

 Open access • Journal Article • DOI:10.1111/OBR.12201

## Reducing occupational sedentary time: A systematic review and meta-analysis of evidence on activity-permissive workstations — [Source link](#)

[Maïke Neuhaus](#), [Elizabeth G. Eakin](#), [Elizabeth G. Eakin](#), [Leon Straker](#) ...+6 more authors

**Institutions:** [University of Queensland](#), [Baker IDI Heart and Diabetes Institute](#), [Curtin University](#)

**Published on:** 01 Oct 2014 - [Obesity Reviews](#) (Wiley)

Related papers:

- [Sit-stand workstations: a pilot intervention to reduce office sitting time.](#)
- [Reducing sitting time in office workers: short-term efficacy of a multicomponent intervention.](#)
- [Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis](#)
- [Workplace interventions for reducing sitting at work](#)
- [Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults: A Systematic Review and Meta-analysis](#)

Share this paper:    

View more about this paper here: <https://typeset.io/papers/reducing-occupational-sedentary-time-a-systematic-review-and-2ofle2xrze>

This is an author-created, uncopyedited electronic version of an article accepted for publication in *Obesity Reviews*. Wiley, publisher of *Obesity Reviews*, is not responsible for any errors or omissions in this version of the manuscript or any version derived from it by third parties. The definitive publisher-authenticated version will be available in a future issue of *Obesity Reviews* in print and online at <http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291467-789X>

This is a link to the final published version of the paper on the journal's Web site: <http://onlinelibrary.wiley.com/doi/10.1111/obr.12201/abstract>

Title: Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations

Authors: Maike Neuhaus<sup>1</sup>, Elizabeth G. Eakin<sup>1,2</sup>, Leon Straker<sup>3</sup>, Neville Owen<sup>1,2,4,5</sup>, David W. Dunstan<sup>1,2,6,7</sup>, Natasha Reid<sup>1</sup>, Genevieve N. Healy<sup>1,2,3</sup>

<sup>1</sup> The University of Queensland, School of Population Health, Cancer Prevention Research Centre, Herston, Queensland, Australia

<sup>2</sup> Baker IDI Heart and Diabetes Institute, Melbourne, Victoria, Australia

<sup>3</sup> School of Physiotherapy, Curtin University, Perth, Western Australia, Australia

<sup>4</sup> The McCaughey Centre, School of Population Health, University of Melbourne, Melbourne, Australia

<sup>5</sup> Monash University, School of Public Health & Preventive Medicine, Melbourne, Australia

<sup>6</sup> Monash University, Epidemiology and Preventive Medicine, Melbourne, Australia

<sup>7</sup> The University of Western Australia, School of Sport Science, Exercise and Health, Perth, Australia

Keywords: active workstations, height-adjustable desks, workplace interventions, sedentary behavior

Running title: Reducing occupational sedentary time using activity-permissive workstations

Acknowledgements: Neuhaus was supported by an Australian Postgraduate Award and UQ School of Population Health Top-Up Scholarship. Eakin was supported by a National Health and Medical Research Council (NHMRC) Senior Research Fellowship [#511001]. Straker was supported by a NHMRC Senior Research Fellowship [#APP1019980]. Reid was supported by an Australian Postgraduate Award and UQ School of Population Health Top-Up Scholarship. Owen was supported by a NHMRC Program Grant [#569940], a NHMRC Senior Principal Research Fellowship [#1003960], and by the Victorian Government's Operational Infrastructure Program. Dunstan was supported by an Australian Research Council Future Fellowship [#FT100100918], and by the Victorian Health Promotion Foundation and the Victorian Government's Operational Infrastructure Program. Healy was supported by a NHMRC [# 569861] and Heart Foundation [PH 12B 7054] Fellowship. Eakin, Owen, Dunstan, and Healy were supported by a NHMRC Centre for Research Excellence Grant on Sitting Time and Chronic Disease Prevention – Measurement, Mechanisms and Interventions (APP1057608).

