Efficacy of a multi-component cluster randomised controlled trial to reduce workplace sedentary behaviour in office workers

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Abstract

Objective: To investigate the efficacy of a work-based multicomponent intervention to reduce office workers' sitting time. **Methods:** Offices (n=12; 89 workers) were randomised into an 8-week intervention (n=48) incorporating organisational, individual, and environmental elements or control arm. Sitting time, physical activity and cardiometabolic health were measured at baseline and after the intervention. **Results:** Linear mixed modelling revealed no significant change in workplace sitting time, but changes in workplace prolonged sitting time (-39 min/shift), sit-upright transitions (7.8 per shift) and stepping time (12 min/shift) at follow-up were observed, in favour of the intervention group ($p<0.001$). Results for cardiometabolic health markers were mixed. **Conclusions:** This short multicomponent workplace intervention was successful in reducing prolonged sitting and increasing physical activity in the workplace, although total sitting time was not reduced and the impact on cardiometabolic health was minimal.

Keywords: sedentary behaviour; workplace sitting; sit-stand; physical activity; behaviour change; RCT

Introduction

Sedentary behaviour can be defined as any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting, reclining, or lying posture (1). High levels of sedentary behaviour are associated with poor metabolic health (2) and an increased risk of cardiovascular disease, Type 2 diabetes, some cancers and all-cause mortality, often independently of moderate-to-vigorous physical activity (MVPA) (3-5). A higher number of interruptions to sedentary time is associated with favourable cardiometabolic risk marker levels in cross-sectional research (6) and in acute experimental trials in participants who are healthy, overweight and obese, dysglycaemic, or have type 2 diabetes (7-11).

Office workers spend the majority of their working day in a sedentary state and often accumulate this in prolonged uninterrupted bouts (12). Therefore, this population are an important target for interventions to encourage reductions in sedentary behaviour. A number of previous studies have included one single intervention component, such as the installation of height-adjustable workstations, over a period of 4-13 weeks in an attempt to reduce workplace sedentary time (13-15). However, interventions incorporating organisational, individual, and environmental-level strategies lasting 4-12 have reported reductions in workplace sedentary time that are more successful than interventions that focus on singular components as reported in a recent systematic review (16). Nevertheless , many of these multicomponent intervention studies have been small-scale and non-randomised (16), which limits the ability to make definitive conclusions of their impact.

There have been a number of powered randomised controlled trials (RCTs) evaluating multicomponent interventions (17-20). However, a major limitation of most previous studies is that participants were randomised at an individual level meaning that there may have been contamination between groups due to control and intervention participants being located within the same office. Workplace intervention studies should thus utilise cluster randomisation at the level of the office or worksite to minimise contamination between groups in addition to providing greater generalisability and providing more precise treatment effect estimates for the study outcomes (21). Moreover, some employers do not have the resources to provide height-adjustable workstations, which have been used in previous multicomponent interventions. The effect of a powered cluster RCT of a multi-component workplace intervention that does not necessitate an active workstation therefore requires investigation.

In addition to reductions in workplace sitting, some studies have also examined effects on cardiometabolic risk markers, with mixed findings. Beneficial mean arterial pressure, diastolic blood pressure, and high-density lipoprotein cholesterol (HDL) responses have been observed following 8-13 week single component interventions (13, 15, 22), and improvements in adiposity have been observed in response to 4-12 week multicomponent interventions (17, 20). However, some studies report no beneficial cardiometabolic response to multicomponent interventions lasting 4-16 weeks (23, 24). This may be because the interventions were focused predominantly on interrupting sitting with standing. There is evidence that reallocating sitting with light or moderate-intensity ambulation is more effective in attenuating cardiometabolic risk than standing (25); thus, multicomponent interventions with a greater focus on ambulation should be examined.

The primary aim of this cluster RCT was to evaluate the effectiveness of an 8-week multicomponent workplace intervention incorporating organisational, individual, and environmental-level strategies that did not include provision of height-adjustable workstations and with a greater focus on ambulation for reducing workplace sitting time in office workers. The secondary aims were to evaluate changes in other workplace activity outcomes (e.g. prolonged sitting and stepping), sitting time and activity outcomes across the waking day, and health-related outcomes.

Methods

Study design

This was a two-arm cluster RCT. Ethical approval was granted by the University of Bedfordshire Institute for Sport and Physical Activity Research Ethics Committee (approval number 2016ISPAR011). The study was conducted, analysed and reported in accordance with the CONSORT guidelines for cluster RCTs (26). Participants were randomised by cluster (i.e., office floor) to receive the intervention or act as the control group.

Study setting

The trial took place with office-based workers at a national property, residential, construction and services group organisation located in Bedfordshire, UK. The worksite consisted of approximately 600 staff working across six floors within two buildings. Recruitment occurred between November 2016 and January 2017.

Recruitment

Recruitment of organisation

The organisation was recruited following discussions between the research team and the worksite Health & Wellbeing Specialist who supported the research team logistically with the recruitment and intervention procedures.

Recruitment of participants

A summary of the study was emailed to all workers at the site and the research team attended the worksite to distribute flyers and discuss the study with interested individuals in communal areas. Workers were required to express their interest in taking part in the study by writing their contact details on a sign-up sheet or registering their email address via a digital online portal. Individuals were then telephone screened by the research team to assess eligibility. A participant information sheet was then provided and written informed consent obtained prior to baseline assessment and randomisation. Each employee also gained consent from their line manager to take part in the study. To encourage participation and full engagement with the data collection procedures, each participant received a £5 gift voucher following provision of complete data at each time point.

Eligibility criteria

Inclusion criteria were: aged 18–70 years, English speaking, spending ≥75% of their working day seated (self-reported), working ≥three days/week at the same desk, able to stand and walk unassisted, and designated access to a phone, internet and desk within the worksite. Exclusion criteria were: pregnancy, non-English speaking, non-ambulatory, night-shift workers, or a planned absence from the worksite for >two weeks during the study period.

