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Systematic review: height-adjustable workstations to reduce sedentary behaviour in office-based workers

G. A. Tew[1], M. C. Posso[2], C. E. Arundel[1] and C. M. McDaid[1]

[1]York Trials Unit, Department of Health Sciences, University of York, York YO10 5DD, UK, [2]Iberoamerican Cochrane Centre, IIB Sant Pau, Universitat Autonoma de Barcelona, Sant Antoni M Claret 167, 08025 Barcelona, Spain.

Correspondence to: G. A. Tew, York Trials Unit, Room A/RC/004, Ground Floor, ARRC Building, University of York, Heslington, York YO10 5DD, UK. Tel: +44 (0)1904 321614; e-mail: garry.tew@york.ac.uk

Background	Time spent sitting in the workplace is an important contributor to overall sedentary risk. Installation of height-adjustable workstations has been proposed as a feasible approach for reducing occupational sitting time in office workers.
Aims	To provide an accurate overview of the controlled trials that have evaluated the effects of height-adjustable workstation interventions on workplace sitting time in office-based workers.
Methods	A comprehensive search was conducted up until March 2014 in the following databases: Medline, PsychINFO, CENTRAL, EMBASE and PEDro. To identify unpublished studies and grey literature, the reference lists of relevant official or scientific web pages were also checked. Studies assessing the effectiveness of height-adjustable workstations using a randomized or non-randomized controlled design were included.
Results	The initial search yielded a total of 8497 citations. After a thorough selection process, five studies were included with 172 participants. A formal quality assessment indicated that risk of bias was high in all studies and heterogeneity in interventions and outcomes prevented meta-analysis. Nevertheless, all studies reported that height-adjustable workstation interventions reduced occupational sitting time in office workers. There was insufficient evidence to determine effects on other relevant health outcomes (e.g. body composition, musculoskeletal symptoms, mental health).
Conclusions	There is insufficient evidence to make firm conclusions regarding the effects of installing height-adjustable workstations on sedentary behaviour and associated health outcomes in office workers. Larger and longer term controlled studies are needed, which include more representative populations.

Key words	Active workstations; height-adjustable desks; sedentary behaviour; workplace interventions.

Introduction

In epidemiological studies, those who are physically inactive have typically been described as sedentary. However, in recent years, this term has begun to be used to describe prolonged sitting time instead of the absence of physical activity [1]. There is now emerging evidence that physical inactivity and sedentary behaviour are two distinct behaviours. Total time spent in sedentary behaviour is, independent of the protective contributions of moderate-to-vigorous physical activity, adversely associated with health risks such as cardiovascular disease and type 2 diabetes mellitus [2,3]. Prolonged periods of uninterrupted sitting might also be detrimental, with lower frequencies of breaks in sitting time linked to metabolic risk for chronic disease [4].

There are three main domains in which sedentary behaviour occurs: sitting in the workplace, sitting while using private and public transport and sitting in leisure time (e.g. while watching television, reading or using a computer). Sitting in the workplace contributes considerably to overall sitting time. For example, occupational sitting has been shown to constitute over two-thirds (~6 h) of total daily weekday sitting time in Australian workers, and employees in administrative and professional/managerial occupations often sit for more than three-quarters of their total time at work [5,6].

The workplace has previously been identified as a convenient setting for targeting a reduction in sitting behaviour; however, up until 2009 there had been no published trials on this topic [7,8]. Since then, there have been a few small trials investigating both behavioural and ergonomic interventions for reducing sitting time in office workers [9–11]. Behavioural interventions have typically involved strategies such as goal setting, self-monitoring and education to support a reduction in office workers' sitting time, whereas ergonomic interventions have included treadmill workstations and height-adjustable workstations [9,11–14]. The latter of these may offer a feasible approach to reducing sitting in the workplace. A height-adjustable workstation is something that attaches to the worker's desk and allows the height of the computer monitor and keyboard to be easily moved up or down for work to be performed in either a sitting or standing position.