Corresponding author:

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; Email: m.neuhaus@uq.edu.au

Conflict of interest statement: Healy presented at an OERC (Office Ergonomics Research Committee) meeting in 2013. OERC covered travel and accommodation expenses and also provided an honorarium. Dunstan and Healy presented at the 'Juststand Wellness Summit', a conference organised by Ergotron, in 2012 and 2013 respectively. Ergotron covered travel and accommodation expenses. No further honoraria or imbursements were received. The funding bodies had no influence on the conduct or the findings of the study.

Summary (current word count: 207 words)

Excessive sedentary time is detrimentally linked to obesity, type 2 diabetes, cardiovascular disease and premature mortality. Studies have been investigating the use of activity-permissive workstations to reduce sedentary time in office workers, a highly sedentary target group. This review systematically summarises the evidence for activity-permissive workstations on sedentary time, health-risk biomarkers, work-performance, and feasibility indicators in office-workplaces.

In July 2013, a literature search identified 38 relevant peer-reviewed publications. Key findings were independently extracted by two researchers. The average intervention effect on sedentary time was calculated via meta-analysis.

In total, 984 participants across 19 field-based trials and 19 laboratory investigations were included, with sample sizes ranging from n=2 to n=66 per study. Sedentary time, health-risk biomarkers, and work performance indicators were reported in 13, 23, and 23 studies respectively. The pooled effect size from the meta-analysis was -77 minutes of sedentary time/8-hour workday (95% CI= -120, -35 minutes). Non-significant changes were reported for most health- and work-related outcomes. Studies with acceptability measures reported predominantly positive feedback.

Findings suggest that activity-permissive workstations can be effective to reduce occupational sedentary time, without compromising work performance. Larger and longer-term randomised-controlled trials are needed to understand the sustainability of the sedentary time reductions and their longer-term impacts on health- and work-related outcomes.

## Introduction

High volumes of sedentary time - time spent sitting or lying down while expending little energy<sup>1</sup> - are associated with excess adiposity and other aspects of chronic disease risk, particularly when the sedentary time is accumulated in prolonged unbroken bouts<sup>2-4</sup>. Much of the documentation of the detrimental health consequences of too much 'static sitting' originates from the field of ergonomics, with a focus on musculoskeletal outcomes<sup>5</sup>. More recently, the broader public health implications of excessive sedentary time have been examined in the context of chronic disease risk. Here, studies have documented detrimental associations with several indicators of poor health including obesity<sup>6</sup>, cardiovascular disease<sup>7</sup>, type 2 diabetes<sup>8</sup>, and some cancers<sup>9, 10</sup>, and with premature mortality<sup>11</sup>.

In industrialised countries, most working adults spend a high proportion of their waking hours in the workplace<sup>12</sup>, in increasingly sedentary occupations<sup>13</sup>. Using objective measures, it has been observed that white-collar workers sit for the majority of their work hours and often in long, unbroken bouts<sup>13-17</sup>. Accordingly, intervention studies conducted from both ergonomic and public-health perspectives have focused on reducing sedentary time in this occupational sector. Along with rapid advances in technology, office work increasingly involves (desk-based) computer work<sup>14</sup>. Many of the studies aiming to reduce workplace sedentary time have therefore used activity-permissive workstations. These include treadmill desks, stepping or pedal devices that are fitted underneath the desk, and height-adjustable workstations, which enable office workers to stand, walk, or pedal while working at their usual computer- and other desk-based job tasks. Overall, findings from both laboratory and field-based studies using such workstations suggest a range of positive benefits including reductions in workplace sedentary time<sup>18</sup>, lower body mass index<sup>19</sup>, and reduced musculoskeletal discomfort<sup>20</sup>. A recent (narrative) literature review concluded that workstations such as treadmill or pedal desks have the potential to elevate office workers'

energy expenditure by approximately 2-4 kcal/minute<sup>21</sup>. That review further reported that the use of activity-permissive workstations is generally well accepted among participants, with mixed impacts regarding work-performance measures. However, to date, the extant evidence has not been systematically summarised, in particular with regard to sedentary time, adiposity and other health-related outcomes.