Assignment to study group

Randomisation was at cluster level to minimise interaction between the intervention and control groups. A cluster was identified as a distinct division within the worksite. Each division was located in a separate office workspace. Contamination was also reduced by asking participants not to disclose their treatment allocation outside of their cluster and by informing control participants that they would receive components of the intervention once the study was complete (27). Randomisation occurred after all baseline assessments were completed. Clusters were randomised 1:1 to either the intervention or control group by the research team. A randomisation plan for 12 clusters in one block was generated using an online tool (www.randomization.com) and clusters were randomly matched against this plan using a list randomiser (www.random.org).

Sample size

Sample size calculations were performed using GPower (28) based on a minimum difference of interest of 60 min/day in the primary outcome (workplace sitting time), a SD of 60 min/day, 90% power and 5% alpha. With a total of 12 clusters, an anticipated average cluster size of six and an estimated intracluster correlation coefficient of 0.05 (29), this gave a design effect of 1.25. Allowing for 20% attrition within each cluster, this resulted in a total of 84 participants being required for the study.

Intervention procedures

Theoretical basis

Beat the Seat is a corporate wellness programme provided by Beat the Seat Ltd. (http://beattheseat.co.uk/). For the purposes of this study, there was no financial cost to the participating worksite. Beat the Seat is a multicomponent intervention comprising organisational, environmental and individual elements focusing on reducing sitting in the workplace. The integration of multiple components is recommended best practice to influence behaviour change in the workplace (30). The intervention components were guided by an intervention taxonomy of behaviour change strategies (31) and published intervention research (described below).

Organisational elements

Educational presentation and brainstorming session

Following baseline assessments, all intervention participants received an educational presentation from the project team informed by scientific evidence on the dangers of excessive sitting and the benefits of interrupting sitting time (32). Participants then took part in a brainstorming session to identify and agree upon strategies to reduce sitting within their workplace. A summary of these strategies was subsequently emailed to all intervention participants by the project team the following work day.

Step challenge

Immediately following the educational presentation and brainstorming session, each participant was provided with a pedometer, goal setting guidance (provided during individual meetings described below), and took part in a step challenge during the intervention period. These strategies have been used effectively to reduce sedentary time in working adults (33, 34). Each participant entered their daily steps onto a virtual leaderboard and spot prizes (shopping gift vouchers) were provided to increase motivation (35).

Individual elements

Health check report and individual meetings

One week after the educational presentation, participants were provided with a personal health check report during a ~20 min face-to-face meeting with a member of the project team. The report was generated from Health Options v9.1.31 software (Health Diagnostics Ltd, Chester, UK), which is designed for use within National Health Service Health Check programmes. The report provides risk scores and educational information on diabetes, cholesterol, cardiovascular disease, and weight management. The elements of this component of the intervention were based on evidence that receiving health assessment feedback can be a motivator for behaviour change (36, 37).

During the individual meeting, each participant received a goodie bag that contained a leaflet briefly outlining the intervention procedures, a facts sheet on the dangers of prolonged sitting, an information card on "what your steps mean" (i.e. the number of daily steps equating to low active, moderately active, active, and highly active), sticky notes to place around their workspace with self-selected reminders to encourage less sitting, and a prompt card to remind participants of sitting reduction strategies.

Prompts

Participants received instructions to download computer software (Break Timer, Tom Watson, Spain) and/or a phone app from a list provided (e.g. Rise & Recharge, Baker Heart and Diabetes Institute, Australia; Break Reminder, TheBigMom, USA) that prompted them to get up and move at regular intervals. Participants were advised to set the regularity of the alerts according to their own personal preference. The use of prompt software in a multicomponent intervention is effective in reducing workplace sitting and prolonged sitting bouts (38). Point of decision poster prompts were also displayed around the working environment (e.g. office walls, notice boards, and near lifts) encouraging employees to interrupt their sitting time and increase their steps. The combination of prompts to reduce sitting and increase physical activity are more effective than prompts that focus on sitting time alone (39).

Telephone support

One-to-one telephone support (5-10 min) was provided weekly from a member of the project team during intervention weeks 2 to 8 and followed a semi-structured script to maintain intervention fidelity. Individual-level support is an effective physical activity behaviour change strategy (36, 40) and reductions in sitting time have been observed when telephone support is used as part of a multicomponent intervention (41). The telephone calls were based on motivational interviewing and involved discussions around participant progress toward goals, problem-solving, and adjustment of goals and behaviour change strategies as necessary.

Environmental elements

Work environment

Participants were asked to make changes to their working environment in line with strategies identified during the brainstorming session. Examples of these strategies included removal or relocation of personal bins and printers, and identification of workspaces or meeting areas to be used specifically for non-computer based work to encourage movement away from the desk.

Data collection

Demographic, anthropometric and cardiometabolic health data were collected at baseline (14-28 days before intervention start) and 8 weeks (3-7 days after the intervention ended) in a designated room at the study worksite. Participants were asked not to take part in any exercise and to avoid alcohol and caffeine from the day preceding data collection until after their testing visit. Participants were also asked to travel to work by car on the day of data collection to minimise their activity levels. Sitting time and physical activity monitoring took place 7-27 days prior to intervention start and during the last week of the intervention period.

Primary outcome

The primary outcome was workplace sitting time measured by the activPAL micro monitor (PAL Technologies, Glasgow, Scotland). Participants were asked to wear the activPAL on their right thigh for 24 h/day for seven consecutive days at baseline and during the last intervention week (week 8). This device provides valid and reliable assessment of sitting, standing, stepping and postural transitions in adults (42-46) and has been used extensively in sedentary behaviour research (47). Participants were asked to complete a short daily diary to note the time they woke up and got out of bed, hours they worked that day, time they went to bed, time they went to sleep, periods of work time spent not at the primary worksite (e.g. working from home), and any periods during the day when the device was removed.