Based on searches of the Cochrane Database for Systematic Reviews and the Database of Reviews of Effects, the effects of height-adjustable workstation interventions on occupational sitting time and associated health outcomes have not been evaluated in a systematic review. A previous systematic review investigated the effects on sedentary behaviour of any type of workplace intervention aimed at increasing energy expenditure [8]. This review did not identify any relevant studies on height-adjustable workstations, probably because the search end date was March–April 2009 and this particular intervention is of more recent interest. Searches of PROSPERO, a database of registered systematic review protocols, indicated that there were no ongoing reviews on this topic that had registered their protocol on the database. The main aim of the current systematic review was to determine the effectiveness of height-adjustable workstation interventions to reduce objectively measured sedentary behaviour in office-based workers. Secondary objectives were to evaluate the effects of height-adjustable workstation interventions on self-reported sedentary behaviour and other health outcomes (i.e. cardiovascular, musculoskeletal, anthropometrics, psychological and adverse events).

Methods

A systematic review published in 2010 stated that up until 2009 there had been no published trials on this topic [8]. Several databases and other sources were searched from 1 January 2008 to 1 March 2014, including Medline, EMBASE, PsycINFO, CENTRAL and PEDro. We checked reference lists of all the potentially relevant papers and searched the websites of specific relevant organizations (e.g. Ergotron) to identify grey literature and ongoing studies. No language restriction was applied. We combined a series of terms for population and intervention. Details of the search strategy are available from the authors. Two reviewers independently screened the search results for eligible studies. Disagreements were resolved by consensus or through consultation with a third reviewer.

Interventions that sought to reduce workplace sitting time in adult workers through installation of a height-adjustable workstation (any design), either alone or as part of a multicomponent intervention, were eligible for inclusion. Included studies must have presented data for at least one of the following outcomes: objectively measured workplace sitting time (primary outcome), self-reported workplace sitting time, cardiovascular events (e.g. stroke, myocardial infarction), musculoskeletal health (e.g. symptoms of back pain), mental health (e.g. depression, anxiety, stress) and objectively measured body composition (e.g. body mass, body fat). Randomized and non-randomized controlled trials where the comparison group did not receive a height-adjustable workstation were included. Non-randomized trials were also considered eligible because we anticipated a paucity of randomized trials. Single-arm studies were not included.

Key study characteristics and outcomes were extracted and studies were quality assessed by one reviewer and checked for accuracy by a second. Disagreements were resolved through consensus, and if necessary a third reviewer was consulted. No papers were identified that required translation. Study quality was determined using the Cochrane Risk of Bias tool, a checklist of design components, including random sequence generation, allocation concealment, incomplete outcome data and selective reporting [15]. Blinding of participants during ergonomic interventions is not possible and while this was not considered in the review of study quality, performance bias as a result of a lack of blinding must be considered as a potential influence on the integrity of the outcomes of the included studies. The adequacy of each category was assessed as 'low', 'unclear' or 'high' risk, as suggested in the Cochrane Collaboration Handbook [15]. Additional data were extracted to inform the quality assessment of non-randomized studies: (i) if the groups were either balanced for key potential confounders at baseline or were they adjusted for in the analysis (e.g. baseline physical activity, baseline weight, sex, baseline sedentary behaviour, type of occupational setting) and (ii) other potential threats to validity (considering external validity, e.g. relevant use of co-interventions).

Given the diversity of the studies in terms of interventions and outcome measures used, we undertook a narrative synthesis. The primary study findings were interpreted, and similarities and differences between the studies investigated. This included consideration of study design, methodological quality, whether the study was appropriately powered, intervention characteristics and delivery, participants and outcome measures.

Results

A flow chart of the trial selection is shown in Figure 1. Five studies met the inclusion criteria for this review [9,12,14,16,17], of which four were non-randomized controlled studies [9,12,14,16], and one was a randomized controlled crossover study [17]. Three of the studies were from Australia [9,12,16], and two were from the USA [14,17], with all five studies published during or after 2012. The total number of included participants was 172, with sample sizes ranging from 29 [17] to 44 [16] for individual studies. The included studies mostly involved middle-aged (mean age ranging 35–43 years), well-educated female volunteers [9,14,16,17], and staff who worked in departments with a focus on health or workplace safety [9,12,14,16]. Summary details of the included studies are provided in Table 1.