The objective of our review was thus to systematically review the impact of activity-permissive workstations on office workers' sedentary time, adiposity and other health- and work-related outcomes; and, feasibility outcomes (acceptability to workers and potential adverse events).

## **Methods**

### *Definitions*

Sedentary behaviour is defined as any waking behaviour characterised by sitting or reclining while expending little energy ( $\leq 1.5$  metabolic equivalents)<sup>1</sup>. Given the considerable variation in sedentary behaviour terminology and the measurement methods thereof across the relevant publications, two overarching terms are used throughout this review: 'overall sedentary time' and 'workplace sedentary time'. Overall sedentary time refers to changes across the whole day (i.e. not just in the workplace) while 'workplace sedentary time' specifically refers to sedentary time occurring in the workplace. Notably, in two studies a direct measure of sedentary time was not available<sup>22, 23</sup>. Here, increases in activity (i.e. via the use of the workstations) were presumed to reflect reductions in workplace sedentary time.

The following workstations were regarded as activity-permissive: fixed standing desks (with or without provision of height-adjustable chairs), workstations adjustable to full standing height, treadmill desks, cycle ergometers, and pedal devices fitted underneath the desk that can be used while doing usual desk-based job tasks.

### *Inclusion and exclusion criteria*

Studies were included in this review if they: evaluated overall and/or workplace sedentary time, health-related (e.g., weight, musculoskeletal symptoms, blood risk markers), work-related (e.g., productivity, absenteeism), or feasibility outcomes (e.g., acceptability, adverse events) following the provision of an activity-permissive workstation; included an adult sample (aged  $\geq 18$  years); engaged in administrative (i.e. not manufacturing, but with reliance on engagement with a computer) tasks while using the activity-permissive workstations; reported at least two data collection points (i.e. baseline and follow-up); and, were published in an English-language peer-reviewed journal. As much of the documentation from the ergonomics research field is published in conference proceeding papers only, relevant studies published in peer-reviewed conference proceedings papers were also included.

### *Search strategy*

The following databases were searched on 18<sup>th</sup> July 2013: Web of Knowledge, Medline (through PubMed), Embase, CINAHL, SPORTDiscus, CENTRAL, Scopus, PsychInfo, and AMED. An initial search was divided into two categories, separated by the Boolean phrase ‘AND’: (i) activity-permissive workstations (e.g., treadmills, height-adjustable desks), and (ii) workplace settings (e.g., workplace, office). There was no limiter on publication years. This search resulted in a total of 1655 peer-reviewed publications. A second search was run to identify any papers related to workplace sedentary time that did not mention activity-permissive workstations specifically in the abstract and/or title. This search contained two clusters pertaining to sedentary time occurring in the workplace (e.g., office sitting, sedentary workplace) and the study design (e.g., intervention, study). A summary of the search strategy is provided in Supplementary Table 1.

### *Study selection and data extraction*

The study selection process is shown in Figure 1. The search identified a total of 4633 publications, of which 2707 were initially excluded for being duplicates (n=2309), not being peer-reviewed (n=159), and for being published in a language other than English (n=239). This step was conducted by MN. Consecutively, NR and MN independently excluded irrelevant publications by screening titles and/or abstracts. This resulted in n=78 unique publications remaining, which were screened in full text by MN and GNH independently, with an agreement regarding inclusion of 96% (calculated as studies agreed upon/studies screened in full text). Any disagreements (n=2) were resolved through discussion.

\*\*\* *INSERT FIGURE 1 ABOUT HERE* \*\*\*

#### *Outcomes included in the review*

Overall and workplace sedentary time: as defined above. If both subjective and objective measures of sedentary time were reported, objective measures were prioritised for the summary and meta-analysis in this review. Similarly, reported changes in workplace sedentary time were prioritised over overall sedentary time. Workplace sedentary time changes reported in percentage were standardised to an eight-hour work day (if not already done so in relevant publications). If studies included a further assessment in addition to a pre- and post-intervention assessment, the end-of-intervention outcomes are included in the main summary, with additional assessment outcomes reported separately.

