Low	High
Bergman et al. [47]	Low	Low	High	Low	Low	Low	High
Bouchard et al. [65]	High	High	High	Low	High	Low	High
Carr et al. [66]	Low	Low	Low	Low	Low	Low	High
Carr et al. [58]	Low	Low	High	Low	Low	Low	N/A
Chia et al. [70]	Low	Unclear	High	Low	Low	Low	High
Danquah et al. [67]	Low	Low	High	High	High	Low	High
Dunning et al. [78]	Low	Unclear	Unclear	Low	Low	Low	High
Garland et al. [63]	Low	High	Unclear	Low	High	Low	High
Gorman et al. [61]	Low	Low	High	Low	Low	Low	High
Graves et al. [71]	Low	High	High	Low	High	Low	High
Healy et al. [68]	High	High	High	Low	Low	Low	High
Healy et al. [51]	Low	Low	Low	Low	Low	Low	N/A
John et al. [72]	High	Low	High	Low	Low	Low	N/A
Koepp et al. [73]	Unclear	High	High	Low	Low	Low	Unclear
Lin et al. [52]	High	High	High	Low	Low	Low	N/A
MacEwen et al. [74]	Low	Unclear	Unclear	Low	Low	Low	N/A
Mailey et al. [62]	Low	Low	High	Low	High	Low	High
Mainsbridge et al. [77]	Low	Low	High	Low	Low	Low	Low
Mainsbridge et al. [79]	High	High	High	Low	High	Low	High
Malaeb et al. [75]	Unclear	Unclear	Unclear	Low	Low	Low	N/A
Mantzari et al. [46]	Low	Low	High	Low	Low	Low	N/A
Maylor et al. [64]	Low	Low	High	Low	Low	Low	N/A
Miyachi et al. [76]	Low	Low	High	Low	Low	Low	High
Puig-Ribera et al. [50]	Low	High	Low	Low	High	Low	High
Schuna et al. [69]	Low	High	High	Low	High	Low	High
Tucker et al. [45]	Low	High	High	Low	High	Low	High
Verweij et al. [53]	Low	Low	High	Low	High	Low	Low
Zhu et al. [54]	High	High	High	Low	Low	Low	N/A
Percent "High"	27%	43%	73%	3%	33%	0%	85%
Percent "Low"	67%	43%	10%	93%	67%	100%	10%
Percent "Unclear"	7%	13%	17%	3%	0%	0%	5%
Percent “N/A”	--	--	--	--	--	--	33%

NOTE: High = high risk of bias; Low = low risk of bias; Unclear = not possible to rate risk of bias; N/A = risk of bias rating not applicable.

Table 5. Number of behaviour change techniques present in very, quite and non-promising interventions and active control groups.

Intervention efficacy	Average number of BCTs	Standard deviation
All promising (n=20)	12.7	6.1
Very promising (n=9)	12.1	4.6
Quite promising (n=11)	13.2	7.4
All non-promising (n=20)	9.7	7.2
Non-promising (n=10)	12.1	6.5
Active controls (n=10)	4.3	3.4
All (n=40)	10.5	6.6

NOTE: No differences were observed for all promising versus non-promising (with and without active controls). BCTs = behaviour change techniques.

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1180 **Table 6**. Frequency of behaviour change techniques in very, quite and non-promising
1181 interventions (with and without active controls). Categories or techniques with a promise
1182 ratio of 2.0 or above and that appeared in at least two interventions are reported here [29].
1183 Techniques unique to all promising interventions only are also shown below but promise
1184 ratios have not been calculated. Details are available for remaining categories/techniques in
1185 Electronic Supplementary Tables S2 and S3.

	Promising			Non-promising				
Behaviour change technique	Very (n=9)	Quite (n=11)	All (n=20)	Non (n=10)	Active Control (n=10)	All Non (n=20)	Freq-uency Ratio	Ratio without Active Control
Social comparison	3	3	6	1	0	1	6.0	6.0
Problem solving	4	4	8	3	0	3	2.7	2.7
Demonstration of the behaviour	1	4	5	2	0	2	2.5	2.5
Goal setting	7	9	16	6	1	7	2.3	2.7
Behaviour substitution	7	9	16	7	1	8	2.0	2.3
Habit reversal	7	9	16	7	1	8	2.0	2.3
Social support (practical)	0	1	1	0	0	0	N/A	N/A
Behavioural experiments	0	1	1	0	0	0	N/A	N/A
Information about others' approval	1	2	3	0	0	0	N/A	N/A
Remove aversive stimulus	1	0	1	0	0	0	N/A	N/A
Generalisation of target behaviour	1	2	3	0	0	0	N/A	N/A
Material incentive (behaviour)	1	0	1	0	0	0	N/A	N/A
Social incentive	0	2	2	0	0	0	N/A	N/A
Restructuring the social environment	1	2	3	0	0	0	N/A	N/A
Identification of self as role model	0	2	2	0	0	0	N/A	N/A

Remove punishment	0	1	1	0	0	0	N/A	N/A
Focus on past success	1	0	1	0	0	0	N/A	N/A

NOTE: N/A = Not applicable.

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1189 **Table 7**. Unintentional behaviour change techniques coded from data collection methods and
1190 percent appearance throughout all interventions.
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Behaviour change techniques	Frequency (n=30)	% Appearance
Monitoring of behaviour by others without feedback	25	86%
Feedback on behaviour	8	28%
Self-monitoring of behaviour	17	59%
Self-monitoring of outcomes of behaviour	5	17%
Monitoring of outcome(s) of behaviour without feedback	25	86%
Bio-feedback	25	86%
Feedback on outcome(s) of behaviour	7	24%

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1195 8. Figures
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1198 **Fig. 1** PRISMA flow diagram of the article selection process
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Fig. 2 Cardiometabolic risk markers and sedentary behaviour outcome summary for each study (grey = non-significant reported outcome measure and black = a significant ($p < 0.05$) intervention improvement)

NOTE: Mailey et al. [62] describes two interventions: (a) short breaks in sedentary time and (b) long breaks. BF% = body fat percentage, BMI = body mass index, BP = blood pressure, cIMT =carotid intima-media thickness, CM risk score = clustered cardiometabolic risk score, FFM = fat-free mass, FMD = flow mediated dilation, HC = hip circumference, HR = heart rate, HbA1c = glycosylated haemoglobin, HDL = high density lipoprotein cholesterol, HOMA2 = homeostatic modelling assessment version 2 (-%B for insulin output and -%S for insulin sensitivity), LDL = low density lipoprotein cholesterol, MAP = mean arterial pressure, PP glucose = postprandial glucose, SB = sedentary behaviour, WC = waist circumference, WT = weight, VLDL = very low density lipoprotein cholesterol

Electronic Supplementary Table S1

Table S1. Template for intervention description and replication (TIDieR) chart for all interventions.

(S1_Brierleyetal_Review.xlsx)

Electronic Supplementary Table S2

Table S2. Behaviour change techniques unique to non-promising interventions.

(S2_Brierleyetal_Review.xlsx)

Electronic Supplementary Table S3

Table S3. Behaviour change techniques in very, quite and non-promising interventions with a frequency ratio of less than 2.0.

(S3_Brierleyetal_Review.xlsx)