Workplace productivity, health and wellbeing: findings from a cluster randomised controlled trial of a workplace intervention to reduce sitting in office workers

Abstract

Objective: To evaluate the feasibility and potential effects of a workplace intervention to reduce and break up sitting. *Methods:* Office workers were randomised in clusters to intervention (=22) or control (n=22). The intervention included a height-adjustable workstation, education, computer prompt software and line manager support. Outcomes included device-measured workplace sitting and ecological momentary assessed (EMA) workplace productivity. Recruitment, retention and data completion rates were assessed. *Results:* Recruitment (n=44), retention (91%) and workplace sitting measurement rates demonstrated study feasibility. At 8 weeks, workplace sitting was 11% lower (95% CI: -20.71, -1.30) in the intervention group compared with control participants. Intervention participants were also more engaged, motivated and productive while sitting ($p \leq 0.016$). *Conclusions:* It was feasible to implement and evaluate this office workplace intervention, with potential benefits on workplace sitting and EMA-measured productivity.

Keywords: sedentary behaviour, sitting, office workers, active workstation, productivity, ecological momentary assessment

Learning outcomes:

- Critically examine the feasibility of delivering and evaluating an intervention to reduce workplace sitting in office employees.
- Critically discuss the potential effects of the intervention on workplace sitting and workplace productivity.
- Identify and discuss the strengths and limitations regarding the delivery and evaluation of this study's intervention.

Introduction

Office workers engage in high volumes of sedentary behaviour, spending an average of 65 to 79% of their work day sitting when measured objectively [1, 2]. Higher sedentary time is associated with an increased risk of adverse health outcomes, including cardiometabolic biomarkers, type 2 diabetes, cardiovascular disease, some cancers, all-cause mortality and poor mental health [3-7]. Although these associations have often been found to be independent of time spent engaging in physical activity, high volumes of moderate-intensity physical activity (e.g. 60 to 75 minutes/day) may be sufficient for offsetting the risk in the most sedentary individuals [8, 9]. However, such high volumes of physical activity are unlikely to be achievable for many individuals. Thus, interventions targeting reductions in sitting may offer an achievable occupational health promotion strategy. An expert statement on sedentary behaviour in the workplace recommended that office workers initially aim to progress towards 2 hours per workday of standing and light-intensity physical activity, eventually progressing to 4 hours per workday [10]. However, previous interventions have not evaluated the feasibility or efficacy of using these recommendations in guiding behaviour change, nor has office worker adherence to these guidelines been evaluated.

In addition to reductions in total sitting, evidence suggests that increasing the number of breaks in sitting and reducing time spent in prolonged sitting may also be important for lowering the risk of non-communicable disease and all-cause mortality [11, 12]. Increased breaks in sitting were also associated with improved cardiometabolic biomarkers, whereas more time in prolonged sitting had unfavourable associations, independent of moderate-to-vigorous physical activity and total sedentary time [6, 13, 14]. This is supported by controlled laboratory studies that have consistently seen improvements in glucose across a single day in response to breaking up sitting with 2 to 5 minutes of light or moderate-intensity physical activity every 20 to 30 minutes across a single day [15-17]. Office workers accumulate a large amount of their occupational sitting in prolonged bouts, with one study finding that this accounted for 42% of total workplace sitting [1]. According to this evidence, sedentary behaviour interventions in the workplace should, alongside reductions in total workplace sitting, target increases in the number of breaks in sitting and reductions in prolonged sitting for optimal effects.

A number of multicomponent interventions incorporating height-adjustable workstations (environmental restructuring) alongside organisational (e.g. manager support and standing meetings) and individual strategies (e.g. self-monitoring and prompts in relation to sitting or computer use) have led to reductions in total and prolonged workplace sitting and increases in sit-to-stand transitions [18-20]. For such interventions to be adopted into occupational health policy and practice, it is important that the productivity of employees is not adversely affected. Previous workplace interventions have resulted in improvements in self-reported work-related outcomes, such as stress, vigour, mood and at-work productivity loss [18, 21, 22]. However, the measures used in these studies may be limited by recall bias and provides information that is limited to a single point in time or a composite perception [23]. Ecological Momentary Assessment (EMA) using smartphones enables the collection of simultaneous data regarding posture, work performance and wellbeing in real-time at various points across a workday. This addresses issues of recall bias and may provide a more in-depth and temporally relevant insight regarding the effects of an intervention on employees' perceptions.

The intervention being evaluated in this study was developed using the Behaviour Change Wheel [24], alongside qualitative evidence [25-27]. The intervention delivers behaviour change techniques (BCTs) [28] that focus on supporting adherence to expert statement guidelines on sedentary behaviour in the workplace [10]. The feasibility of evaluating an intervention using this novel approach, in addition to the measurement of work performance and wellbeing using EMA, warrants investigation to appropriately inform a definitive RCT. The aim of this study was, therefore, to evaluate the feasibility of a protocol for a cluster RCT of a multicomponent workplace intervention to reduce and break up sitting in office workers.

