Workplace sitting and height-adjustable workstations: a randomized controlled trial.

Authors and affiliations:

Maike Neuhaus[1], MPsych, Genevieve N Healy [1,2], PhD, David W Dunstan[1, 2, 3, 4], PhD, Neville Owen[1,2,5, 6], PhD, Elizabeth G Eakin[1,2], PhD

[1]The University of Queensland, School of Population Health, Cancer Prevention Research Centre, Herston, Queensland, Australia

[2]Baker IDI Heart and Diabetes Institute, Melbourne, Victoria, Australia

[3]Monash University, Epidemiology and Preventive Medicine, Melbourne, Australia

[4]The University of Western Australia, School of Sports Science, Exercise and Health, Perth, Australia

[5]The University of Melbourne, School of Population & Global Health, Melbourne, Australia

[6]Monash University, Medicine, Melbourne, Australia

Corresponding author:

Maike Neuhaus, Cancer Prevention Research Centre, School of Population Health, The University of Queensland, Herston Rd, Herston, Queensland, Australia 4006; Tel: +61 7 33655350; Fax: +61 7 3365 5540

Word count: 4000 (4000 max.); 31 pages, 3 tables, 3 figures

Number of tables: 3

Number of figures: 3

Funding and conflict of interest:

Neuhaus was supported by an Australian Postgraduate Award Scholarship. Healy was supported by a National Health and Medical Research Council (NHMRC) [# 569861] and Heart Foundation [PH 12B 7054] Fellowship. Dunstan was supported by an Australian Research Council Future Fellowship [#FT100100918]. Owen was supported by a NHMRC Program Grant [#569940] and a Senior Principal Research Fellowship [NHMRC #1003960]. Eakin was supported by a NHMRC Senior Research Fellowship [#511001].

Height-adjustable workstations were provided by Ergotron (www.ergotron.com). The funding bodies had no influence on the conduct or the findings of the study.

Clinical Trial Registration:

Australian New Zealand Clinical Trials Registry 00363297; date of registration: 26 November 2012; funding source for the trial: Australian Postgraduate Award Scholarship, UQ School of Population Health Top-Up Scholarship & research student funding, Queensland Health Core Infrastructure Funding, and UQ Major Equipment and Infrastructure & NHMRC Equipment Grant; Ethics approval granted 4th August 2011 by the School of Population Health Ethics Committee, The University of Queensland.

Abstract (270 words; 300 max.)

Background: Desk-based office employees sit for most of their working day. To address excessive sitting as a newly-identified health risk, best practice frameworks suggest a multi-component approach. However, these approaches are resource intensive and knowledge about their impact is limited.

Purpose: To compare the efficacy of a multi-component intervention to reduce workplace sitting time, to a height-adjustable workstations-only intervention, and to a comparison group (usual practice).

Design: Three-arm quasi-randomized controlled trial in three separate administrative units of The University of Queensland, Brisbane, Australia. Data were collected between January and June 2012 and analyzed the same year.

Setting/ participants: Desk-based office workers aged 20-65 (multi-component intervention, n=16; workstations-only, n=14; comparison, n=14).

Intervention: The multi-component intervention comprised installation of height-adjustable workstations, organizational-level (management consultation, staff education, manager emails to staff) and individual-level (face-to-face coaching, telephone support) and elements.

Main outcome measures: Workplace sitting time (mins/8-hour workday) assessed objectively via activPAL3 devices worn for seven days at baseline and 3 months (end-of-intervention).

65 Results: At baseline, the mean proportion of workplace sitting time was approximately 77%
66 across all groups [multi-component group 366 mins/8hrs (SD 49); workstations-only group
67 373 mins/8hrs (SD 36), comparison 365 mins/8hrs (SD 54)]. Following intervention and
68 relative to the comparison group, workplace sitting time in the multi-component group was
69 reduced by 89 mins/8-hour workday (95% CI= -130, -47 mins; p<0.001) and 33 mins in the
70 workstations-only group (95% CI= -74, 7 mins, p=0.285).

71 Conclusions: A multi-component intervention was successful in reducing workplace sitting.
72 These findings may have important practical and financial implications for workplaces
73 targeting sitting time reductions.

Background

Too much sitting is detrimentally associated with musculoskeletal symptoms[1] and several risk biomarkers of cardio-metabolic health,[2, 3] particularly when accumulated in prolonged, unbroken bouts.[4] Desk-based office workers sit for an average of six hours during an eight-hour work day.[5-7] With much of this sitting time accrued in bouts of 30 mins or more,[7-9] office workers are an important target for intervention.[10]

Height-adjustable workstations are a potentially feasible option to reduce workplace sitting. They offer the opportunity to complete desk-based/computer tasks while alternating between sitting and standing, without significant disruption of work practices. Traditionally acquired for the prevention of musculoskeletal problems,[11, 12] their utility in reducing sitting time for broader preventive-health benefits is increasingly being recognized.[13] Studies in the USA, Europe, and Australia have reported reductions in workplace sitting between 0 to 143 mins/workday following workstation installation in office environments.[5, 14-19] However, preliminary indications suggest that installation of height-adjustable workstations alone may not be sufficient for sustained reductions in sitting time.[20] These findings support recommendations from the broader workplace health promotion literature, [21, 22] and ecological models of sedentary behavior.[23] Both emphasize the importance of intervening on the multiple interrelated influences on individual behavior in the workplace, including the organizational structure, the physical and social/interpersonal environment, and intrapersonal factors.