An automated algorithm (48) implemented in STATA was used to process the data (EventsXYZ.csv file) and identify valid days of wear. Data for working hours were extracted by matching the work times reported in the daily diary to the processed device data. Where events (i.e., sitting, standing, stepping) crossed the self-reported start and end work times, ≥50% of the event was required to be within the period of interest for inclusion within that period (47). Workplace data was deemed valid upon the device being worn ≥80% of self-reported working hours (49) and ≥1 valid work day was provided during the monitoring period (18).

Secondary outcomes

Physical activity and other sitting variables

Other variables of interest calculated were: daily sitting time, and time spent in sitting bout durations of <30 min and ≥30min (the latter being defined as a prolonged sitting bout based on experimental evidence (10)), the number of sit-upright transitions, standing time, time spent stepping, and steps for work hours and daily (total waking hours). A valid day for daily data was accepted when meeting the following criteria: a) wear time >10 h, b) >500 steps, and c) not recording $\geq$95% data in one activity category (i.e. sitting, standing or stepping). All valid days were visually compared to diary notes for quality control prior to the creation of summative variables.

Demographic, anthropometric, and cardiometabolic measures

Participant age, sex, ethnicity, marital status, education, and smoking status were recorded at baseline. At baseline and 8 weeks (post-intervention), participants had height measured (Leicester Height Measure; Seca, Birmingham, UK) and waist circumference measured at the umbilicus using an adjustable tape measure (HaB International Ltd., Southam, UK). Body mass and body fat% were measured using the Tanita BC-418 device (Tanita Corporation, Tokyo, Japan). Blood pressure was measured whilst sitting using the Omron M5-I automated oscillatory device (Omron Matsusaka Co Ltd, Matsusaka, Japan) after the participant had rested for 5 min; three readings were taken and the average recorded. Mean arterial pressure was calculated as: $MAP \cong P_{Dias} + \frac{1}{3}(P_{Sys} - P_{Dias})$. Participants also had total cholesterol and HDL measured at these time points via finger prick using the CardioChek® system (PTS Diagnostics, Indianapolis, US) in the non-fasted stated (50).

Statistical analyses

Statistical analyses were completed using SPSS v23.0 (SPSS Inc., Armonk, N.Y., USA). Data normality assumption was determined using graphical procedures (quantile-quantile plots) and deemed plausible in all instances. Outcome variables were analysed using linear mixed models. Fixed factors (‘arm’ and ‘time’) and random factors (‘participant ID’ and ‘cluster ID’) were fitted to each model and baseline values for each outcome were included as covariates to explain residual outcome variance. Post hoc analyses were adjusted using the Sidak correction for multiple comparisons. Normality for outcome residuals from the final models were checked and deemed plausible in each instance. Subgroup analysis was performed for individuals who sat ≥75% and <75% of their working hours (objectively measured) at baseline to explore any potential subgroup differences. Sensitivity analyses were also conducted on all workplace sitting and activity data to assess the impact of number of valid days provided by including only those with ≥4 days of valid wear. All data are presented as mean (95% confidence interval [CI]). The two-tailed alpha level for significance testing was set as $p \leq 0.05$. Cohens' d effect sizes were calculated to describe the magnitude of differences between conditions; 0.2, 0.5 and 0.8 indicated a small, medium or large effect, respectively (51).

Results

Participant progression through the study is presented in Figure 1. All participants were recruited by January 2017 and ended their participation in the study by April 2017. Twelve clusters were recruited and randomly allocated 1:1 to the intervention or control arm (six each). Overall, 89 participants were recruited at baseline, with slightly more participants in the intervention group (n=48) than the control group (n=41). Of these, 100% of clusters and 87.6% of participants were seen at follow up. At baseline and follow up, 100% and 76.4% of participants provided valid daily and workplace activPAL data, respectively, all of which contained valid primary and secondary sitting and activity outcome data for ≥1 day and were thus included for analysis. Of the sample who provided activPAL data, none were excluded based on the inclusion restrictions for daily data and workplace data described above. In total, 74.2% of participants provided valid primary and secondary sitting and activity outcome data at both time points.

Table 1 provides descriptive data for participants in each study arm. The sample contained slightly more women than men, were on average approaching middle age, and more than half of participants were educated to at least tertiary level. Daily activity data at baseline showed that the sample recruited were highly sedentary, engaging in 10.5 [95% CI: 10.3, 10.6] h/day of sitting, which accounted for 67.4 [65.7, 69.0] percent of waking hours.

Primary outcome

Changes in workplace sitting are shown in Table 2. There was no significant difference between intervention and control in change in sitting time at work (p=0.164).

Secondary outcomes

Other workplace sitting and activity outcomes

There were significant differences in the change between groups for time spent in prolonged sitting bouts (-39.2 [95% CI -62.5 to -16.0, p=0.001] min/shift), number of prolonged sitting bouts (-0.59 [-0.18 to -1.00, p=0.006] bouts/shift), number of sit-upright transitions (7.8 [3.9 to 11.6, p<0.001] transitions/shift), stepping time (12.0 [7.4 to 16.6, p<0.001] min/shift), and number of steps (1156 [690 to 1622, p<0.001] steps/shift), all in favour of the intervention group with large effect sizes. Although not significant, there was also a medium effect for the change in standing time in favour of the intervention.

The subgroup analyses (Supplementary Table 1) showed a significant difference in change in favour of the intervention group for participants spending >75% of their working hours sitting in prolonged sitting bouts (-61.4 min/shift; p<0.001), number of prolonged sitting bouts (-0.8 bouts/shift; p=0.004), sit-upright transitions (9.0 transitions/shift; p=0.002) and standing time (27.0 min/shift; p=0.007). There were no significant differences in the change in total workplace sitting time between intervention and control groups irrespective of whether participants spent ≤75% or >75% of their working hours sitting. Increases in stepping time (11.3 and 11.7 min/shift; p<0.001) and steps per shift (1068 and 1114 steps/shift; p<0.001) were significantly different in favour of the intervention group for both of the ≤75% workplace sitting and >75% workplace sitting subgroups, respectively.