Health-related outcomes: these included weight, waist circumference, blood-derived biomarkers, musculoskeletal symptoms, fatigue and other physiological measures reported. Given that the primary interest was in the implementation of activity-permissive workstations in real-world contexts, and the acknowledgement of a recently published review on the impact of such workstations on energy expenditure<sup>21</sup>, studies exclusively examining energy expenditure were not considered for inclusion.



Work-related outcomes: defined as work-performance (e.g., concentration or production levels), presenteeism, absenteeism, or cultural-organisational outcomes (e.g., time spent in face-to-face interactions).

Feasibility outcomes: any quantitative or qualitative employee ratings of the acceptability of the activity-permissive workstations as well as reported adverse events related to their use.

### *Quality assessment*

Study quality of the included publications was evaluated independently by MN and GNH using a published scoring system<sup>24</sup>. Quality assessment was based on eight criteria relating to the reporting of study methods (description of recruitment, participants, allocation, measures, sample size) and results (description of variance, confounding, detail of results) with answer categories being ‘yes’, ‘partial’, ‘no’, and not applicable (‘N/A’). The summary score was calculated as:  $\text{total sum} [( \text{number of “yes”} * 2 ) + ( \text{number of “partial”} * 1 )] / \text{total possible sum} [ 16 - ( \text{number of “N/A”} * 2 ) ]$ , with a maximum possible total score of 1. Inter-rater agreement was calculated as [proportion of quality scores given the same score by the reviewers/ all quality scores provided]. Any discrepancies between the assessors were resolved through discussion.

### *Meta-analysis*

Studies using a controlled design and reporting overall and/or workplace sedentary time were eligible for inclusion in the meta-analysis. Between-group changes in sedentary time following intervention were entered as changes in minutes during work hours and standardised to an eight-hour work day. The DerSimonian–Laird method was used to estimate the pooled effect of included studies<sup>25</sup>. Statistical heterogeneity was tested using the Eggers test<sup>26</sup>. The small number of studies included, along with high heterogeneity precluded

investigation of publication bias. All analyses were conducted using STATA 12 (StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP).

## **Results**

A total of 26 relevant publications were identified by the database search<sup>16, 18, 19, 22, 27-48</sup>. A search of the authors' personal libraries and reference lists of identified papers resulted in an additional twelve relevant publications (n=10<sup>20, 23, 49-56</sup> and n=2<sup>57, 58</sup>, respectively). Thus, this review included a total of 38 peer-reviewed publications meeting the inclusion criteria, reporting on 45 independent comparisons (i.e. comparison of one or more activity-permissive workstations with a control or usual practice comparator). Seven publications were peer-reviewed proceedings of conference papers<sup>31, 40, 42-44, 53, 55</sup>. All relevant data were extracted by GNH and MN independently and discussed in the event of disagreement. Corresponding authors of included publications were contacted to request any relevant data not reported in the published article (details were followed up for four publications).

### *Study and sample characteristics and range of outcomes assessed*

Table 1 provides a description of the included publications. Studies included a total of 984 participants across the 38 studies (one study did not report sample size), with an average sample size of 27 per study (range: 2-66). Twenty-three studies included samples of office workers. Other groups included 'adults' (not otherwise specified; n=7), students (n=5), 'university staff' (not otherwise specified; n=2), and medical practitioners (n=1).

Studies were conducted in North-America (n=23), Europe (n=4), Asia (n=3), and Australia (n=8). Half of the studies were laboratory-experimental, with the other half being field-based (i.e. conducted within the workplace setting). Across the 45 independent comparisons, 17 evaluated height-adjustable desks (of which twelve were fully adjustable desks and five were height-adjustable desk-mounts for the computer only), two evaluated standing desks with

height-adjustable chairs, eight evaluated standing desks without height-adjustable chairs, twelve evaluated treadmill desks, two evaluated pedal-devices, two evaluated cycle-ergometers, one evaluated a stepping device, while one study<sup>54</sup> evaluated both treadmills and cycle ergometers. Of the studies evaluating height-adjustable desks, only six (of 15) reported whether these were electric or operated via alternative mechanisms<sup>16, 18, 34, 43, 45, 56</sup>.