A recent study that used such a multi-component approach achieved substantial reductions in workplace sitting time,[18] with intervention group participants reducing their workplace sitting

by two hours relative to comparison group participants. However, given the two-group design, it was not possible to determine the contribution of the organizational- and individual-level elements, as distinct from the provision of height-adjustable workstations alone. Given that these elements are resource intensive, this issue has important practical and financial implications.

The aim of this study was to compare changes in objectively-measured workplace sitting time following a multi-component intervention versus the installation of height-adjustable workstations alone, relative to a comparison condition, over three months.

Methods

Study design

The study ('Stand Up UQ') was conducted within three separate administrative units of The University of Queensland (UQ) in Brisbane, Australia and included: 1) a 'multi-component' intervention group; 2) a (height-adjustable) 'workstations-only' intervention group and, 3) a comparison group (usual practice; assessment-only). Due to one of the units being located ~90km from the research center, the two local units were randomized to the intervention arms, with the distant unit allocated to the comparison group.

The study was approved by UQ's School of Population Health Ethics Committee. Data were collected January - June 2012, at baseline and three months thereafter. Research staff and participants were not blinded to group allocation.

Recruitment

Organization

The three units were identified by the University's Wellness Program Manager (who volunteered her own unit (HR/Payroll) for study participation), and located on three different campuses. Unit selection was based on the following criteria: all potential participants were to be located on the same office floor (to control for unit-specific norms; intervention groups only); and, potential participants were to be employed in jobs primarily involving computer/administrative desk-based tasks with a designated desk within the workplace. Unit managers, were given details of the study rationale and procedures and all provided consent for their unit to participate.

Employees

A recruitment email explaining the study purpose and procedures was sent to all staff from consenting units. Interested employees emailed the project manager (MN) and were interviewed via telephone to assess eligibility: aged 18 to 65 years; speaking English; ambulatory; not pregnant; working at least 0.5 FTE; without allergies to medical tape (used to attach the activity monitor); not experiencing any musculoskeletal discomfort or neck/back/shoulder strain; and, not relocating to another worksite during the study period. A total of 44 participants (16 multi-component group; 14 workstations-only group; 14 comparison group) were recruited and underwent baseline assessment (Figure 1).

PLEASE INSERT FIGURE 1 ABOUT HERE

Multi-Component Intervention

The intervention was based on social cognitive theory, with emphasis on self-efficacy, outcome expectancies, and socio-structural factors.[24] The operationalization of theoretical constructs into intervention strategies was guided by an intervention taxonomy,[25, 26] and focused on provision of normative feedback, goal-setting, self-monitoring and problem-

144 solving. Strategies were applied at the organizational (e.g. through group-level normative
145 feedback in comparison to the average sitting time in Australian office workers),
146 environmental (e.g. normative cues from co-workers standing at height-adjustable desks), and
147 individual level (e.g. through normative individual feedback at baseline in comparison to the
148 groups' sitting time) (details below).
149
150 The key intervention messages were *Stand Up, Sit Less, Move More*. *Stand Up* was the main
151 prompt to break-up long bouts of sitting (≥ 30 mins) by changing posture frequently (at least
152 every 30 mins). *Sit Less* communicated the importance of reducing overall sitting time.
153 Participants were encouraged to substitute some sitting with standing or moving time,
154 primarily by using the height-adjustable workstation. A sitting-to-standing ratio of
155 approximately 50:50, accumulated through short bouts and regular postural transitions, was
156 suggested. Both of these suggestions were guided by recommendations from the university's
157 occupational health and safety (OHS) advisor that regular postural changes should be
158 implemented every 30 mins.[27] The principle of *Move More* targeted an increase in incidental,
159 light-intensity physical activity throughout the workday (e.g. taking the stairs instead of the
160 elevator).

161 Intervention Delivery

162 Multi-component intervention

163 All intervention components were delivered and recorded by the same project manager (MN;
164 Master's-level, health coach; Table 1). Intervention fidelity was maintained through the use
165 of detailed intervention scripts and checklists, and weekly meetings with senior study
166 investigators.

167 *Insert Table 1 about here.*

The organizational intervention addressed some aspects of workplace culture and norms via inclusion of a consultation with the unit manager, an all-of-staff information session, and manager emails to employees. The manager consultation (~30 mins) provided the rationale for the study, details of participation, and a discussion of approaches to *Stand Up, Sit Less, and Move More* within their unit. The ensuing 30-min staff information and brainstorming session addressed the study rationale and procedures, as well as feedback on the unit's baseline workplace sitting time. Over the course of the intervention, six fortnightly emails were sent from the manager to staff. They supported program participation, and included a study information booklet (provided by research staff). The remaining five emails encouraged staff to *Stand Up, Sit Less, and Move More* and commented on strategies that appeared to be working well within the unit. Email templates were provided by research staff and tailored to the group by the manager.