Daily sitting and activity variables

Daily sitting and activity data are shown in Table 3. Significant differences were found between groups for change in the number of sit-upright transitions (4 [0.8, 7.2] transitions/day) and total steps (1100 [552, 1650] steps/day), in favour of the intervention group with large effect sizes. No other significant differences were observed.

Cardiometabolic variables

Data for cardiometabolic health outcomes are shown in Table 4. The change in waist circumference between groups (-1.6 cm) was significant (p=0.015) in favour of the intervention group (large effect), whereas changes in systolic blood pressure (-4.4 mmHg), mean arterial pressure (-2.4 mmHg) and fat free mass (-0.4 kg) were significant, in favour of the control group (p=0.010, p=0.040 and p=0.025, respectively) with medium-large effects. There were no significant differences between groups in any other cardiometabolic health outcome.

Sensitivity analyses

Sensitivity analyses (Supplementary Table 2) identified that including only those participants who provided ≥4 days of valid activPAL wear data did not affect any of the intervention effects observed for the primary or secondary activity outcome results.

Discussion

This study demonstrates the efficacy of a short-term multi-component workplace intervention for reducing prolonged sitting time in an office setting. During working hours, the intervention significantly reduced time spent in prolonged sitting in comparison to the control group, which indicates that the intervention participants interrupted their sitting time more often, as evidenced by the concomitant increase in the number of workplace sit-upright transitions. More frequent sit-upright transitions may have been promoted by a number of the intervention elements, such as the educational presentation and prompt software. The intervention did not result in a significant difference (-15.7 min/shift) in workplace sitting time, although there was a medium effect size in favour of the intervention group. Previous multicomponent interventions have reported larger reductions (50-125 min/day) in workplace sitting time (17, 19, 20, 23, 24) and some have seen an accompanied reduction in prolonged sedentary time (17, 23). However, these interventions involved the provision of height-adjustable workstations or portable pedal machines, whereas the present study did not. This suggests that active workstation provision may be required in order to significantly reduce total workplace sitting time. The provision of a height-adjustable workstation permits continued work at a computer whilst standing (23, 52, 53) as opposed to encouraging regular ambulation. Yet, interrupting sitting with short frequent bouts of standing only appears to be beneficial metabolically in those with impaired metabolic health (10), whereas light and moderate intensity ambulation has stronger associations with metabolic health across the general population, which is more reflective of the sample in the present study (25). The reduction in prolonged sitting may be beneficial to health despite the total time spent sitting remaining similar. Indeed, Healy *et al.* (6) observed significant beneficial associations between a higher number of interruptions in sedentary time and cardiometabolic risk markers, independent of total sedentary time. The current multicomponent intervention was indeed effective in reducing prolonged sitting in the workplace but may need to be accompanied by an active workstation to significantly reduce total workplace sitting time.

The number of daily (total waking hours) sit-upright transitions and daily steps significantly increased in the intervention group compared with controls. However, the change between groups in daily prolonged sitting time, total sitting time and the number of daily prolonged sitting bouts did not differ at follow-up. Although there were reductions in daily prolonged sitting time and the daily number of prolonged sitting bouts in the intervention group, a concomitant improvement in the control group rendered the differences between groups non-significant. As the intervention group reduced prolonged sitting time and increased the number of sit-upright transitions during work hours compared with the control, it could be inferred that being part of the study motivated the control group to change their behaviour outside of working hours, given that they did not receive any intervention to assist them in making changes during work hours. Despite efforts to minimise contamination between study arms, the control group were aware of the aims of the study and may have had some knowledge of the nature of the intervention that could have influenced their daily behaviour. The intervention groups' change in daily sitting and activity was very similar to their change in workplace sitting and activity, which suggests that most of the changes observed were not outside of work hours. Therefore, although there were beneficial changes in daily sit-upright transitions and total steps, this intervention resulted in more improvements in sitting time and activity variables during working hours, suggesting that complementary components targeting behaviour changes outside of work may also be needed.

Given that the present intervention focused on reducing sitting time, the increased workplace stepping time appears to be an additional, albeit related, benefit. Previous interventions targeting sitting reductions using multicomponent interventions involving a height-adjustable workstation have decreased sitting time at work, whilst marginally increasing workplace stepping (i.e. by 7%) (17), or observing no effect on stepping at all (18, 23, 52). The only other established method by which stepping time has been increased was via the use of treadmill desks in the workplace (54-56). However, the major challenges of large capital investment, shared usage and long-term adherence remain prominent issues with regards to the implementation of these in an office environment (54). Nonetheless, it appears that multicomponent strategies including the provision of both active workstations and pedometers may be necessary to maximise changes in workplace behaviour (i.e. sitting and physical activity) for health promotion.

The present study incorporated the use of pedometers and a step challenge to encourage an increase in workplace steps, which is an effective strategy for reducing sedentary behaviour (32, 33). Despite the relatively low cost of pedometers, self-monitoring is an important technique for behaviour change (31) and intervention groups with the ability to track their own behaviour have greater improvements in stepping compared to those with no pedometer access (57). De Cocker, De Bourdeaudhuij, Brown and Cardon (58) and Compernolle, Vandelanotte, Cardon, De Bourdeaudhuij and De Cocker (59) reported an 896 and 1056 increase in total daily steps, respectively, in addition to reduced daily sitting time (58), in response to interventions that focused on increasing physical activity levels. However, in the present study, the intervention did not reduce total workplace or daily sitting, possibly because the pedometer used did not enable participants to self-monitor their sitting time (the primary target behaviour). Indeed, there is a distinct lack of self-monitoring tools that focus on sitting time rather than physical activity (60), hence why a pedometer was chosen supplemented with computer software to prompt regular breaks in sitting. Nevertheless, the present intervention appears to have promise for increasing workplace physical activity (in addition to reductions in prolonged sitting time) given the increase of 1520 steps per day during working time. This increase in steps, however, had a limited clinical impact on the health variables in the current study. Previous research has associated an increase of >2000 steps per day with a 10% reduced risk of a cardiovascular event (61) and a 6% lower risk of all-cause mortality per 1000 steps per day increase (62). More research is warranted to investigate whether similar increases in steps can evoke health benefits over longer follow-up periods.