In the experimental studies, the duration of the workstation exposure protocols was typically short: <1 day (range 1 hour to 2 weeks). In the field studies, the mean intervention duration was 15 weeks (range: 1 day to 12 months). Three of the field studies included an additional follow-up assessment taken at 3 months<sup>18</sup>, 9 months<sup>37</sup>, and 12 months<sup>38</sup> post baseline. Twelve field studies implemented strategies in addition to the installation of activity-permissive workstations (e.g., instructions to stand for certain durations during the day; provision of pedometers; and/or motivational messages to increase physical activity/ reduce sedentary time)<sup>16, 18-20, 22, 33, 42, 43, 45, 54, 56</sup>.

Sedentary time was reported in 13 studies (across 14 independent comparisons). These were reported as overall sedentary time (n=3), workplace sedentary time (n=6), or both (n=5).

Health-related outcomes were reported in 23 studies. These included musculoskeletal symptoms (including body part discomfort, muscle load, spinal shrinkage, and bone mineral density), cardio-metabolic biomarkers (weight, body mass index, waist circumference, body composition, and blood profile), fatigue, psychological well-being (stress, emotional well-being, mood, and nervousity), leg/foot swelling, and other (eye strain, headache, digestion problems, sleep problems, physical well-being). Work-related outcomes were reported for 23 studies. Due to overlap in the terminology across included publications, for the purpose of this review, most work-related outcomes were summarised as a compound-category of 'work-performance'. This included reports of cognitive performance (e.g., selective attention), attention control/ concentration, accuracy, maths and reading comprehension,

short-term auditory verbal memory, work pace, work-performance, production levels, typing performance, and productivity. Three other work-related outcome categories were separately summarised as absenteeism, presenteeism, and cultural-organisational (quality of interactions with co-workers, perceived group interaction, and time spent in face-to-face interaction with co-workers). Feasibility outcomes were reported for 19 studies. These included acceptability (including preference, tolerance, and enjoyment) and adverse events.

Study quality scores ranged from 0.21 to 1 (Table 1 and Supplementary Table 2), with an inter-rater agreement of 96%. On average, most studies provided an adequate description of the study participants (0.84), measurement methods used (0.80), and results (0.93). However, group allocation procedures, sample size calculations, and methods to control for confounding were less well reported and were only rated a 'yes' by four, eight, and four studies respectively.

\*\*\**INSERT TABLE 1 ABOUT HERE*\*\*\*

### *Sedentary time outcomes*

Of the 14 comparisons reporting sedentary time at both baseline and follow-up, eleven used objective methods (n=5 ActivPAL [a thigh-worn activity monitor that derives sedentary time from both posture and motion]<sup>16, 18, 37, 44, 56</sup>; n=2 hip-worn accelerometer [sedentary time derived from motion only]<sup>38, 54</sup>; n=1 wrist-worn accelerometer [sedentary time derived from motion only]<sup>33</sup>; n=2 software linked to workstation<sup>22, 23</sup>; and, n=1 CUELA system [consisting of seven inertial accelerometers and gyroscopes placed on the back, arms, and legs]<sup>19</sup>) and three used self-report measures (n=1 'Occupational Sitting and Physical Activity Questionnaire'<sup>34</sup>, n=1 questionnaire about work patterns [not further specified]<sup>55</sup>, and n=1 experience sampling methodology and participants' estimates of time spent sitting per day<sup>45</sup>). A significant intervention effect for sedentary time was reported in 11/14

comparisons with an average reduction in workplace sedentary time of 90 minutes per 8-hour workday (range: -8 to -143 minutes; n=8) and in overall sedentary time of 111 minutes per day (range: -59 to -182 minutes; n=3). One study reported a reduction of workplace sedentary time through the use of portable pedal exercise machines on 12/20 days for 23 minutes each day (no further data regarding statistical significance or average workplace sedentary time reduction across the 20 days were available)<sup>22</sup>. One study, using manually height-adjustable desk mounts, reported a (non-significant) reduction in workplace sedentary time of 33 minutes/8-hour workday (95% CI= -74, 7 minutes, p=0.285)<sup>56</sup>. One study reported no change in workplace sedentary time following installation of height-adjustable ('hot') desks<sup>33</sup>.