The environmental intervention strategy modified the personal physical office environment through the provision of fully installed height-adjustable workstations (*WorkFit-S*) with an attached work surface tray (www.ergotron.com) for each intervention participant. Employees also received verbal (10-min duration) and written instructions from the project manager on correct usage and how to alternate their working posture in line with OHS guidelines.

Individual intervention strategies included face-to-face coaching, a tailored email, three telephone calls, an information booklet, and a self-monitoring tool. The initial 30-min face-to-face coaching session was delivered at the worksite within two days following the workstation installation. This included a discussion of graphical feedback on the individual's baseline sitting, standing and moving time (Figure 2), and collaborative goal-setting in

relation to the three program messages. An email summarizing the goals agreed upon was sent to each participant on the same day. Three follow-up telephone calls (approx. 10 mins each) were delivered at one, three and seven weeks following the coaching session to assess goal achievement, problem-solve potential barriers and re-set goals as necessary. Participants also received a laminated self-monitoring tool (Figure 3). This 'Tracker' was attached to the workstation, clearly visible to the participant and used during the coaching session and telephone calls for the participant to document and adjust specific goals and strategies used. Participants were able to contact the project manager at any time in the case of adverse events or problems with their workstation.

PLEASE INSERT FIGURES 2 & 3 ABOUT HERE

Workstations-only intervention

Participants in the workstations-only group received the same workstations and OHS instructions from the project manager as the multi-component intervention group. No further contact was scheduled.

Comparison group

No workspace modification was provided for comparison group participants. They were advised to maintain their usual day-to-day activity.

Data collection

Individual assessments occurred at baseline and three months (follow-up) in a designated testing room at or near to the participating units. At each assessment, participants also wore

an activity monitor (activPAL3; PAL Technologies Limited, Glasgow, UK) and self-completed an online questionnaire.

Measures

The activPAL3 monitor (53 x 35 x 7mm; 15g) was waterproofed and attached on the anterior mid-line of the right thigh using a breathable hypoallergenic adhesive patch. Participants were asked to wear the monitor for seven consecutive days (24 hours per day). The monitor, a valid and responsive measure of posture and motion during everyday activities,[28, 29] was initialized and downloaded (manufacturer provided software: version 6.3.0) using the default settings. Participants recorded any monitor removal times, their wake/sleep and work hours in a diary.

Height (nearest 0.1cm) was measured in duplicate without shoes using a stadiometer (Seca limited, Germany). Weight was measured using an electronic scale (Soehnle-Waagen GmbH & Co. KG, Germany) with footwear and heavy clothing removed. Body Mass Index (BMI) was then calculated as [average weight (kg)/ average height (m^2)].

The online questionnaire was used to collect data on demographics (age, gender, ethnicity, educational attainment, employment history, smoking history, medical history; baseline only), work-related elements [(work-performance (e.g. *"Rate your highest level of efficiency this week"*; 10-item scale ranging from 1-10 with higher scores indicating better work-performance),[30] absenteeism[31] (*"How many days in the LAST 3 MONTHS have you stayed away from your work for more than half the day because of health problems?"*) and presenteeism[31] *("How many days in the LAST 3 MONTHS did you go to work while suffering from health problems?")*], musculoskeletal symptoms,[32] and adverse events (open-question

format). Intervention group participants also answered questions about the acceptability and feasibility of the intervention, including the acceptability of the height-adjustable workstations, which was rated on a ten-item scale (1= 'disagree strongly' to 5='agree strongly'), and via an open question. Participants in the multi-component group further evaluated (1= 'not useful at all' to 5= 'very useful') the usefulness of all individual intervention components.

Information on intervention fidelity (i.e., completion of coaching sessions, calls, emails and unscheduled contacts with participants) was systematically recorded.

Activity monitor data processing

The activPAL3 records the beginning and ending of each bout of sitting or lying (referred to as sitting), standing, and moving at different speeds and the estimated metabolic equivalents (METs; energy expended above resting metabolic rate; 1 MET= 1.0 kcal/kg/hr) expended during those bouts. Data were processed in SAS 9.3 (SAS Institute Inc., Cary, NC) using a customized program. For each of the outcomes, totals were calculated for each day at the workplace. Averages were calculated from valid days (i.e. activity monitor worn ≥80% of time spent at the workplace; 171 days at baseline, 147 days at follow-up). Outcomes were standardized to an eight-hour workday except for sit-to-stand transitions, which were divided by hours of workplace sitting.

In accordance with the key intervention messages, changes from baseline to follow-up in the following outcomes were assessed for time spent at the workplace: *Stand up*: Standing time and prolonged sitting (time accumulated in prolonged sitting bouts ≥30 mins); *Sit less*: Sitting time (primary outcome) and the number of sit-to-stand transitions; *Move more*: Stepping

time, number of steps, and MET mins of moderate-to-vigorous physical activity (MVPA) at ≥4 METs (≥120 steps per min).