Despite the relatively short nature of the present intervention, a significant 1.6 cm reduction in waist circumference was observed in the intervention group relevant to the controls. Previous research has reported no change in waist circumference after a one-month multicomponent workplace intervention that reduced total and prolonged sedentary time during working hours (17). This may have been due to sitting time in the study by Danquah *et al.* (17) being primarily replaced with standing, while in the present study sitting time appeared to be primarily replaced with stepping, which elicits a greater increase in energy expenditure (63). Carr, Karvinen, Peavler, Smith and Cangelosi (20) observed a significant 1.0 cm reduction in waist circumference following a three-month multicomponent intervention and Freak-Poli, Wolfe, Backholer, de Courten and Peeters (34) observed a significant 1.6 cm reduction in waist circumference following a four-month workplace pedometer intervention; each of these studies primarily replaced sedentary time with cycling or stepping. This supports the efficacy of workplace sedentary behaviour interventions for improving adiposity levels when sitting is replaced with activities that expend more energy than standing. Unexpectedly, the control group had favourable responses in systolic blood pressure, mean arterial pressure and fat-free mass in the present study compared with the intervention group. This could be due to various factors including changes in dietary behaviours, stress, or treatment contamination during the study period. A previous single component (height-adjustable workstations) 8-week intervention that resulted in an 80 min/day reduction in workplace sitting reported beneficial diastolic blood pressure and total cholesterol responses (22), while a single component prompt intervention significantly reduced mean arterial pressure (13). However, several multicomponent interventions lasting 4-16 weeks that reduced workplace sitting by 59-125 min have reported no cardiometabolic benefits other than reduced waist circumference (20, 23, 24, 64). The reason for the lack of change in many cardiometabolic markers across these studies may be that the samples were relatively healthy in terms of their cardiometabolic health and the benefits of interrupting sitting may be more pronounced in obese/dysmetabolic populations (65-67). Thus, the dose of physical activity (i.e., intensity and duration) and reductions in prolonged sitting in these studies may have not been sufficient to evoke beneficial changes in cardiometabolic health. It is well established that interrupting sitting with short, frequent walking breaks are acutely beneficial to numerous cardiometabolic risk markers in heterogeneous populations (65). However, these study designs measure postprandial responses, which may be more sensitive than the single time-point measures used in the present study (68). Therefore, it is also possible that the lack of cardiometabolic changes are due to the type of measures employed or the timing of the measurement (i.e., chronic rather than acute responses). Further research is thus required to examine the comparative effects of reductions in total sitting time and prolonged sitting time and explore whether the duration and intensity of activity used to interrupt sitting is an important factor for cardiometabolic health changes. Moreover, the efficacy of these interventions for improving cardiometabolic health in obese and dysmetabolic populations requires investigation.

Strengths of the present study include the fully powered cluster RCT design. Additionally, there was a successful change in prolonged sitting time at work without the use of height-adjustable workstations. This is important as the cost-effectiveness of active workstations for reducing sitting and improving health is yet to be reported (69). Furthermore, sitting, standing and stepping were measured objectively with a high compliance rate, which presents a further strength. However, the use of subjective diaries for quality control of the activPAL data is a potential limitation as participants' reported waking and working times may not be accurately reported. Further limitations include the intervention being conducted across one worksite, which limits the generalisability of the findings to other workplaces where environmental and cultural differences may affect the impact of the intervention. Additionally, this study was unable to assess the effectiveness of each individual intervention component. Although research comparing different intervention strategies is limited, Parry, Straker, Gilson and Smith (70) reported that no one single strategy was more effective for reducing workplace sitting. Further research is warranted to determine the comparative effectiveness of different workplace sitting reduction strategies. The blood sample collection time for the measurement of lipids was not standardised at each data collection point. Although non-fasting lipid profiles predict cardiovascular risk (50), it is possible that the timing of prior food intake may minimally affect HDL concentrations, which could have influenced the findings in the present study. Additionally, there was no follow-up period post-intervention to ascertain the sustainability of the behavioural changes observed and whether any longer-term cardiometabolic benefits could have been achieved.

In conclusion, this cluster RCT observed a significant reduction in workplace prolonged sitting time with a concomitant increase in sit-upright transitions and ambulation in office workers. These workplace changes in sitting and activity occurred without the use of an active workstation, which suggests that this multicomponent intervention may be an effective low-cost health promotion strategy.

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Clinical Significance

This study demonstrates the efficacy of an 8-week multicomponent workplace intervention for reducing prolonged sitting and increasing physical activity in office workers. The intervention did not use active workstation equipment and may thus offer a cost-effective approach for workplace health promotion.