The objectives were to evaluate (1) the feasibility of recruiting and retaining office workers within the trial, (2) data completion rates for the intended outcomes in a definitive RCT, (3) adherence to guidelines for sedentary behaviour in the workplace, and (4) potential effects of the intervention on device-measured workplace sitting (primary outcome for a definitive RCT), standing and stepping; workplace productivity, stress, mood and wellbeing as measured by questionnaires and EMA; and cardiometabolic biomarkers (secondary outcomes). The potential effects of the intervention on these outcomes were evaluated to give an indication as to whether the intervention could be working, thus further informing support for progressing to a definitive RCT.

Methods

Study design and overview

This was an office-based 8-week, two-arm cluster RCT design study that was intended as a precursor to a full definitive RCT. Individuals (office workers) were the unit of analysis and workers' offices were the unit of randomisation. After baseline measurements were taken, clusters were randomised to either (1) a workplace intervention aimed at reducing and breaking up sitting (intervention group), or (2) current practice (passive control group). Participants in both groups took part in the same outcome measurements eight weeks after baseline measurements. The study was conducted, analysed and reported following the CONSORT statement for pilot and feasibility trials [29] and was registered on ClinicalTrials.Gov (NCT03560544). The full trial protocol has been published previously [26]. The XXX [Anonymized by request from JOEM] provided approval for the conduct of the study. Written informed consent to take part in the study was provided by each participant prior to their involvement in any study procedures.

Study setting and participants

The study was conducted with office workers employed at a single local council site and a single University site in the East of England region. The intervention and wider study were discussed with senior management at the participating sites to gain consent and support for implementing the study protocols. Participants were eligible to take part if they were employed at either of these sites, worked full-time, had a desk-based job and were aged 18-60 years. They also needed to be based in the same open-plan office as at least one other person who was volunteering to take part in the study in order to satisfy the cluster design. Participants were excluded from the trial if they were pregnant, had a history of musculoskeletal complaints, non-ambulatory, or had a planned holiday that meant they would miss more than two weeks of the 8-week intervention period.

Sample size

A target sample size of 44 was used for this study, which is approximately in line with recommended sample sizes for pilot studies of between 24 and 50 [30, 31]. This sample size was considered to be pragmatic for the allocated recruitment time period and deemed sufficient to provide estimates of recruitment, retention and data collection completion rates for a definitive RCT.

Participant recruitment

With manager approval, the opportunity to take part in the study was advertised to employees during staff meetings, internal emails and flyers distributed in offices and around the workplace at each organisation. Individuals expressed their interest by email to the research team and were then screened for eligibility.

Randomisation

Cluster randomisation was used in an attempt to minimise contamination between groups in open plan offices. There were 14 clusters with an average cluster size of three. Randomisation was carried out by assigning a cluster ID to each cluster, which were then randomly allocated to the intervention or control groups using https://www.randomlists.com/team-generator; this was carried out by an independent researcher. Participants and researchers were blinded to their group allocation until baseline measures had been taken.

Intervention protocol

The full intervention protocol and methodology outlining the development of the intervention was previously published [25, 26]. Briefly, the intervention was developed using the Behaviour Change Wheel approach [32, 33], which included interviewing office workers to identify barriers and facilitators for breaking up prolonged sitting in the workplace [27]. From this, potential intervention strategies (intervention types/functions, policy options/categories) and BCTs were identified. The Acceptability, Practicability, Effectiveness/cost-effectiveness, Affordability, Safety/side-effects, Equity (APEASE) criteria [34, 35] was then used by the research team to decide on which intervention strategies and content would be included in the intervention and how they would be delivered [26].

The multi-component intervention delivered in this study was designed to support participants with adhering to the sedentary behaviour in the workplace guidelines that recommend initially standing and/or stepping for ≥2 h during the work day, progressing to ≥4 h per workday [10]. The intervention comprised of a short educational session with a researcher and an accompanying leaflet to provide information on the health risks associated with excess prolonged sitting, the potential health benefits of breaking up sitting, support with goal setting and action planning for reducing and breaking up sitting, and information and targets from the expert statement guidelines for office workers [10]. A height-adjustable workstation (Ergotron Work-Fit-T, Ergotron, St Paul, USA) was also installed at each intervention participant's desk to restructure their environment. Computer prompt software (Marinara: Pomodoro Assistant Google Chrome extension) was installed on each intervention participant's work computer. This software delivered alerts on the computer screen at customisable intervals to prompt the participant to break up their sitting. The duration of the breaks was customisable and the participant was alerted to the end of the break period. Line manager support was provided via bi-weekly emails in weeks 2, 4 and 6 that contained tips for breaking up sitting, encouragement in working towards the expert statement guidelines, providing appreciation regarding their employees' commitment to breaking up prolonged sitting, and reminding them of their bi-weekly goals.

Control group

Participants in the control clusters were advised to continue their job as normal. This group completed the same set of measurements as the intervention participants.

Study outcomes

Study measurements were taken at baseline and 8 weeks following the start of the intervention period. Questionnaire measures were completed online using Qualtrics (Qualtrics, Provo, Utah, USA), while physical measures were taken in a private room at each participant's workplace.