Statistical analyses

Data were analyzed in 2012 using PASW Statistics, version 20.0.0 (SPSS, Inc, Chicago IL), with statistical significance at $p < 0.05$ (two-tailed). Within-group changes were assessed by paired t-tests (normal data) or Wilcoxon signed rank test (non-normal data). Multivariate analyses were by linear regression, using the Sidak method to control significance for multiple comparisons,[33] with adjustment for baseline values of the outcome. For each outcome, baseline values of the other outcomes and socio-demographic characteristics were considered as potential confounders, and were adjusted for in analyses if their inclusion changed the mean differences between groups in the outcome by more than 20%[34] and if statistically significant at $p<0.2$.[35] Non-normally distributed outcomes (sit-to-stand transitions; MVPA MET mins) were log-transformed, with their mean group differences expressed as rate ratios (RR, e.g. ratio of mean multi-component intervention group/ comparison group).

Sample size calculation

The trial aimed to recruit 15 and retain 13 participants in each arm. A priori calculations in STATA (Stata Statistical Software version 11.2; College Station, TX: StataCorp LP) revealed this to be sufficient to achieve at least 80% power (5% significance, two-tailed), for the detection of differences between the multi-component group versus the comparison/ workstations-only group of 70/90 mins, respectively, per 8-hour workday for workplace sitting. This was based on expected standard deviations of change in workplace sitting of 70 mins (intervention group) and 24 mins (comparison group).[18] Minimum detectable

differences for the other activity monitor outcomes were: 75/95 mins (standing), 85/95 mins (prolonged sitting), 15/15 mins of stepping, 4/3 MET mins of moderate-to-vigorous physical activity, 600/700 number of steps, and 2.1/3.0 sit-to-stand transitions between the multi-component group versus the comparison/ workstations-only group respectively.

Missing data

Missing diary information was followed up with participants whenever possible. The online questionnaire structure did not permit missing values. Missing data on the activity monitor outcomes was low (n = 6; 11.4%; see Figure 1), occurring for three participants (multi-component group) due to becoming ineligible before (n=2) or during the intervention (n=1), one participant (workstations-only group) due to withdrawal, one (multi-component group) due to monitor malfunction, and one (comparison group) due to adverse reaction to the adhesive tape holding the monitor in place. Accordingly, data were assumed to be missing completely at random and multivariate analyses conducted with completers.

Results

Participant characteristics

The majority of participants were women (the multi-component condition had only women), Caucasian, non-smokers, and general university staff in full-time employment (Table 2). On average (all groups combined) at baseline, 77% (±10%) of time at the workplace was spent sitting, 16% (±7%) standing, and 8% (±3%) stepping. Overall, 38% (±16%) of the total time at the workplace was spent in prolonged sitting bouts ≥30 mins.

PLEASE INSERT TABLE 2 ABOUT HERE

Changes in sitting, standing and moving

Following intervention, a significant overall effect of study group on workplace sitting time was observed (p=.001; Table 3). For the multi-component group, the average reduction in daily workplace sitting time was 89 mins (95% CI= -130, -47 mins; p<0.001) relative to the comparison group and nearly an hour (-56 mins, 95% CI= -107, -4 mins; p=0.033) compared to the workstations only group. There was no statistically significant change in daily sitting time observed in the workstations-only group relative to the comparison group (-33 mins, 95% CI= -84, 17 mins; p=0.285). Within groups, mean sitting time reductions were 94 mins (95% CI= -146, -43 mins, p=0.002) and 52 mins (95% CI= -79, -26 mins, p=0.001) in the multi-component group and workstations-only group, respectively. No significant change was observed in workplace sitting time within the comparison group (-11 mins, 95% CI= -22, 43 mins, p=0.484).

PLEASE INSERT TABLE 3 ABOUT HERE

A significant overall effect of intervention condition on workplace standing time (p<.001) was observed. Relative to the comparison group, workplace standing time increased by 93 mins (95% CI= 45, 141 mins; p< .001) in the multi-component group: an hour greater (59 mins, 95% CI= 10, 107 mins; p= .014) when compared to workstations-only group participants. No statistically significant changes were seen in any of the other secondary activity monitor outcomes. However, we were not adequately powered to detect these changes and 95% confidence intervals could not rule out potentially meaningful intervention effects in prolonged sitting time (-31 mins, 95% CI= -79, 17 mins; p= .296) in the multi-component group and in standing time (35 mins, 95% CI= -12, 81 mins; p= .200) in the workstations-only group compared to the comparison group.

338

339 Changes in work-related outcomes and musculoskeletal symptoms

340 No statistically significant changes were observed in work-related or musculoskeletal
341 outcomes. However, changes of ≥20%, indicating potentially meaningful intervention
342 effects,[36] were observed in the following outcomes: increased absenteeism and presenteeism
343 within the comparison group; musculoskeletal symptoms within the multi-component
344 condition (shoulders increased; neck, knees, ankles/feet decreased) and the comparison group
345 (hips/thighs/buttocks and knees increased; Appendix).

346

347 Adverse events

348 Seven weeks following the provision of the height-adjustable workstation, one participant
349 (workstations-only condition) withdrew from the study due to overall bodily pain. While it
350 cannot be ruled out that this was completely unrelated to the use of the workstation, this
351 participant exclusively wore high-heels while standing at the workstation (which was not
352 recommended per the intervention protocol). No other adverse events were reported.