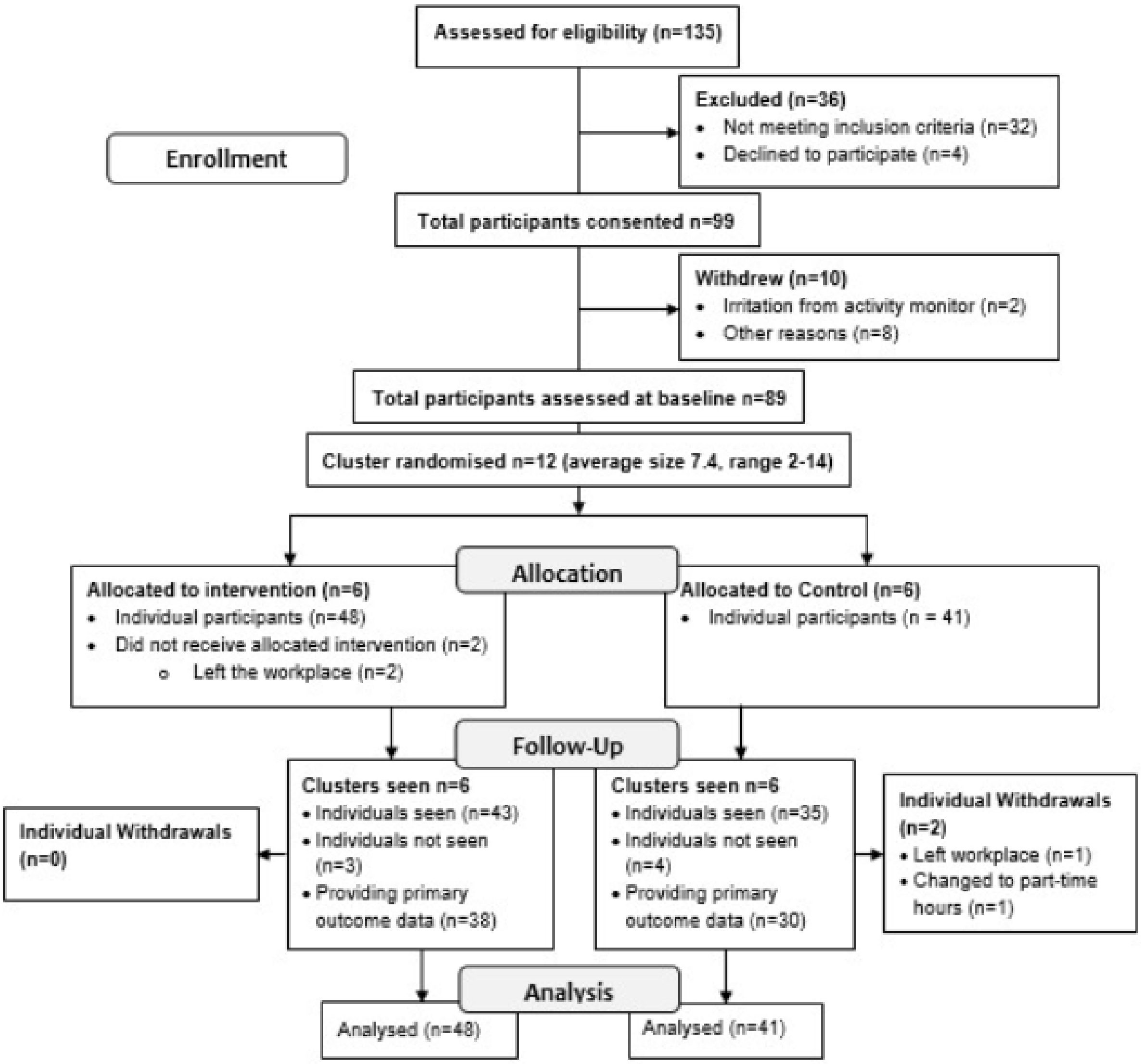

Figure captions

Figure 1 – CONSORT diagram of participant progression through the study

Table 1 Baseline characteristics of the study sample by randomisation group

Characteristic	Intervention group	Control group	All
n	48	41	89
Sex (women)	26 (54%)	25 (61%)	51 (57%)
Age (years)	43.0 (39.4, 46.7)	43.7 (39.7, 47.7)	43.4 (40.7, 45.9)
Ethnicity (BME)	16.7%	14.6%	15.7%
Married	33.3%	29.3%	31.5%
Education (Tertiary)	50.0%	63.4%	56.2%
Current smoker	4.2%	9.8%	6.7%
Previous smoker	31.3%	26.8%	29.2%

BME; Black and minority ethnic group. Age is presented as mean (95% CI).

Table 2 Changes in workplace sitting and activity outcomes at follow up by randomisation group

Variable	Intervention group		Control group		Adjusted difference (95% CI)[b]	Effect Size[b]	p value
	n	Mean (95% CI)[a]	*n*	Mean (95% CI)[a]			
Sitting time per shift (min)							
Baseline	46	395.0 (381.7, 408.3)	41	394.1 (380.1, 408.1)			
Change at 8 weeks	38	-15.7 (-35.7, 4.3)	30	0.9 (-20.6, 22.5)	-15.7 (-38.0, 6.5)	0.42	0.164
Time in sitting bouts ≥30 min (min)							
Baseline	46	193.0 (179.1, 206.9)	41	191.5 (176.8, 206.2)			
Change at 8 weeks	38	-41.4 (-62.3, -20.5)	30	-0.7 (-23.3, 21.9)	-39.2 (-62.5, -16.0)	0.98	**0.001**
Number of sitting bouts ≥30min							
Baseline	46	3.68 (3.43, 3.93)	41	3.63 (3.37, 3.89)			
Change at 8 weeks	38	-0.69 (-1.06, -0.32)	30	-0.05 (-0.45, 0.35)	-0.59 (-1.00, -0.18)	0.87	**0.006**
Number of sit-upright transitions							
Baseline	46	33.1 (30.9, 35.4)	41	33.2 (30.8, 35.6)			
Change at 8 weeks	38	5.9 (2.5 ,9.3)	30	-1.9 (-5.7, 1.7)	7.8 (3.9, 11.6)	1.16	**<0.001**
Standing time (min)							
Baseline	46	95.4 (85.5, 105.3)	41	96.1 (85.7, 106.6)			
Change at 8 weeks	38	15.7 (0.8, 30.5)	30	0.8 (-15.2, 16.9)	14.1 (-2.5, 30.6)	0.51	0.095
Stepping time (min)							
Baseline	46	34.2 (31.5, 36.9)	41	35.4 (32.5, 38.3)			
Change at 8 weeks	38	15.8 (11.8, 19.9)	30	2.6 (-1.8, 7.0)	12.0 (7.4, 16.6)	1.64	**<0.001**
Steps per work shift							
Baseline	46	3264 (2986, 3540)	41	3396 (3104, 3688)			
Change at 8 weeks	38	1520 (1106, 1934)	30	230 (-218, 678)	1156 (690, 1622)	1.57	**<0.001**

Bold text indicates a statistically significant intervention effect ($p \le 0.05$).
[a]Estimated marginal means adjusted for outcome values at baseline.
[b]Estimated from pairwise comparisons of marginal means adjusted for outcome values at baseline.