Intervention details are included in Table 1. All five studies used height-adjustable workstations or desks supplied by Ergotron, Inc. (www.ergotron.com). Three of the studies specifically used the Workfit-S® height-adjustable workstation, which is a set-up that attaches to the front of one's existing desk and holds the computer monitor, keyboard and mouse [9,12,16]. The study of Pronk *et al.* [14] allowed participants to use the Workfit-S® or Workfit-C®, the latter of which has a height-adjustable work surface on a moveable cart. The study of Dutta *et al.* [17] allowed participants to use either of the Workfit-S®, Workfit-A® or Workfit-D® models. The Workfit-A® is a set-up that is identical to Workfit-S® but attaches to the back of one's existing desk, whereas the Workfit-D® is a whole desk that is easily moved up and down. The intervention duration varied between 4 weeks and 3 months [9,12,14,16,17].

Four of the five studies included objective measures of sedentary behaviour; these are described in Table 2 [9,12,16,17]. Three of the five studies assessed workplace sitting time, standardized to an 8-h workday, using an ActivPAL3 monitor that was worn on the thigh for 7 days continuously [9,12,16]. This is a validated device for assessing time spent sitting, standing and stepping [18]. The study of Dutta *et al.* [17] assessed workplace sitting times, calculated as percentage of total time and mean minutes per hour, using a Modular Signal Recorder accelerometer that was worn on the thigh for two randomly selected days within the same week. The authors cited an unpublished validation study involving seven participants for this device. Pronk *et al.* [14] used experience-sampling methodology to assess sitting behaviour at work. For this, participants were sent text messages three times per day asking them to respond as to whether they were currently sitting, standing or walking. Change in sitting behaviour was quantified as count data from the responses. As this measure is based on participant self-report, we did not classify it as an objective measure. Of our pre-specified secondary outcomes (PROSPERO: CRD42014008723), self-reported sitting behaviour was

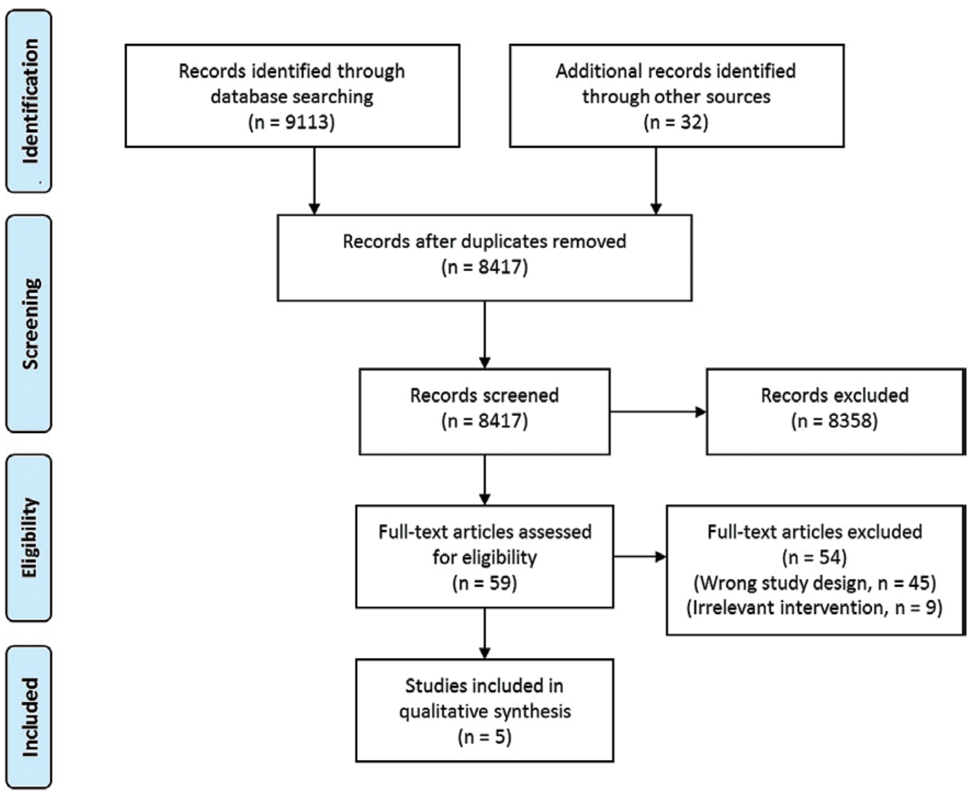

Figure 1. PRISMA diagram.