353

354 Fidelity of intervention delivery

355 Overall, fidelity of intervention delivery in the multi-component condition was high. All
356 participants received all intervention elements, with the exception of the staff information
357 session, which was attended by 12/14 participants .

Study feasibility and acceptability

Acceptability of the height-adjustable workstations was high in both groups (mean score of 3.9/5 (SD 0.5) in the multi-component group and 3.7/5 (SD 0.6) in the workstations-only group). However, noted limitations included diminished desk-space, and not being able to adjust the distance from the computer screen to the eyes. All multi-component intervention group participants rated additional intervention components as either useful or very useful, and 12/13 rated the manager emails as either useful or very useful (minimum score= 3).

Discussion

The multi-component intervention resulted in an approximate three-fold greater reduction of office workers' sitting time during work hours relative to the provision of height-adjustable workstations alone. Likewise, the increase in standing time in the multi-component intervention group significantly exceeded that of the workstations-only intervention group. To our knowledge, this is the first study to evaluate the benefit of adding individual- and organizational-level intervention elements to the installation of height-adjustable workstations.

Compared to the only other study (*'Stand Up Comcare'*) to have evaluated such a multi-component intervention to reduce sitting time including workstations, the reduction in workplace sitting time in the multi-component group of this study was less (125 mins versus 94 mins respectively).[18] While both of the studies used activPAL devices for the assessment of sitting time, it is unknown how the reductions in sitting time were accumulated (i.e. at the workstation, through organizational strategies such as standing meetings, or a mixture of both). A potential reason for the observed differences of intervention effects could be related to stronger organizational standing routines (i.e. standing meetings) in the better performing

sample of the *Stand Up Comcare* study. In fact, as the name indicates, that group consisted of office workers from *Comcare*, the Australian agency responsible for workplace safety, rehabilitation and compensation in the Commonwealth jurisdiction, which likely has an increased awareness for healthy workplace practices and motivation for the implementation thereof.

The sitting time reduction in the workstations-only condition was not statistically significant relative to the comparison group. The magnitude of change (-33 mins) lies within the change reported by other studies that have installed height-adjustable workstations to reduce sitting time (0 – 66 mins)[14-17], with the exception of one study which reported a reduction of 143 minutes/8hour workday.[5] This difference might be related to the representativeness of the study sample, as the latter study was conducted within a group of public health researchers working in the area of sedentary behavior research in which sitting time-reducing strategies (e.g. standing meetings) were already part of the organizational culture. More studies including measures of when and how sitting time changes occur will be needed to put these differences into perspective.

Although no statistically significant changes were observed for prolonged sitting, considering the benefits of even short breaks in sitting time on biomarkers of cardiovascular health is needed. [4,37,38] While both intervention groups replaced some of their sitting time with standing, it is unknown how this increase in standing time was accumulated.

Consistent with previous studies,[5, 18] no significant changes were observed in the number of steps, stepping time, or MVPA MET mins during work hours. This may reflect the nature of desk-based office work, where the majority of time is spent at the desk to complete job tasks,

and where time spent moving is minimal. Other workplace studies have successfully combined the installation of height-adjustable workstations with physical activity program strategies.[14, 17] However, while the magnitude of sitting time reduction in these studies was statistically significant, the magnitude of the changes (66 mins and 58 mins respectively) was not as substantial as observed in the multi-component intervention group of this study. Although yet to be evaluated, an optimal approach may be to use the multi-component approach to sitting time implemented in the current study in combination with successful exercise intervention strategies.

Our results suggest that it is feasible to implement a multi-component intervention such as was used in Stand Up UQ with high fidelity, no perceived decrease in productivity, and few adverse outcomes. However, such study components are also resource intensive, including the installed workstations (currently retailing for approximately $499USD, plus installation cost), and delivery of other intervention elements. While our findings indicate that individual and organizational supports are important for reducing workplace sitting time, it is not possible to identify if any particular strategies were more important than others. As the individual-level intervention components are the most cost-intensive, future studies could evaluate the efficacy of the multi-component intervention in comparison to an intervention including height-adjustable workstations and organizational strategies only.

The three-arm design and objective measurement of sitting time are key strengths of this study. However, there were a number of limitations. The sample size was small. However, the socio-demographic characteristics of the three groups involved are broadly comparable with office workers involved in previous sedentary behavior studies,[5, 14, 16, 18, 39] noting that the range of such characteristics has varied widely across the various studies. Likewise, the

study was not powered for all outcomes examined, and it was not possible to fully randomize all intervention groups for reasons outlined in the Methods. Although all analyses controlled for baseline values, and tested socio-demographic as well as workplace characteristics for potential confounding, the possibility that unmeasured confounders may have impacted the results cannot be ruled out and true cause and effect cannot be claimed. Furthermore, with regard to the recruitment of study groups, the response rate in the comparison group was low (3% in comparison to 46% and 69% in the multi-component and workstations-only group, respectively). However, while the two intervention groups were recruited from desk-based administrative staff groups only, the recruitment email for the comparison group was sent to all staff working on this campus (i.e., including staff who are not desk-based, such as agricultural field workers).