Sitting, standing and stepping

The intended primary outcome for a definitive RCT informed by this pilot study is daily workplace sitting. Secondary outcomes included prolonged sitting (sitting bouts lasting ≥30 min), sit-to-upright transitions, standing and stepping at work in addition to these same measures across the whole waking day. These outcomes were measured using the activPAL3 activity monitor (PAL Technologies Ltd., Glasgow, UK). This device was worn on the anterior of the mid-thigh for seven consecutive days at baseline and during the final week of the intervention. A diary was completed by each participant so that sleep, wake and work times could be identified during the data processing and analysis. The activPAL data was processed using Processing PAL (v1.1, University of Leicester, Leicester, UK). A valid work day was defined as the activPAL having been worn for ≥ 75% of the recorded working hours. A valid full day was defined as ≥ 10 hours of waking wear time. To be included in the analysis, participants required a minimum of three valid workdays and one valid weekend day. Sitting, standing and stepping time were normalised by expressing them as a percentage of the duration of the work day (for workplace outcomes) and the waking wear time (for daily outcomes) for each participant. The number of sitting bouts and sit-to-upright transitions were normalised by expressing them as counts per hour.

Feasibility of the research procedures

Feasibility of the study procedures was measured in the context of the following:

1. Number of individuals who express interest in taking part / number of invitations sent out to employees x 100 i.e. response rate.
2. Number of employees eligible / number screened x 100 i.e. eligibility rate.

3. Number of participants who provide data at 8-weeks / number of participants enrolled in the study x 100 i.e. retention rate.
4. Number of complete datasets for outcome measures / number of participants enrolled × 100 i.e. data completion rates.

The thresholds for determining feasibility of the study were recruiting the target sample size within a 2-month period, a recruitment rate of ≥70%, a retention rate of ≥80%, and a data completion rate of ≥80% for the study outcomes.

Adherence to workplace sedentary behaviour guidelines

Based on workplace sitting time measured by the activPAL, each intervention participant was classified according to expert statement recommendations for sitting in the workplace [10]. These groups were: (1) meeting the guidelines (MEETING) of standing and/or stepping for ≥4 h during the work day, (2) meeting the minimal guidelines (MINIMAL) for standing and/or stepping for ≥2 h during the work day, or (3) not meeting the MINIMAL or MEETING guidelines and considered sedentary (SED).

Ecological momentary assessment of productivity and mood

Ecological momentary assessment was used to measure self-reported state productivity and mood by individually rating the following items on a Likert scale from 1 (“not at all”) to 10 (“extremely”): Happy, Stressed, Energised, Anxious, Productive, Motivated, Engaged and Creative. This was immediately preceded with questions on current posture (“sitting, standing or walking”), any musculoskeletal pain being experienced right not (“Yes or No”), what the participant was currently doing (i.e. working at a desk, working away from a desk, in a meeting, taking a break, eating, in transit or other) and how many people they were with. The scales were derived from previous research utilising EMA to evaluate workplace health and performance [23, 36]. The EMA was administered via a custom smartphone app at four random times during each work day, up to 12 times per week.

Absenteeism and presenteeism

Absenteeism was measured using a validated 3-item questionnaire that assesses workdays missed over the past two weeks due to sickness, mental health reasons and excused work e.g. parental leave [37]. This questionnaire had good reliability compared with organisation records. The number of workdays missed across these questions were summed. The 8-item Work Limitations Questionnaire (WLQ) was used to measure presenteeism; this is a valid and reliable shorter version of the original 25-item WLQ [38]. This questionnaire asks individuals to rate their level of difficulty or ability to perform time management, physical, mental and output demand work during the past two weeks. A presenteeism score is calculated to express a percentage of at-work productivity loss.

Stress, mood and wellbeing

General perceived stress over the past month was measured using a published Likert scale [39]. The Positive and Negative Affect Schedule was used to evaluate general mood state over the past week [40]. General psychological wellbeing over the last two weeks was measured using the Warwick-Edinburgh Mental Well-Being Scale [41]. Each of these questionnaires has demonstrated good to strong validity and reliability [39-41].

Cardiometabolic biomarkers

These measures were taken at baseline and within five days post-intervention. Fasting blood glucose and lipid profile were measured from finger prick samples using the Cholestech LDX analyzer (Cholestech Corp., Hayward, CA., USA) after an overnight fast. Resting systolic and diastolic blood pressure were measured in seated position after a 10 min rest using the automated Omron HEM705 CP device (Omron Healthcare UK Limited, Milton Keynes, UK). Height, body mass and waist circumference were also measured. The same researcher took all measures.

Demographics

Demographic information was collected by self-report for each participant, including age, sex, ethnicity, marital status and education level.