Eight independent comparisons (derived from seven studies) were suitable for inclusion in the meta-analysis, with all of them reporting workplace sedentary time<sup>16, 18, 19, 22, 45, 54, 56</sup>. The observed pooled effect size on workplace sedentary time was -77 minutes per 8-hour workday (95% CI= -120, -35 minutes). Heterogeneity was high and statistically significant ( $I^2= 91%$ ,  $p<0.001$ ; Supplementary Figure).

Of the three studies including an additional assessment of sedentary time, all reported sedentary time occurring during work hours<sup>18, 37, 38</sup>. One reported average workplace sedentary time reductions of 143 minutes per workday from baseline to 1 week (95% CI= -184, -102;  $p<0.001$ ), and of 137 minutes per workday (95% CI= -179, -95;  $p<0.001$ ) from baseline to 3 months<sup>18</sup>. While the other two studies reported somewhat attenuated intervention effects at the additional follow-up, they also observed statistically significant workplace sedentary time reductions: One study reported reductions of 182 minutes from baseline to 3 months and of 88 minutes from baseline to 9 months<sup>37</sup>; and the other one reported -91 minutes from baseline to 6 months and -42 minutes from baseline to 12 months<sup>38</sup>.

### *Adiposity and other health- and work-related outcomes*

Table 2 shows a summary of the findings for the health- and work-related outcomes. Twenty-three studies included measures of health across a total of 239 outcomes. For the majority of outcomes, no significant change was observed. Notable improvements were seen for waist circumference and psychological wellbeing in 5/6 and 12/15 studies, respectively. Worsening of outcomes was observed in two (of ten) health-related outcome categories: musculoskeletal outcomes and leg/foot swelling. Musculoskeletal outcomes worsened in 16/122 outcome reports among 6/17 studies, of which two used standing desks without height-adjustable chairs, three used standing desks with height-adjustable chairs, and one used height-adjustable desks. An increase in leg circumference was observed in 1/5 leg/foot swelling outcomes, with standing desks without height-adjustable chairs being used in this study. Twenty-three studies reported work-related outcomes across a total of 112 outcomes. The majority of work-performance outcomes (84/112) remained unchanged following installation of activity-permissive workstations. Deleterious impacts were observed in 21/99 work-performance outcomes across 7/23 studies, of which six used treadmill desks and one cycle ergometers.

\*\*\* *INSERT TABLE 2 ABOUT HERE* \*\*\*

### *Feasibility outcomes*

Nineteen studies reported on the feasibility of activity-permissive workstations in the workplace setting. Due to the typically qualitative nature of the measures used, it was not possible to summarise them numerically. However, studies reported overall positive feedback from participants, with only 1/19 studies specifically reporting less ‘liking’ of standing posture when compared to sitting<sup>49</sup>. Three studies reported negative feedback from participants regarding the workstation design<sup>16, 18, 56</sup>. Seven 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 pain<sup>56</sup> and one study reporting leg discomfort in three participants<sup>46</sup>. One study qualitatively examined the acceptability and usability of height-adjustable desks in the workplace as a main outcome and reported high acceptability feedback from participants<sup>34</sup>. In this study, the use of activity-permissive workstations was strongly driven by perceived health benefits and improved productivity and suggestions for successful implementation and continued use were given (e.g., re-arrangement of surrounding office furniture to standing height, and use of electric rather than wind-up mechanisms for height-adjustable desks).