Key reasons for the choice of the desk-mounts used in this study were their ability to retro-fit existing office furniture as well as their substantially lower cost in comparison to fully height-adjustable desks. However, some design flaws were apparent in this study (i.e. lost desk-space, non-adjustable computer screen distance to eyes etc.). Considering the rapid advancements in design and increasing demand for height-adjustable furniture, fully height-adjustable desks are becoming increasingly more affordable; it is recommended that these newer models be used in future research. Finally, this study examined short-term (three months) results only. Future studies should examine the sustainability (over six months or more) of reductions in workplace sitting time following intervention. Incorporating the increasing evidence-base on successful strategies to reduce office-workers' sitting time (e.g. height-adjustable desks) into OHS policies may be crucial.

Conclusions

This is the first study to suggest that multi-component programs targeting workplace sitting may achieve more substantial reductions in office workers' sitting time than the provision of height-adjustable desks alone. These findings have important practical and financial implications for workplaces considering interventions to reduce sitting time among staff.

Acknowledgements

The authors would like to thank all participating UQ units, their management, and study participants. Further, we would like to acknowledge UQ's Deputy Director OH&S Division, Kris Fraser, who provided consultation on the use of the workstations in line with the university's OHS guidelines. Finally, the authors thank Dr Elisabeth Winkler for her support regarding data processing and statistical analyses.

References

1. Gerr F, Marcus M, Ensor C, Kleinbaum D, Cohen S, Edwards A, et al. A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. Am J Ind Med 2002;41(4):221-35.

2. Wilmot EG, Edwardson CL, Achana FA, Davies MJ, Gorely T, Gray LJ, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia 2012;14:14.

3. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults: A systematic review of longitudinal studies, 1996-2011. Am J Prev Med 2011;41(2):207-215.

4. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Breaks in sedentary time - beneficial associations with metabolic risk. Diabetes Care 2008;31(4):661-666.

5. Alkhajah TA, Reeves MM, Eakin EG, Winkler EAH, Owen N, Healy GN. Sit-stand workstations: a pilot intervention to reduce office sitting time. Am J Prev Med 2012;43(3):298-303.

6. Thorp AA, Dunstan D, Clark B, Gardiner P, Healy GN, Keegel T. Stand Up Australia: sedentary behaviour in workers. Docklands, Victoria, Australia: Medibank Private Limited; 2009.

7. Ryan CG, Grant PM, Dall PM, Granat MH. Sitting patterns at work: objective measurement of adherence to current recommendations. Ergonomics 2011;54(6):531-538.

8. Evans RE, Fawole HO, Sheriff SA, Dall PM, Grant M, Ryan CG. Point-of-choice prompts to reduce sitting time at work: a randomized trial. Am J Prev Med 2012;43(3):293-297.

490 9. Thorp AA, Healy GN, Winkler E, Clark BK, Gardiner PA, Owen N, et al. Prolonged
491 sedentary time and physical activity in workplace and non-work contexts: a cross-sectional
492 study of office, customer service and call centre employees. Int J Behav Nutr Phys Act
493 2012;9:128.
494 10. Owen N, Bauman A, Brown W. Too much sitting: a novel and important predictor of
495 chronic disease risk? Br J Sports Med 2009;43(2):81-83.
496 11. Nerhood HL, Thompson SW. Adjustable sit-stand workstations in the office. In:
497 Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting. Nashville,
498 Tennessee; 1994. p. 668-672.
499 12. Winkel J, Oxenburgh M. Towards optimizing physical activity in VDT/office work.
500 In: Sauter S, Dainoff M, Smith M, editors. Promoting health and productivity in the
501 computerized office. Bristol, PA, USA: Taylor & Francis / Hemisphere; 1991. p. 94-117.
502 13. Healy GN, Lawler S, Thorp A, Neuhaus M, Robinson E, Owen N, et al. Reducing
503 prolonged sitting in the workplace (An evidence review: full report). In. Melbourne,
504 Australia: Victorian Health Promotion Foundation; 2012.
505 14. Pronk NP, Katz AS, Lowry M, Payfer JR. Reducing Occupational Sitting Time and
506 Improving Worker Health: The Take-a-Stand Project, 2011. Prev Chronic Dis
507 2012;9(110323).
508 15. Hedge A. Effects of an electric height-adjustable worksurface on self-assessed
509 musculoskeletal discomfort and productivity in computer workers. Ithaca, NY: Cornell
510 University, Design & Environment Analysis; 2004.
511 16. Gilson ND, Suppini A, Ryde GC, Brown HE, Brown WJ. Does the use of standing
512 'hot' desks change sedentary work time in an open plan office? Prev Med 2012;54(1):65-67.
513 17. Ellegast R, Weber B, Mahlberg R. Method inventory for assessment of physical
514 activity at VDU workplaces. Work and Stress 2012;41:2355-2359.