Statistical analysis

Statistical analysis was undertaken using SPSS v25 (IBM Corp., Armonk, New York, USA). The Shapiro-Wilk test was used to assess normality of the data. The Wilcoxon signed rank test compared sedentary behaviour guideline adherence at baseline and 8 weeks. Participants were analysed per-protocol to identify the potential effects of the intervention on the study measurement. Linear mixed models were employed to analyse the effects of the intervention on the study outcomes. Condition and time were entered as fixed effects. Cluster allocation, participants ID and baseline values for each outcome (covariates) entered as random effects. Sidak post-hoc correction was used for multiple comparisons. A large number of variables were non-normally distributed. The bias-corrected and accelerated bootstrap method was, therefore, used for all data to derive unbiased estimates of the confidence limits [42]. Data for this analysis is presented as means and 95% confidence intervals. Statistical significance was accepted as two-tailed $p \leq 0.05$. Hedges' g was used to calculate magnitudes of effects. This is suitable for use in small sample sizes to provide unbiased population effect size estimates based on Cohen's d [43]. Effect sizes were considered to be trivial if Hedge's $g < 0.2$, small if ≥ 0.2, moderate if ≥ 0.6, and large if ≥ 1.2; effect sizes ≥ 0.2 were considered to be potentially meaningful [44]. The Wilcoxon signed rank test was used to compare baseline and 8-week classifications for adherence to workplace sedentary behaviour guidelines. The resultant test statistic was divided by the square root of N to yield an effect statistic that was interpreted as r using published scales [44, 45].

Results

Feasibility of the research procedures

Participant recruitment occurred April to May 2018. All participants completed baseline measures and were randomised into the relevant experimental arm during June 2018. All 8-week measurements took place in August 2018. Progression of participants throughout the study is shown in Figure 1. Eighty-four percent of employees contacted about the research expressed an interest in taking part. The screening process identified 44 participants (72%) that were eligible to take part. These participants were allocated into 14 clusters, which were then randomised on a 1:1 ratio. Descriptive characteristics of the participants are shown in Table 1. At the 8-week measurement time point, 100% of clusters and 91% of participants were assessed. Of the 40 participants that completed the study, 100% provided valid data for the activPAL and cardiometabolic health data at both baseline and follow-up (this represented 91% of participants enrolled into the study). All participants (n=44) provided absenteeism, presenteeism, stress and wellbeing data at baseline. Nineteen of the control participants (86%) and 15 of the intervention participants (68%) provided data at 8-weeks. For EMA measures, all intervention participants provided data at baseline; only 18 control participants (82%) provided data due to software malfunctions with the app. Similar problems were encountered at follow-up, with only 13 participants from each group (59%) providing EMA data.

Potential effects on workplace sitting, standing and stepping

Sitting, standing and stepping at work outcomes are shown in Table 2. The intervention appeared to have potential for reducing the proportion of working hours spent sitting, which was significantly lowered by 11% (reduced from 76% at baseline to 60% at 8 weeks, with a small effect size) in the intervention group compared with control participants. Workplace sitting was replaced predominantly with standing, which was 11% higher in the intervention group compared with the control group at 8 weeks, with a moderate effect size. There were no differences in time spent in prolonged sitting or stepping time between groups, with trivial effect sizes.

Potential effects on daily sitting, standing and stepping

Daily sitting, standing and stepping outcome data can be seen in Supplementary Material 1. There was a trend (p = 0.054) for daily sitting being lower in the intervention group (61.2 [95% CI: 57.4, 64.9] % of waking wear time) at 8 weeks compared with control participants (64.1 [60.3, 67.8] % of waking wear time). Daily standing was higher in the intervention group than the control group at 8 weeks (27.8 [24.8, 30.8] and 24.3 [21,3, 27.3] % of waking wear time, respectively, p = 0.045).

Adherence to workplace sedentary behaviour guidelines

There was a significant effect of the intervention on participants adhering to the workplace sedentary behaviour guidelines (Z = 2.982, p = 0.003, r = 0.47), with this corresponding to a moderate effect. At baseline, 5% of intervention participants were classified as MEETING (standing and/or stepping for ≥4 h during the work day), 45% as MINIMAL (standing and/or stepping for ≥2 h during the work day) and 50% as SED (not meeting the MINIMAL or MEETING guidelines). At 8 weeks, 40% of intervention participants were classified as MEETING, 50% as MINIMAL and 10% as SED. At an individual level, 70% of intervention participants became less sedentary (i.e. moving from SED to MINIMAL or MINIMAL to MEETING), 20% remained the same, while 10% became more sedentary (i.e. moving from MEETING to MINIMAL or MINIMAL to SED).

Potential effects on work productivity

The analysis of EMA outcomes found that intervention participants were significantly more engaged, motivated and productive while sitting at 8 weeks compared with control participants with small to moderate effect sizes (Table 3). The improvement for creative while sitting was approaching significance and was potentially meaningful with a small effect size. Ecological Momentary Assessment outcomes whilst in a standing posture did not differ significantly between groups (Supplementary Material 2). Similarly, there were no differences between intervention and control participants for presenteeism and absenteeism (Supplementary Material 3).

Potential effects on stress, mood, wellbeing and cardiometabolic biomarker outcomes

There were no significant differences ($p > 0.05$) between the intervention and control groups for stress, mood, wellbeing or cardiometabolic biomarker outcomes (Supplementary Materials 4 and 5).