Table 3 Changes in daily sitting and activity outcomes at follow up by randomisation group

Variable	Intervention group		Control group		Adjusted difference (95% CI)[b]	Effect size[b]	p value
	n	Mean (95% CI)[a]	*n*	Mean (95% CI)[a]			
Sitting time per day (min)							
Baseline	46	627.6 (612.3, 643.0)	41	626.5 (609.8, 643.2)			
Change at 8 weeks	38	-14.7 (-37.3, 8.0)	30	-12.5 (-37.9, 12.9)	-1.0 (-26.4, 24.4)	0.05	0.936
Time in sitting bouts ≥30 min (min)							
Baseline	46	335.2 (317.8, 352.6)	41	334.1 (315.1, 353.1)			
Change at 8 weeks	38	-35.5 (-61.3, -9.7)	30	-26.3 (-55.2, 2.5)	-8.1 (-36.9, 20.8)	0.18	0.582
Number of sitting bouts ≥30min							
Baseline	46	5.98 (5.69, 6.27)	41	5.91 (5.60, 6.23)			
Change at 8 weeks	38	-0.59 (-1.02, -0.17)	30	-0.36 (-0.83, 0.12)	-0.16 (-0.64, 0.31)	0.27	0.498
Number of sit-upright transitions							
Baseline	46	53.5 (51.6, 55.5)	41	53.8 (51.7, 55.9)			
Change at 8 weeks	38	5.2 (2.4, 8.1)	30	1.0 (-2.2, 4.2)	4.0 (0.8, 7.2)	0.73	**0.013**
Standing time (min)							
Baseline	46	220.0 (209.8, 230.2)	41	219.7 (208.5, 230.9)			
Change at 8 weeks	38	2.4 (-12.8, 17.5)	30	15.1 (-1.8, 32.1)	-12.5 (-29.5, 4.5)	0.42	0.149
Stepping time (min)							
Baseline	46	89.0 (84.9, 93.2)	41	90.0 (85.5, 94.5)			
Change at 8 weeks	38	11.8 (5.7, 17.8)	30	9.8 (3.0, 16.6)	1.0 (-5.8, 7.8)	0.16	0.770
Steps per day							
Baseline	46	7668 (7336, 7998)	41	3863 (7726, 8086)			
Change at 8 weeks	38	1212 (726, 1700)	30	52 (-492, 596)	1100 (552, 1650)	1.19	**<0.001**

Bold text indicates a statistically significant intervention effect (p≤0.05).

[a]Estimated marginal means adjusted for outcome values at baseline.

[b]Estimated from pairwise comparisons of marginal means adjusted for outcome values at baseline.

Table 4 Cardiometabolic health changes at follow up by randomisation group

Variable	Intervention group		Control group		Adjusted Difference (95% CI)[b]	Effect Size[b]	p-value
	n	Mean (95% CI)[a]	*n*	Mean (95% CI)[a]			
Weight (kg)							
Baseline	48	76.8 (74.7, 79.0)	41	76.0 (73.6, 78.3)			
Change at 8 weeks	43	-2.6 (-5.8, 0.6)	35	-0.1 (-3.6, 3.3)	-1.6 (-5.1, 1.9)	0.40	0.373
Body mass index (kg/m^2)							
Baseline	48	25.9 (25.8, 26.1)	41	25.9 (25.8, 26.1)			
Change at 8 weeks	43	0.1 (-0,2, 0.2)	35	0.0 (-0.2, 0.3)	0.1 (-0.2, 0.3)	0.23	0.675
Waist circumference (cm)							
Baseline	48	86.5 (85.7, 87.3)	41	86.4 (85.6, 87.3)			
Change at 8 weeks	43	-2.5 (-3.7, -1.4)	35	-0.9 (-2.2, 0.4)	-1.6 (-2.9, -0.3)	0.69	**0.015**
Body fat%							
Baseline	48	28.8 (28.4, 29.2)	41	28.8 (28.3, 29.2)			
Change at 8 weeks	43	0.0 (-0.5, 0.6)	35	-0.2 (-0.9, 0.4)	0.3 (-0.3, 0.9)	0.18	0.374
Fat-free mass (kg)							
Baseline	48	53.4 (53.1, 53.6)	41	53.3 (53.0, 53.6)			
Change at 8 weeks	43	-0.4 (-0.7, 0.0)	35	0.1 (-0.3, 0.5)	-0.4 (-0.8, 0.1)	0.70	**0.025**
Systolic blood pressure (mmHg)							
Baseline	48	125.4 (123.4, 127.4)	41	126.8 (124.6,129.0)			
Change at 8 weeks	44	-0.4 (-3.3, 2.6)	35	-6.1 (-9.4, 2.8)	4.4 (-7.7, 1.1)	0.65	**0.010**
Diastolic blood pressure (mmHg)							
Baseline	48	77.8 (76.5, 79.1)	41	78.8 (77.4, 80.2)			
Change at 8 weeks	44	1.0 (-0.9, 2.9)	35	-1.7 (-3.8, 0.4)	1.7 (-0.5, 3.9)	0.71	0.120
Mean arterial pressure (mmHg)							
Baseline	48	93.8 (92.4, 95.2)	41	94.8 (93.3, 96.3)			
Change at 8 weeks	44	0.2 (-1.8, 2.2)	35	-3.1 (-5.4, -0.9)	2.4 (0.1, 4.6)	0.82	**0.040**