515 18. Healy GN, Eakin EG, La Montagne AD, Owen N, Winkler E, Wiesner G, et al.
516 Reducing sitting time in office workers: short-term efficacy of a multicomponent
517 intervention. Prev Med 2013;57(1):43-48.
518 19. Straker L, Abbott RA, Heiden M, Mathiassen SE, Toomingas A. Sit-stand desks in
519 call centres: Associations of use and ergonomics awareness with sedentary behavior. Appl
520 Ergon 2013;44(4):517-22.
521 20. Wilks S, Mortimer M, Nylén P. The introduction of sit-stand worktables; aspects of
522 attitudes, compliance and satisfaction. Appl Ergon 2006;37:359-365.
523 21. LaMontagne AD, Noblet AJ, Landsbergis PA. Intervention development and
524 implementation: Understanding and addressing barriers to organisational-level interventions.
525 In: Biron C, Karanika-Murray M, Cooper CL, editors. Improving organisational interventions
526 for stress and well-being: Routledge; 2012.
527 22. Pronk NP, Kottke TE. Physical activity promotion as a strategic corporate priority to
528 improve worker health and business performance. Prev Med 2009;49(4):316-321.
529 23. Owen N, Sugiyama T, Eakin EE, Gardiner PA, Tremblay MS, Sallis JF. Adults'
530 sedentary behavior determinants and interventions. Am J Prev Med 2011;41(2):189-196.
531 24. Bandura A. Health promotion by social cognitive means. Health Education &
532 Behavior 2004;31(2):143-164.
533 25. Abraham C, Michie S. A taxonomy of behavior change techniques used in
534 interventions. Health Psychology 2008;27(3):379-387.
535 26. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined
536 taxonomy of behaviour change techniques to help people change their physical activity and
537 healthy eating behaviours: The CALO-RE taxonomy. Psychology & Health 2011:1-20.

538 27. The University of Queensland OSD. Computer Workstations: Design & Adjustment.
539 In: Queensland TUo, editor. http://www.uq.edu.au/ohs/ERGO/ERGO-CompWS-
540 Guideline.pdf: The University of Queensland; 2009.
541 28. Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity
542 monitor in the measurement of posture and motion during everyday activities. Br J Sports
543 Med 2006;40(12):992-7.
544 29. Ryan CG, Grant PM, Tigbe WW, Granat MH. The validity and reliability of a novel
545 activity monitor as a measure of walking. Br J Sports Med 2006;40(9):779-784.
546 30. Sundstrom E, Town JP, Rice RW, Osborn DP, Brill M. Office noise, satisfaction, and
547 performance. Environment and Behavior 1994;26(2):195-222.
548 31. Sanderson K, Tilse E, Nicholson J, Oldenburg B, Graves N. Which presenteeism
549 measures are more sensitive to depression and anxiety? J Affect Disord 2007;101(1-3):65-74.
550 32. Dickinson CE, Campion K, Foster AF, Newman SJ, Orourke AMT, Thomas PG.
551 Questionnaire development - an examination of the nordic musculoskeletal questionnaire.
552 Appl Ergon 1992;23(3):197-201.
553 33. Abdi H. The Bonferonni and Šidák Corrections for Multiple Comparisons. In: Salkind
554 NJ, editor. Encyclopedia of Measurement and Statistics. Thousand Oaks (CA): Sage; 2007. p.
555 103-107.
556 34. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in
557 logistic regression. Source Code Biol Med 2008;3:17-17.
558 35. Bendel RB, Afifi AA. Comparison of stopping rules in forward stepwise regression.
559 Amer Statist Assoc 1977;72(357):46-53.
560 36. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. Int J
561 Sports Physiol Perform 2006;1(1):50-57.

562 37. Dunstan DW, Kingwell BA, Larsen R, Healy GN, Cerin E, Hamilton MT, et al.
563 Breaking up prolonged sitting reduces postprandial glucose and insulin responses. Diabetes
564 Care 2012;35(5):976-983.
565 38. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and
566 cardio-metabolic biomarkers in US adults: NHANES 2003-06. Eur Heart J 2011;32(5):590-
567 597.
568 39. Thorp AA, Healy GN, Winkler E, Clark BK, Gardiner PA, Owen N, et al. Prolonged
569 sedentary time and physical activity in workplace and non-work contexts: a cross-sectional
570 study of office, customer service and call centre employees. International Journal of
571 Behavioral Nutrition and Physical Activity 2012;9.
572
573

Figure titles

Figure 1. Flow diagram of enrolment, participation, and analyses.

Figure 2. Self-monitoring sheet for participants in multi-component intervention group.

Figure 3. Extract from participant feedback sheet used in coaching sessions in multi-component intervention group.

Tables

Table 1. Intervention elements and timing of implementation

Intervention elements	***Timing***	**Intervention level**		
		Organizational	Environmental	Individual
	Week 1	Management consultation		
	Week 2	Staff information & brainstorming session; Manager email 1		Information booklet
	Week 3		Workstation provision	Coaching session & email summary
	Week 4	Manager email 2		Phone call 1
	Week 5			
	Week 6	Manager email 3		Phone call 2
	Week 7			
	Week 8	Manager email 4		
	Week 9			Phone call 3
	Week 10	Manager email 5		
	Week 11			
	Week 12	Manager email 6		
	Week 13	Manager email 7		Phone call 4