Table 1. Study characteristics

Study details	Population and setting	Intervention	Comparator	Study duration follow-up points	Funding and conflicts of interest
Dutta *et al.* [17] Randomized controlled crossover trial	Single workplace setting in Minnesota, USA. Participants aged 18+ working >20 h per week in a sedentary job. Excluded if have contraindications to standing.	*n* = 28 Ergotron Workfit-S, -A or -D installed for 4 weeks. Type of workstation dependent on the needs of the participant. Ergonomic evaluation conducted.	*n* = 28 No intervention: no modifications made. Participants to maintain usual activity for 4 weeks. Washout period as per comparator group for 2 weeks.	Study duration 10 weeks: 4-week intervention period, 4-week control period, 2-week washout period. Primary outcome of sitting time was assessed on two random days every week of the intervention and control periods.	Funding provided by University of Minnesota Obesity Prevention Centre and Minnesota Partnership for Biotechnology and Medical Genomics. Height-adjustable workstations were provided by Ergotron. One author has patents for accelerator algorithms used in the study. This author did not access or analyse associated data.
Neuhaus *et al.* [16] Three-arm non-randomized controlled trial	University staff recruited from three separate campuses in Australia. Patients aged 18–65 years, working >0.5 full-time equivalent (FTE), ambulatory. Not pregnant, allergic to medical tape, intending to relocate during study and without existing musculoskeletal conditions.	*n* = 16 Multicomponent intervention Organizational component: staff information session, information booklet and emails from managers. Environmental component: Ergotron Workfit-S installed for 3 months. Verbal and written instruction provided. Individual component: health coaching.	(a) Workstation only *n* = 14 Ergotron Workfit-S installed for 3 months. Verbal and written instruction provided. (b) No intervention *n* = 14 No modifications made. Participants to maintain usual activity.	Study duration: 3 months Follow-up at 3 months	Funding provided by Australian Postgraduate Award Scholarship, UQ School of Population Health Top-Up Scholarship and research student funding, Queensland Health Core. Infrastructure Funding, and UQ Major Equipment and Infrastructure and NHMRC Equipment Grant. Height-adjustable workstations were provided by Ergotron. Two authors presented at a conference organized by Ergotron, for which travel and accommodation expenses were covered by Ergotron. No further honoraria or imbursements were received. Stated that the funding bodies had no influence on the conduct or the findings of the study.

Table 1. *Continued*

Study details	Population and setting	Intervention	Comparator	Study duration follow-up points	Funding and conflicts of interest
Healy *et al.* [12] Non-randomized controlled trial	Single workplace setting in Government workplace safety department, Melbourne, Australia. Ambulatory participants aged 18–65, working >0.6 FTE with access to telephone, internet and desk. Excluded if pregnant, absent for >1 week during study period or with existing musculoskeletal disorders.	*n* = 22 Multicomponent intervention: organizational component: education workshop, reminder emails. Environmental component: Ergotron Workfit-S installed for 4 weeks. Verbal and written instruction provided. Individual component: health coaching	*n* = 21 No intervention: no modifications made. Participants to maintain usual activity.	Study duration: 4 weeks Follow-up at 4 weeks	Funding provided by NHMRC project grant and Victorian Health Promotion Foundation. Height-adjustable workstations were provided by Ergotron. No conflicts of interest.
Alkhajah *et al.* [9] Non-randomized controlled trial	Public Health Research Centres academic institute in Brisbane, Australia. Participants were office workers aged 20–65 years using a non-adjustable work surface. Participants excluded if working <0.5 FTE, pregnant, due to relocate during study or non-ambulatory.	*n* = 18 Ergotron Workfit-S installed for 3 months. Written and verbal instruction provided.	*n* = 14 No intervention: no modifications made. Participants to maintain usual activity.	Study duration: 3 months Follow-up at 1 week and 3 months	Funding provided by University of Queensland Major Equipment and Infrastructure grant. Unclear who supplied the height-adjustable workstations. Conflicts of interest not reported.
Pronk *et al.* [14] Non-randomized controlled trial	Health Promotion department, Minnesotta, USA. Health promotion employees in a sedentary job. Exclusion criteria not explicitly stated.	*n* = 24 Ergotron Workfit-S or -C installed for 4 weeks.	*n* = 10 No intervention: no modifications made. Participants to maintain usual activity.	Study duration 7 weeks: 1-week baseline period, 4-week intervention period, 2-week post-intervention period. Sitting behaviour was assessed every day of the 7-week period and average sitting behaviour scores were calculated for each study period	Project supported by HealthPartners and Ergotron, Minneapolis, MN.