Discussion

The main findings of this study were that participant recruitment and retention were feasible, in addition to acceptable measurement completion rates for the primary outcome (device-measured workplace sitting) for both intervention and control groups. The intervention appeared to have potential for reducing workplace sitting, increasing adherence to sedentary behaviour in the workplace guidelines and improving state work productivity. This supports progression to a full definitive RCT. However, low data completion rates for questionnaire and EMA measurements (secondary outcomes) at 8 weeks require improving, as do issues in relation to EMA software malfunctions.

The recruitment strategy employed in this study was appropriate to recruit the target sample size in the allocated timeframe (two months). The eligibility and uptake rate of the individuals who were screened was also sufficiently high. As long as sufficient support from participating workplaces is provided to facilitate recruitment of their employees, the recruitment of office workers to take part in studies evaluating multicomponent workplace interventions to reduce and break up sitting is feasible, as demonstrated in previous pilot studies and full definitive RCTs [18, 46, 47]. Participant retention in the present study was high with all clusters being retained at 8 weeks and only four individual withdrawals at this timepoint. Taking into consideration findings from other pilot studies with similar sample sizes evaluating multicomponent sedentary behaviour interventions in the workplace [47, 48], these studies are feasible in the context of participant retention.

The high data completion rate for the primary outcome, activPAL measured workplace sitting (91% of participants provided data at both timepoints), is in line with previous pilot studies lasting 2 to 4 weeks in similar sample sizes [47-49]. With regards to secondary outcomes, the data completion rate was high for cardiometabolic biomarkers. Baseline data rates were also acceptable for questionnaire (absenteeism, presenteeism, stress, mood and wellbeing) and EMA outcomes at baseline. However, at 8 weeks, questionnaire data completion rates were low for intervention participants (68%) and EMA completion rates were low for both groups (59%). Intervention participants may have been faced with competing priorities from work tasks and engaging in the intervention, which could have made it difficult for them to find time to complete the questionnaires. The low EMA completion rate was at least partly due to malfunctions with the EMA app with participants reporting sometimes not receiving prompts from the app. This may have been a result of network problems or technical glitches. Participants may also find responding to frequent EMA notifications as repetitive and become less engaged or responsive [48], albeit this was not evaluated in the present study. The activPAL can, therefore, be recommended for evaluating changes in workplace sitting in a definitive RCT, but it is recommended that future studies collecting EMA measures ensure rigorous testing and refinements, if required, to this type of software prior to it being used.

The multicomponent intervention led to an 11% reduction in workplace sitting time, which is equivalent to a 53-min reduction for an eight-hour working day. This reduction in workplace sitting appeared to be replaced exclusively by standing, with no change in ambulation. The effect sizes for these differences indicated that these changes in sitting and standing are potentially meaningful. Other studies the incorporated height-adjustable workstations have reported that workplace sitting was replaced with standing, rather than ambulation [19, 50, 51]. This suggests that participants likely choose to reduce their occupational sitting by carrying out their work tasks while in a standing posture at their desk height-adjustable workstation. Workplace interventions that do not include a height-adjustable workstation may have limited potential for reducing workplace sitting, although they may be more effective for increasing ambulation and the number of breaks in sitting [52].

In contrast to previous multicomponent interventions that incorporated height-adjustable workstations [18, 19, 49, 51], the present intervention appeared to have limited potential for reducing prolonged sitting or increasing sit-to-stand transitions with no differences between groups and trivial effect sizes. This could be explained by the intervention including a focus on achieving expert statement guidelines of initially aiming to stand for at least 2 hours per workday, gradually increasing to 4 hours [10]. Indeed, after 8 weeks 90% of the participants accumulated at least 2 hours per workday of standing, which was a 40% increase compared to baseline. Participants may, therefore, have been more focused on achieving these guidelines as opposed to reducing time spent in prolonged sitting or increasing sit-to-stand transitions. It is possible that participants worked towards these guidelines by accumulating standing in longer bouts, which could then have less effect on prolonged sitting or sit-to-stand transitions. This extends knowledge of previous intervention research by demonstrating the potential effectiveness of using expert statement recommendations to guide targets within workplace sitting interventions. The feasibility and acceptability of this approach within the present intervention could help guide workplace policy and practice and support organisations with implementing the World Health Organization model for heathy workplaces [53].

Despite no changes in general stress, mood and wellbeing, the EMA measurement indicated that intervention participants perceived potentially meaningful higher levels of state engagement, motivation, creativity and productivity while sitting at work. In an occupational context, sitting is often considered to be necessary in order to perform well at work [54]. The intervention in this study may have potential for promoting work productivity via reductions in sitting. A systematic review found that the use of height-adjustable workstations does not negatively affect worker productivity and performance [55]. Office workers in other interventions using height-adjustable workstations have reported increased feelings of general productivity, focus, efficiency and alertness [21, 47, 56]. Although EMA demonstrated potential benefits of the intervention for improving productivity in this study, issues around data completion rates for this measure should be addressed in future research to yield accurate estimates of effect on mood, stress and work-related outcomes.