Table 2. Baseline characteristics by study group

	MC (n=16)	WO (n=14)	Comparison (n=14)	All (N=44)
Age in years	37.3 ± 10.7	43.0 ± 10.2	48 ±11.6	42.6 ± 11.5
Males	0% (0)	21.4% (3)	29% (4)	16% (7)
Caucasian	94% (15)	93% (13)	93% (13)	93% (41)
Married/ living together	81% (13)	71% (10)	64% (9)	73% (32)
Tertiary education	75% (12)	64% (9)	71% (10)	70% (31)
Tenure at workplace				
≤ 1 year	6% (1)	21% (3)	36% (5)	20% (9)
1 – 3 years	50% (8)	21% (3)	7% (1)	27% (12)
≥ 3 years	44% (7)	57% (8)	57% (8)	52% (23)
1.0 Full Time Equivalent	75% (12)	79% (11)	93% (13)	82% (36)
Staff Type				
Permanent	50% (8)	71% (10)	79% (11)	66% (29)
Contract	50% (8)	29% (4)	21% (3)	34% (15)
Job Category				
Managers/ professionals	38% (6)	71% (10)	57% (8)	55% (24)
Clerical/ service/ sales	63% (10)	29% (4)	43% (6)	46% (20)
Smoker	6% (1)	14% (2)	0% (0)	7% (3)
Body Mass Index, kg/m^2	25 ± 5.0	24 ± 3.7	28 ± 5.7	26 ± 5.1
History of high cholesterol	31% (5)	21% (3)	21% (3)	25% (11)
History of diabetes	0% (0)	0% (0)	7% (1)	2 % (1)
Activity Monitor Data	(n=16)	(n=14)	(n=13)[a]	(N=43)[a]
Time monitor worn at the workplace, hrs/day	8.1 (1.0)	8.0 (1.1)	7.9 (1.0)	8.0 (1.0)
Stand Up				
Standing time, mins/8-h workday	81 (40)	68 (30)	76 (35)	75 (35)
Sit-to-stand transitions, N/hour sitting[b]	5.1 (4.2, 6.3)	4.9 (3.4, 6.0)	4.2 (3.0, 5.2)	4.9 (3.6, 5.8)
Sit Less				
Sitting time, mins/8-h workday	366 (49)	373 (36)	365 (54)	368 (46)
Time accrued in prolonged sitting ≥30 mins, mins/8-h workday	159 (63)	186 (67)	200 (96)	180 (76)
Move More				
Stepping time, mins/8-h workday	34 (12)	39 (15)	40 (20)	37 (16)
MVPA MET mins, mins/8-h workday[b]	10 (4, 24)	9 (6, 20)	3 (2, 15)	7 (3, 22)
Steps, n/8-h workday	1548 (525)	1920 (568)	1789 (1015)	1742 (786)

Table presents means (standard deviations) or % (n) of group; mins/8-hr workday = mins at the workplace standardized to eight hours of work time; MC= Multi-component intervention group; WO= Workstations-only intervention group; [a] activity monitor data was missing for one participant; [b] non-normal outcomes reported as median (25th percentile, 75th percentile)

Table 3. Between-group differences at 3 months for sitting, standing and moving outcomes at the workplace

Measure	MC (n=12) vs. Comparison (n=13)		WO (n=13) vs. Comparison (n=13)		MC (n=12) vs. WO (n=13)		Overall-effect of arm
	Mean diff (95% CI)	p	Mean diff (95% CI)	p	Mean diff (95% CI)	p	p
Stand Up							
Standing time, mins/8-h workday	93 (45, 141)	<.001	35 (-12, 81)	.200	59 (10, 107)	.014	<.001
Sit-to-stand transitions, N/hour sitting[a]	RR = 1.11 (0.87, 1.40)	.636	RR = 1.15 (0.92, 1.45)	.320	RR = 0.96 (0.76, 1.22)	.963	.276
Sit Less							
Sitting time, mins/8-h workday (primary outcome)	-89 (-140, -38)	<.001	-33 (-84, 17)	.285	-56 (-107, -4)	.033	.001
Time accrued in prolonged sitting ≥30 mins, mins/8-h workday[b]	-31 (-79, 17)	.296	-15 (-59, 30)	.799	-17 (-63, 29)	.752	.274
Move More							
Stepping time, mins/8-h workday	-1 (-12, 10)	.997	-1 (-12, 9)	.988	1 (-10, 11)	.999	.956
MVPA MET mins/8-h workday[a]	RR = 1.06 (0.60, 1.90)	.991	RR = 1.00 (0.57, 1.75)	>.999	RR = 1.06 (0.61, 1.85)	.989	.951
Steps, n/8-h workday	-12 (-535, 512)	>.999	-74 (-584, 437)	.978	62 (-461, 585)	.988	.928

Mean change from baseline (95% Confidence Interval), adjusted for baseline value of outcome (ANCOVA); p-values and 95% CIs corrected for multiple comparisons (Sidak method); mins/8-hr workday = mins at the workplace standardized to eight hours of work time (i.e. standardized mins = mins * 8/ observed hours at the workplace); MC= Multi-component intervention group; WO= Workstations-only intervention group; [a] values reported are back-transformed from natural log scale; differences are interpreted as relative rates (RR), e.g. the back-transformed mean for the multi-component group divided by the back-transformed mean for the comparison group; [b] adjusted for full-time employment