assessed in two studies [14,17], musculoskeletal symptoms were reported in four studies [9,12,14,16], body mass in two studies [9,12], body mass index in one study [16], fat mass and waist circumference in two studies [9,12] and adverse events in three studies [9,12,16].

Table 3 shows the risk of bias ratings for each study. The methodological quality was generally poor, with a high risk of bias in all included studies. The main problem was in relation to selection bias. In relation to selection bias, four of the five included studies were non-randomized trials, which may explain why there appeared to be some differences in baseline characteristics between the compared groups of the individual studies. For example, in the study of Alkhajah *et al.*, there appeared to be group imbalances for age, job type and baseline sitting time, and in the study of Healy *et al.*, there was a much lower

Table 2. Objective measures for sedentary behaviour

Study	How behaviour was measured	Behavioural outcomes measured	Metric reported
Dutta *et al.* [17]	Modular Signal Recorder (MSR) accelerometer testing on two random days per week (sit/stand time). Time worn for not detailed Secured to lower thigh	Sitting time Standing time	% time spent sitting during workday and entire day
Neuhaus *et al.* [16]	ActivPAL3 activity monitoring 24 h/day for 7 days Secured to interior midline of right thigh	Standing time Sitting time Number of sit–stand transitions Metabolic equivalent (MET) minutes of moderate–vigorous exercise	Mean difference with standard deviation Data adjusted to standardized 8-h day
Healy *et al.* [12]	ActivPAL3 activity monitoring 24 h/day for 7 days Secured to interior midline of right thigh	Standing time Sitting time Number of sit–stand transitions MET minutes of moderate–vigorous exercise	Mean difference with standard deviation Data adjusted to standardized 8-h day
Alkhajah *et al.* [9]	ActivPAL3 activity monitoring 24 h/day for 7 days Thigh mounted	Standing time Sitting time Number of sit–stand transitions Stepping time	Mean difference with standard deviation Data adjusted to standardized 8-h day

Table 3. Risk of bias summary

Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome assessment	Selective reporting	Other bias
Alkhajah *et al.* [9]	−	−	−	?	+	+	−
Pronk *et al.* [14]	−	−	−	?	+	+	−
Healy *et al.* [12]	−	−	−	−	+	+	−
Neuhaus *et al.* [16]	−	−	−	−	+	+	−
Dutta *et al.* [17]	+	−	−	−	+	+	−

+, low risk of bias; −, high risk of bias; ?, unclear.

proportion of men in the intervention group (23 versus 67%) [9,12]. Of the four non-randomized trials, only the study of Neuhaus *et al.* [16] appeared to adequately adjust for potential confounders in the analysis. In addition, the lack of blinding leads to a risk of bias in the outcome assessment particularly for the more subjective outcome measures. The studies are also limited by small sample sizes (all ≤44 participants).

A summary of the results for the primary outcome of objectively measured sedentary behaviour is provided in Table 4. All four of the two-arm studies reported reduced workplace sitting time at follow-up in the intervention group compared with the control group [9,12,14,17]. In the study of Dutta *et al.* [17], there was an absolute reduction in workplace sitting time of 21% (95% confidence interval [CI] 18, 25) in the intervention period compared with the control period. Alkhajah *et al.* [9] reported an adjusted mean difference of −137 min (95% CI −179, −95; $P < 0.001$) in the intervention group versus the control group, at 3 months of follow-up. The intervention in the study of Healy *et al.* [12] reduced workplace sitting time by −125 min (95% CI −161, −89; $P < 0.001$) relative to control at 4 weeks. In the three-arm study of Neuhaus *et al.* [16], the multicomponent group had lower workplace sitting time relative to the control group at 3-month follow-up (adjusted mean difference = −89 min; 95% CI −140, −38; $P < 0.001$) and relative to the workstations-only group (−56 min, 95% CI −107, −4; $P = 0.033$). There was no significant difference in daily sitting time between the workstations-only group and the control group (−33 min, 95% CI −84, 17; $P = 0.285$).