Total cholesterol (mmol/L)							
Baseline	48	4.42 (4.30, 4.55)	41	4.43 (4.29, 4.56)			
Change at 8 weeks	44	0.06 (-0.12, 0.24)	34	-0.01 (-0.21, 0.19)	0.06 (-0.14, 0.26)	0.19	0.538
HDL (mmol/L)							
Baseline	48	1.39 (1.34, 1.43)	41	1.40 (1.35, 1.45)			
Change at 8 weeks	44	-0.01 (-0.08, 0.05)	34	0.02 (-0.04, 0.09)	0.04 (-0.03, 0.12)	-0.24	0.221
Total cholesterol / HDL ratio							
Baseline	48	3.52 (3.37, 3.66)	41	3.45 (3.29, 3.60)			
Change at 8 weeks	44	-0.02 (-0.24, 0.19)	34	-0.06 (-0.30, 0.18)	0.11 (-0.13, 0.34)	0.09	0.360

HDL, high-density lipoprotein cholesterol.
Bold text indicates a statistically significant intervention effect ($p \leq 0.05$).
[a]Estimated marginal means adjusted for outcome values at baseline.
[b]Estimated from pairwise comparisons of marginal means adjusted for outcome values at baseline.

Supplementary Table 1 Changes in workplace sitting and activity outcomes at follow-up by subgroup and randomisation group

Variable	Intervention group		Control group		Adjusted difference (95% CI)[b]	p value
	n	Mean (95% CI)[a]	*n*	Mean (95% CI)[a]		
Sitting time per day (min)						
Change in ≤75% workplace sitting	13	-2.7 (-32.5, 27.1)	19	-4.7 (-30.1, 20.7)	2.8 (-25.3, 30.9)	0.842
Change in >75% workplace sitting	33	-23.3 (-50.5, 3.8)	22	9.4 (-25.4, 44.2)	-33.8 (-68.6, 0.9)	0.056
Time in sitting bouts ≥30 min (min)						
Change in ≤75% workplace sitting	13	-12.1 (-51.5, 27.2)	19	2.8 (-30.7, 36.4)	-7.8 (-45.2, 29.5)	0.677
Change in >75% workplace sitting	33	-56.6 (-80.7, -32.5)	22	-0.2 (-31.2, 30.9)	-61.4 (-92.3, -30.5)	**<0.001**
Number of sitting bouts ≥30min						
Change in ≤75% workplace sitting	13	-0.1 (-0.9, 0.6)	19	0.2 (-0.4, 0.8)	-0.2 (-0.9, 0.5)	0.551
Change in >75% workplace sitting	33	-1.0 (-1.4, -0.6)	22	-0.3 (-0.8, 0.3)	-0.8 (-1.3, -0.3)	**0.004**
Number of sit-upright transitions						
Change in ≤75% workplace sitting	13	0.8 (-4.5, 6.2)	19	-3.6 (-8.2, 0.9)	4.2 (-0.7, 9.2)	0.094
Change in >75% workplace sitting	33	8.7 (4.2, 13.1)	22	-0.3 (-6.0, 5.5)	9.0 (3.3, 14.7)	**0.002**
Standing time (min)						
Change in ≤75% workplace sitting	13	-17.9 (-47.6, 11.8)	19	-4.4 (-29.7, 20.9)	-13.6 (-41.6, 14.4)	0.334
Change in >75% workplace sitting	33	33.8 (18.7, 48.9)	22	7.5 (-12.1, 27.0)	27.0 (7.7, 46.4)	**0.007**
Stepping time (min)						
Change in ≤75% workplace sitting	13	12.8 (5.2, 20.4)	19	0.1 (-6.4, 6.6)	11.3 (4.0, 18.5)	**0.003**
Change in >75% workplace sitting	33	17.2 (12.3, 22.1)	22	5.2 (-1.1, 11.5)	11.7 (5.4, 17.9	**<0.001**
Steps per shift						
Change in ≤75% workplace sitting	13	620 (237, 1004)	19	-10 (-337, 316)	534 (168, 900)	**0.005**
Change in >75% workplace sitting	33	821 (572, 1071)	22	251 (-70, 572)	557 (238, 875)	**0.001**

Bold text indicates a statistically significant intervention effect (p≤0.05).

[a]Estimated marginal means adjusted for outcome values at baseline.

[b]Estimated from pairwise comparisons of marginal means adjusted for outcome values at baseline.

Supplementary Table 2 Sensitivity analysis for workplace sitting and activity outcomes at follow-up

Variable	Intervention group Mean (95% CI)	Control group Mean (95% CI)	Adjusted difference (95% CI)[a]	p-value
Sitting time per day (min)				
<4 days activity data removed	-17.5 (38.1, 3.0)	-2.6 (-25.1, 19.8)	-14.3 (-37.6, 8.9)	0.225
Time in sitting bouts ≥30 min (min)				
<4 days activity data removed	-44.0 (-65.2, -22.8)	-0.1 (-23.3, 23.0)	-41.6 (-65.5, -17.7)	**0.001**
Number of sitting bouts ≥30min				
<4 days activity data removed	-0.76 (-1.14, -0.38)	0.02 (-0.39, 0.43)	-0.72 (-1.14, -0.29)	**0.001**
Number of sit-upright transitions				
<4 days activity data removed	5.9 (2.3, 9.7)	-2.9 (-7.0, 1.1)	8.8 (4.6, 13.0)	**<0.001**
Standing time (min)				
<4 days activity data removed	16.1 (0.3, 32.0)	1.1 (-16.1, 18.4)	14.2 (-3.7, 32.1)	0.120
Stepping time (min)				
<4 days activity data removed	16.7 (12.7, 20.7)	2.2 (-2.2, 6.6)	13.6 (9.0, 18.3)	**<0.001**
Steps per shift				
<4 days activity data removed	1612 (1204, 2018)	230 (-216, 674)	1288 (820, 1754)	**<0.001**

Bold text indicates a statistically significant intervention effect ($p \leq 0.05$).
[a]Estimated from pairwise comparisons of marginal means adjusted for outcome values at baseline.