The intervention appeared to have limited potential for reducing absenteeism and presenteeism over an 8-week period. Literature is equivocal regarding the effects of sedentary behaviour interventions on these outcomes [18, 57]. The present study also suggests there may be limited potential for the intervention to improve cardiometabolic biomarker outcomes. Other multicomponent interventions lasting 4 to 12 weeks, which led to 59 – 125 minutes per day reductions in workplace sedentary time also found no effect on cardiometabolic biomarkers [49, 58]. However, a systematic review found that 67% of sedentary behaviour interventions in the workplace led to improvements in at least one cardiometabolic biomarker, such as waist circumference, blood pressure and glucose [59]. Variations in findings from previous research and the present investigation may be due to studies not being powered to detect changes in cardiometabolic outcomes. Evaluating the intervention reported here on work-related measures and cardiometabolic health over a longer period in a definitive RCT would be a logical next step to determine its effectiveness for improving these outcomes.

As the intervention and study measurements took place in real-world office environments, the findings of this study are ecologically valid. The rigorous theory-led development of the intervention based on the needs of target population, as described previously [25-27], is a further strength of this study. Furthermore, the cluster-randomised controlled design was adopted to minimise contamination between the intervention and control groups. In addition to problems collecting questionnaire and EMA measures at 8 weeks, other limitations include the sample potentially not being representative of the general office worker population as the participants were mostly educated to a high level and were White females. The generalisability of the study to desk-based employees who work at home is also unclear. Each of the intervention components (i.e. education, height-adjustable desk, prompt software and line manager support) could be implemented in a home-working setting, but the reduced social support and different work environment could impact engagement with the intervention. This should be explored in future studies. Lastly, the intervention took place during a busy University period in which several participants explained having to attend examination board meetings during which they were unable to use their height-adjustable workstations. This may have limited the intervention's fidelity and, thus, potential effectiveness. Longer-term studies should consider the impact of when an intervention is delivered and when measurements are taken to encourage a valid representation of the intervention's effects in an organisation across varying times, demands and work schedules.

In conclusion, this study has demonstrated the feasibility of delivering and evaluating an intervention to reduce workplace sitting that was developed following a systematic and theory-driven approach. The intervention appears to have potentially benefits on workplace sitting and work productivity, which could be considered for informing occupational health and workplace productivity strategies. These findings support the conduct of a future definitive RCT.

References

1. Hadgraft, N.T., G.N. Healy, N. Owen, et al., Office workers' objectively assessed total and prolonged sitting time: Individual-level correlates and worksite variations. Prev Med Rep. 2016;4:184-91.
2. Keown, M.K., C.M. Skeaff, T.L. Perry, J.J. Haszard, and M.C. Peddie, Device-Measured Sedentary Behavior Patterns in Office-Based University Employees. J Occup Environ Med. 2018;60:1150-1157.
3. Bailey, D.P., D.J. Hewson, R.B. Champion, and S.M. Sayegh, Sitting Time and Risk of Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. Am J Prev Med. 2019;57:408-416.
4. Wilmot, E.G., C.L. Edwardson, F.A. Achana, et al., Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia. 2012;55:2895-905.
5. Biswas, A., P.I. Oh, G.E. Faulkner, et al., Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med. 2015;162:123-32.
6. Huang, B.H., M. Hamer, S. Chastin, N. Pearson, A. Koster, and E. Stamatakis, Cross-sectional associations of device-measured sedentary behaviour and physical activity with cardio-metabolic health in the 1970 British Cohort Study. Diabet Med. 2021;38:e14392.
7. Hamer, M., N. Coombs, and E. Stamatakis, Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from the Health Survey for England. BMJ Open. 2014;4:e004580.
8. Ekelund, U., J. Steene-Johannessen, W.J. Brown, et al., Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. Lancet. 2016;388:1302-10.

9. Ekelund, U., W.J. Brown, J. Steene-Johannessen, et al., Do the associations of sedentary behaviour with cardiovascular disease mortality and cancer mortality differ by physical activity level? A systematic review and harmonised meta-analysis of data from 850 060 participants. Br J Sports Med. 2019;53:886-894.

10. Buckley, J.P., A. Hedge, T. Yates, et al., The sedentary office: an expert statement on the growing case for change towards better health and productivity. Br J Sports Med. 2015;49:1357-62.

11. Wu, J., Y. Fu, D. Chen, et al., Sedentary behavior patterns and the risk of non-communicable diseases and all-cause mortality: A systematic review and meta-analysis. International Journal of Nursing Studies. 2023;146:104563.

12. Dempsey, P.C., T. Strain, E.A.H. Winkler, et al., Association of Accelerometer-Measured Sedentary Accumulation Patterns With Incident Cardiovascular Disease, Cancer, and All-Cause Mortality. J Am Heart Assoc. 2022;11:e023845.

13. Zheng, C., X.Y. Tian, F.H. Sun, et al., Associations of Sedentary Patterns with Cardiometabolic Biomarkers in Physically Active Young Males. Med Sci Sports Exerc. 2021;53:838-844.