Table 5 provides a summary of the results for the secondary outcome measures. Among the five studies, there was no clear evidence of an effect of the interventions on musculoskeletal symptoms or anthropometric characteristics. Anthropometric outcome data were only presented in two studies [9,12]. Anxiety and stress were not measured in any of the studies. Pronk *et al.* [14] assessed depression as an outcome measure; however, this was measured as a component of a larger well-being scale and comparisons were not made between the intervention and control groups, limiting the reporting of this outcome. Four studies collected data on adverse events with one study reporting an incident of a participant asking for removal of the workstation for reasons of body

Table 4. Results—objective measures of sedentary behaviour

Study	Baseline, Mean (SD)	Follow-up, Mean (SD)	Difference between groups, Mean (95% CI)
Dutta *et al.* [17]	Not available due to the study design	Intervention period (n = 28): 46% sitting time at work 49% sitting time in full day Control period (n = 28): 67% sitting time at work 63% sitting time in full day	The mean reduction in workplace sitting time during the intervention period was 21% (95% CI 18 to 25%) The mean reduction in whole-day sitting time during the intervention period was 14% (95% CI 11 to 17%)
Neuhaus *et al.* [16]	Multicomponent group: n = 16 366 (49) Workstation only group: n = 14 373 (36) Control group: n = 14 365 (54)	Only mean differences provided n = 12 n = 13 n = 13	Multicomponent versus control: −89 min (−140 to −38 min; $P \leq 0.001$) Workstation versus control: −33 min (−84 to 17 min; $P = 0.285$) Multicomponent versus workstation: −56 min (−107 to −4 min; $P = 0.033$)
Healy *et al.* [12]	Multicomponent group: n = 18 338.5 min (35.3) Control group: n = 18 334.7 min (52.4)	Multicomponent group: n = 18 216.7 (67.9) Control group: n = 18 339.3 (51.4)	−125.2 min (−161.4 to −88.9 min; $P \leq$ 0.001)
Alkhajah *et al.* [9][a]	Intervention group: n = 18 329 min (55) Control group: n = 13 377 (56)	Intervention group: n = 18 −125 min (95% CI −150 to −99 min) Control group: n = 12 12 min (95% CI −20 to 44 min)	−137 min (−179 to −95 min; $P \leq 0.001$)

[a]Only data for the 3-month (i.e. final) time point are presented.

pain [16]. Dutta *et al.* [17] also stated that most participants reported experiencing increased fatigue, especially in the lower back and lower extremities, during the beginning of the intervention as they were adjusting to the height-adjustable workstations and increased standing time at work.

We identified five relevant ongoing studies: one non-randomized controlled trial in Finland involving sport and health sciences staff as participants (ISRCTN Register: ISRCTN43848163); one randomized controlled trial in the USA (ClinicalTrials.gov Identifier: NCT01846013); a randomized controlled trial in Australia recruiting staff from the Heart Foundation Sydney and Newcastle offices (WHO International Clinical Trials Registry Platform: ACTRN12612000072819); another randomized controlled trial from Australia involving University Health Sciences staff and a cluster randomized controlled trial from Australia involving 16 worksites in Victoria [19,20].

Discussion

All five identified studies reported that the height-adjustable workstation interventions reduced workplace sitting time in office workers; however, firm conclusions could not be drawn because the studies were all small and the risk of bias was high. A meta-analysis was not conducted because there was large variability in the interventions and outcomes used. The most likely direction of the bias would have been to overestimate the benefit of the interventions because of the study design and selection bias. For example, the volunteers will likely have known (due to the use of non-randomized designs) whether or not they would be in the intervention group when agreeing to participate. Little is currently known about the effect of height-adjustable workstation interventions on relevant health outcomes such as body composition, musculoskeletal symptoms, cardiometabolic risk and mental health.

This review found that the majority of height-adjustable workstation intervention studies conducted to date had methodological shortcomings that could be associated with biased findings. Important limitations included non-random group allocation, lack of blinding of the outcome assessors and non-representative sampling. Regarding the latter, the populations used raise concerns about the generalizability of the included studies. For example, in the study of Alkhajah *et al.* [9], we suspect that the effect size of the intervention was exaggerated because the study was conducted with a group of public health researchers working in the area of sedentary behaviour research. Poor generalizability was also a concern in three of the other studies [12,14,16]. Our

Table 5. Results—summary of secondary outcomes

Outcome	Study	Method of assessment	Baseline, Mean (SD)	Follow-up, Mean (SD)	Difference between groups, Mean (95% CI)
Subjective sedentary behaviour	Pronk *et al.* [14]	(1) Sedentary behaviour score assessed using experience sampling methodology (2) Self-estimate of workplace sitting time	(1) Unable to present raw data as results provided as graphs (2) Intervention group: $n = 23$ Mean = 409 (SD not provided) Control group: $n = 10$ Mean = 441	(1) Unable to present raw data as results provided as graphs (2) Intervention group: $n = 23$ 343 Control group: $n = 10$ 458	No comparisons made between groups (1) The intervention group increased average experience-sampling methodology scores (representing reduced sitting behaviour) by 224% during period 2 compared with period 1 ($P < 0.001$) (2) Within-group change was significant for the intervention group ($P = 0.03$), but not the control group ($P = 0.31$)
	Dutta *et al.* [17]	Sitting time measured subjectively via the self-reported Occupational Sitting and PA Questionnaire	Data not presented	Data not presented	Decreased sitting time at follow-up of 40% (95% CI 36 to 44%)
Weight	Healy *et al.* [12]	Measured when voided without heavy shoes and clothing using a bioimpedance analysis scale to nearest 0.1 kg	Intervention group: $n = 19$ 77.6 kg (15.6) Control group: $n = 19$ 82.7 kg (18.4)	Intervention group: $n = 19$ 77.6 kg (15.8) Control group: $n = 19$ 82 kg (17.3)	Adjusted group difference = 0.47 kg (−1.0 to 1.95 kg; $P = 0.519$) Adjusted for baseline score
	Alkhajah *et al.* [9]	Weight measured to nearest 0.1 kg using Taylor 7023WA Lithium electric scale. Measurement taken without shoes or heavy clothes	Intervention: $n = 18$ 64.8 kg (10) Control group: $n = 12$ 58.3 kg (8.3)	Intervention: $n = 18$ 64.4 kg (9.9) Control group: $n = 12$ 58.7 kg (9)	Adjusted group difference = −0.9 kg (−1.9 to 0.2 kg; $P = 0.097$) Includes only completers. Adjusted for baseline score
Body fat	Healy *et al.* [12]	Measured when voided without heavy shoes and clothing, using a bioimpedance analysis scale to nearest 0.1 kg	Intervention: $n = 19$ 26.3% (12.3) Control: $n = 19$ 22.1% (10.1)	Intervention: $n = 19$ 26.1% (12.4) Control: $n = 19$ 21.2% (9.2)	Adjusted group difference = 0.85% (−0.41 to 2.1%; $P = 0.180$) Adjusted for baseline score
	Alkhajah *et al.* [9]	Measured using Impedimed SFB7 bioimpedance spectroscopy device	Intervention: $n = 16$ 20% (4.7) Control: $n = 10$ 15.6% (4.1)	Intervention: $n = 16$ 20% (4.5) Control: $n = 10$ 15.3% (4.8)	Adjusted group difference = 0.1% (−1.1 to 1.2%; $P = 0.931$) Includes only completers. Adjusted for baseline score
Waist circumference	Healy *et al.* [12]	Waist and hip circumference measured in duplicate to nearest 0.1 cm	Intervention: $n = 19$ 91.1 cm (12) Control: $n = 19$ 91.2 cm (15)	Intervention: $n = 19$ 90.9 cm (11.7) Control: $n = 19$ 90.6 cm (14.6)	Adjusted group difference = 0.39 cm (−1.70 to 2.47 cm; $P = 0.710$) Adjusted for baseline score
	Alkhajah *et al.* [9]	Measured in duplicate to nearest 0.1 cm using a non-expandable tape measure at the superior border of the iliac crest	Intervention: $n = 18$ 83.3 cm (9.0) Control: $n = 12$ 79.6 cm (8.4)	Intervention: $n = 18$ 84.5 cm (9.1) Control: $n = 12$ 79.1 cm (7.3)	Adjusted group difference = 2.0 cm (−0.7 to 4.7 cm; $P = 0.134$) Includes only completers. Adjusted for baseline score