14. Healy, G.N., D.W. Dunstan, J. Salmon, et al., Breaks in sedentary time: beneficial associations with metabolic risk. Diabetes Care. 2008;31:661-6.

15. Bailey, D.P. and C.D. Locke, Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. J Sci Med Sport. 2015;18:294-8.

16. Bailey, D.P., B.D. Maylor, C.J. Orton, and J.K. Zakrzewski-Fruer, Effects of breaking up prolonged sitting following low and high glycaemic index breakfast consumption on glucose and insulin concentrations. Eur J Appl Physiol. 2017;117:1299-1307.

17. Dunstan, D.W., B.A. Kingwell, R. Larsen, et al., Breaking up prolonged sitting reduces postprandial glucose and insulin responses. Diabetes Care. 2012;35:976-83.

18. Edwardson, C.L., S.J.H. Biddle, S.A. Clemes, et al., Effectiveness of an intervention for reducing sitting time and improving health in office workers: three arm cluster randomised controlled trial. BMJ. 2022;378:e069288.
19. Healy, G.N., E.G. Eakin, N. Owen, et al., A Cluster Randomized Controlled Trial to Reduce Office Workers' Sitting Time: Effect on Activity Outcomes. Med Sci Sports Exerc. 2016;48:1787-97.
20. Shrestha, N., K.T. Kukkonen-Harjula, J.H. Verbeek, S. Ijaz, V. Hermans, and Z. Pedisic, Workplace interventions for reducing sitting at work. Cochrane Database Syst Rev. 2018;6:CD010912.
21. Pronk, N.P., A.S. Katz, M. Lowry, and J.R. Payfer, Reducing occupational sitting time and improving worker health: the Take-a-Stand Project, 2011. Prev Chronic Dis. 2012;9:E154.
22. Peterman, J.E., G.N. Healy, E.A. Winkler, et al., A cluster randomized controlled trial to reduce office workers' sitting time: effect on productivity outcomes. Scand J Work Environ Health. 2019;45:483-492.
23. Engelen, L. and F. Held, Understanding the Office: Using Ecological Momentary Assessment to Measure Activities, Posture, Social Interactions, Mood, and Work Performance at the Workplace. Buildings. 2019;9:54.
24. Michie, S., S. Ashford, F.F. Sniehotta, S.U. Dombrowski, A. Bishop, and D.P. French, A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. Psychol Health. 2011;26:1479-98.
25. Ojo, S.O., D.P. Bailey, M.L. Brierley, D.J. Hewson, and A.M. Chater, Breaking barriers: using the behavior change wheel to develop a tailored intervention to overcome workplace inhibitors to breaking up sitting time. BMC Public Health. 2019;19:1126.

26. Ojo, S.O., D.P. Bailey, A.M. Chater, and D.J. Hewson, Workplace Intervention for Reducing Sitting Time in Sedentary Workers: Protocol for a Pilot Study Using the Behavior Change Wheel. Front Public Health. 2022;10:832374.

27. Ojo, S.O., D.P. Bailey, D.J. Hewson, and A.M. Chater, Perceived Barriers and Facilitators to Breaking Up Sitting Time among Desk-Based Office Workers: A Qualitative Investigation Using the TDF and COM-B. Int J Environ Res Public Health. 2019;16:2903.

28. Michie, S., M. Richardson, M. Johnston, et al., The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 2013;46:81-95.

29. Eldridge, S.M., C.L. Chan, M.J. Campbell, et al., CONSORT 2010 statement: extension to randomised pilot and feasibility trials. BMJ. 2016;355:i5239.

30. Sim, J. and M. Lewis, The size of a pilot study for a clinical trial should be calculated in relation to considerations of precision and efficiency. J Clin Epidemiol. 2012;65:301-8.

31. Julious, S.A., Sample size of 12 per group rule of thumb for a pilot study. Pharmaceutical Statistics. 2005;4:287-291.

32. Michie, S., M.M. van Stralen, and R. West, The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6:42.

33. Michie, S., M. Johnston, R. West, C. Abraham, W. Hardeman, and C. Wood, Designing Behavior Change Interventions: The Behaviour Change Wheel and Behavior Change Techniques. Annals of Behavioral Medicine. 2014;47:S157-S157.

34. West, R., S. Michie, P. Chadwick, L. Atkins, and F. Lorencatto, *Achieving behaviour change: A guide for local government and partners*, P.H. England, Editor. 2019: London.

35. Michie, S., L. Atkins, and R. West, *The Behaviour Change Wheel: A Guide to Designing Interventions*. 2014, London: Silverback Publishing.

36. Engelen, L., J.Y. Chau, S. Burks-Young, and A. Bauman, Application of ecological momentary assessment in workplace health evaluation. Health Promotion Journal of Australia. 2016;27:259-263.