hypothesis here is that people who work in the area of sedentary behaviour and health are more likely to change their behaviour when exposed to a height-adjustable workstation intervention (perhaps because of a greater 'buy-in' to the idea that reducing sitting time is good for health), when compared with individuals in other areas of work. Therefore, the findings of these studies may not be generalizable to general office-based workers such as those working in call centres and non-health-focused settings.

The main limitation of this systematic review is the small number of studies included. Although it is possible that the literature search did not identify all published workplace interventions that have measured sitting, the literature search was comprehensive, with >9000 articles published between 2008 and 2014 examined. Furthermore, we paid special attention to the workplace physical activity interventions, workplace ergonomics and occupational health interventions literature.

The results of our review indicate that there is considerable uncertainty regarding the effects of height-adjustable workstation interventions on workplace sitting time in office workers. Therefore, well-conducted and adequately powered randomized controlled trials are needed to help determine the impact of height-adjustable workstation interventions on occupational sedentary behaviour, both in the short and long term. This conclusion is somewhat more conservative than that of Neuhaus *et al.* who, in their recent systematic review and meta-analysis of activity-permissive workstations (which includes fixed standing desks, height-adjustable workstations, treadmill desks and cycle ergometers and pedal devices fitted underneath the desk), stated that 'activity-permissive workstations can be effective to reduce occupational sedentary time' [21]. Given the diversity of interventions included in their meta-analysis, and the methodological limitations of the included studies, the results of the meta-analysis should, in our view, be interpreted cautiously. The Neuhaus review also took a different approach to quality assessment and three non-randomized controlled studies received a maximum quality score, which is not possible with the risk of bias tool that we used [9,12,16]. There are inherent limitations of non-randomized study design when assessing the effectiveness of in intervention [22].

A key reason for using a height-adjustable workstation intervention is that it may confer health benefits without having detrimental effects on work productivity. We identified limited data on health outcomes, and changes in work productivity were not investigated in this review. Therefore, these issues should both be addressed in future trials and reviews. The inclusion of cost-effectiveness analyses in future studies is also important to help stakeholders and decision makers to determine whether the cost of a given intervention is justified by improvements in health and work-related outcomes. In this arena, one economic evaluation including a cost-effectiveness analysis of a height-adjustable workstation intervention in a trial population of 160 participants is currently underway [20]. It would also be particularly interesting to compare height-adjustable workstations with other less costly interventions such as organizational strategies without specialized workstation adaptations (e.g. information sessions, email prompts). Further studies are also necessary to identify which concomitant strategies (i.e. management involvement, individually focussed behaviour change strategies) are required to facilitate successful behaviour change.

The findings of our systematic review suggest that the evidence base for height-adjustable workstations is currently limited and includes only small studies with important methodological limitations. Despite this, the available data suggest that height-adjustable workstation interventions may offer a practical approach to reducing workplace sitting time, but further research is warranted to determine the true magnitude of the effect particularly over health-related and work-productivity outcomes.

Key points

- Prolonged sitting in the workplace is associated with adverse health outcomes.
- Installation of height-adjustable workstations has been proposed as a feasible approach for reducing occupational sitting time in office workers.
- This systematic review highlights that height-adjustable workstation interventions may offer a practical approach to reducing workplace sitting time, but further research is warranted to determine the true magnitude of the effect on health-related and work-productivity outcomes.

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Conflicts of interest

None declared.

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