37. Gaudine, A. and C. Gregory, The accuracy of nurses' estimates of their absenteeism. J Nurs Manag. 2010;18:599-605.

38. Lerner, D., B.C. Amick, 3rd, W.H. Rogers, S. Malspeis, K. Bungay, and D. Cynn, The Work Limitations Questionnaire. Med Care. 2001;39:72-85.

39. Cohen, S., *Perceived stress in a probability sample of the United States*, in *The social psychology of health.* 1988, Sage Publications, Inc: Thousand Oaks, CA, US. p. 31-67.

40. Crawford, J.R. and J.D. Henry, The positive and negative affect schedule (PANAS): construct validity, measurement properties and normative data in a large non-clinical sample. Br J Clin Psychol. 2004;43:245-65.

41. Stewart-Brown, S.L., S. Platt, A. Tennant, et al., The Warwick-Edinburgh Mental Well-Being Scale (Wemwbs): A Valid and Reliable Tool for Measuring Mental Well-Being in Diverse Populations and Projects. Journal of Epidemiology and Community Health. 2011;65:A38-A39.

42. Kelley, K., The Effects of Nonnormal Distributions on Confidence Intervals Around the Standardized Mean Difference: Bootstrap and Parametric Confidence Intervals. Educational and Psychological Measurement. 2016;65:51-69.

43. Lakens, D., Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Front Psychol. 2013;4:863.

44. Hopkins, W.G., S.W. Marshall, A.M. Batterham, and J. Hanin, Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009;41:3-13.

45. Cohen, J., *Statistical power analysis for the behavioral sciences*. 2nd ed. 1988, Hillsdale, NJ: Erlbaum.

46. Graves, L.E.F., R.C. Murphy, S.O. Shepherd, J. Cabot, and N.D. Hopkins, Evaluation of sit-stand workstations in an office setting: a randomised controlled trial. BMC Public Health. 2015;15:1145.

47. Chau, J.Y., M. Daley, S. Dunn, et al., The effectiveness of sit-stand workstations for changing office workers' sitting time: results from the Stand@Work randomized controlled trial pilot. Int J Behav Nutr Phys Act. 2014;11:127.

48. Nicolson, G.H., C.B. Hayes, and C.D. Darker, A Cluster-Randomised Crossover Pilot Feasibility Study of a Multicomponent Intervention to Reduce Occupational Sedentary Behaviour in Professional Male Employees. Int J Environ Res Public Health. 2021;18:9292.

49. Healy, G.N., E.G. Eakin, A.D. Lamontagne, et al., Reducing sitting time in office workers: short-term efficacy of a multicomponent intervention. Prev Med. 2013;57:43-8.

50. Neuhaus, M., G.N. Healy, D.W. Dunstan, N. Owen, and E.G. Eakin, Workplace sitting and height-adjustable workstations: a randomized controlled trial. Am J Prev Med. 2014;46:30-40.

51. Edwardson, C.L., T. Yates, S.J.H. Biddle, et al., Effectiveness of the Stand More AT (SMArT) Work intervention: cluster randomised controlled trial. BMJ. 2018;363:k3870.

52. Maylor, B.D., C.L. Edwardson, J.K. Zakrzewski-Fruer, R.B. Champion, and D.P. Bailey, Efficacy of a Multicomponent Intervention to Reduce Workplace Sitting Time in Office Workers: A Cluster Randomized Controlled Trial. J Occup Environ Med. 2018;60:787-795.

53. World Health Organization, Healthy workplaces: a model for action for employers, workers, policymakers and practitioners.

https://www.who.int/southeastasia/publications-detail/who-healthy-workplace-framework-and-model (accessed 8 Feb 2024). 2010;

54. Ten Broeke, P., B. Gardner, D.G.J. Beckers, S.A.E. Geurts, and E. Bijleveld, Why do people sit? A framework for targeted behavior change. Health Psychol Rev. 2023;17:641-654.

55. Ojo, S.O., D.P. Bailey, A.M. Chater, and D.J. Hewson, The Impact of Active Workstations on Workplace Productivity and Performance: A Systematic Review. Int J Environ Res Public Health. 2018;15:417.

56. Alkhajah, T.A., M.M. Reeves, E.G. Eakin, E.A. Winkler, N. Owen, and G.N. Healy, Sit-stand workstations: a pilot intervention to reduce office sitting time. Am J Prev Med. 2012;43:298-303.

57. Chau, J.Y., W. Sukala, K. Fedel, et al., More standing and just as productive: Effects of a sit-stand desk intervention on call center workers' sitting, standing, and productivity at work in the Opt to Stand pilot study. Prev Med Rep. 2016;3:68-74.

58. Carr, L.J., C. Leonhard, S. Tucker, N. Fethke, R. Benzo, and F. Gerr, Total Worker Health Intervention Increases Activity of Sedentary Workers. Am J Prev Med. 2016;50:9-17.

59. Brierley, M.L., A.M. Chater, L.R. Smith, and D.P. Bailey, The Effectiveness of Sedentary Behaviour Reduction Workplace Interventions on Cardiometabolic Risk Markers: A Systematic Review. Sports Med. 2019;49:1739-1767.

Figure captions

Figure 1. Progression of participants throughout the study.