## **Discussion**

This is the first systematic literature review and meta-analysis to collate the evidence on the impact of activity-permissive workstations on office workers' sedentary time, health- and work-related outcomes, and their feasibility in office-based settings. It builds on an earlier narrative review that specifically focused on the potential of such workstations to increase energy expenditure, and on their use and acceptability among office workers<sup>21</sup>. Our findings suggest that the installation of such workstations can lead to substantial reductions in sedentary time without impacting negatively on work-related outcomes; and, that they are acceptable to workers. As many of the findings regarding adiposity and other health-related outcomes were based on evidence from short-term studies with weak-to-moderate designs and/or insufficient statistical power, the impact of activity permissive workstations on health-related parameters is at this point inconclusive and warrants further attention. While only three studies included an additional assessment of workplace sedentary time (i.e. 3-12 months), all of these studies observed sustained behaviour change suggesting the potential for long-term benefits.

The pooled intervention effect on workplace sedentary time of -77 minutes per 8-hour workday across studies included in the meta-analysis is markedly higher than what has been observed in intervention studies without an environmental support element (ranging from -21 minutes/8-hour workday,  $p=0.084^{22}$  to -48 minutes/ 16-hour waking day,  $p<0.05^{22}$ )<sup>59-61</sup>.

Furthermore, the intervention effect seen in this review may be clinically relevant, with a recent meta-analysis reporting that the risk of all-cause mortality increased by 5% for each 1-hour increment in daily sitting time per day for adults who sit seven or more hours per day<sup>11</sup>. However, our findings should be interpreted with caution, given the methodological quality and sample size issues in many of the studies included in this review.

Strikingly few detrimental effects on health-related outcomes were reported across included studies and only in those with a short duration (i.e. <12 weeks), suggesting that the use of activity-permissive workstations is unlikely to cause harm in the workplace. However, as few of the studies included were sufficiently powered to detect changes in health-related outcomes<sup>16</sup>, this finding should be interpreted with caution. Predominantly positive findings were observed on psychological wellbeing and waist circumference. The positive impact on psychological wellbeing is consistent with findings from epidemiological studies showing an association of sedentary time with lowered mood and depression<sup>62, 63</sup>. Whether this is mediated through increased perceived behavioural control (i.e. self-control in relation to work posture without being constrained to the chair) as suggested by occupational health psychology literature<sup>64</sup>, remains to be examined. The reduction in waist circumference observed across several studies is consistent with epidemiological findings showing beneficial associations of breaks in sedentary time (i.e. regular postural transitions) with waist circumference<sup>65</sup>, and may be the result of higher skeletal muscle activation of the postural muscles through more frequent postural changes and higher volumes of standing time<sup>66-68</sup>. However, the evidence is still limited and more studies are needed to confirm these results.



Worsening of health-related outcomes was only observed in 2/10 categories (musculoskeletal symptoms and leg swelling). Notably, increases in musculoskeletal symptoms were predominantly observed in studies using standing (i.e. not height-adjustable) desks. While the amount of standing time, (as well as the pattern of time spent sitting, standing, and moving throughout the working day) may be an important predictor of these or other adverse health outcomes<sup>69, 70</sup>, none of the studies included in this review reported such information in detail. Furthermore, whilst provision of standing desks without access to a seated workstation enables office workers to decrease their workplace sedentary time, it is likely to result in increased discomfort as a result of the absence of postural variety opportunities<sup>71, 72</sup>. Standing-only workstations also do not conform to ergonomic recommendations encouraging postural variety through regular and frequent postural changes<sup>14, 73</sup>. Overall, to fully understand the impact of activity-permissive workstations and associated sedentary time reductions on health-related outcomes, larger-scale randomised controlled trials are needed<sup>74</sup>.

Intervention effects were also statistically non-significant for the majority of work-related outcomes. However, our review findings suggest that the use of treadmill desks or cycle ergometers during work time may lead to some decreases in work-performance: Of the 112 work-related outcomes that were measured, 21 worsened. Of these, 16 were reported in studies using treadmill desks<sup>36, 41, 46, 48, 51</sup>, with the other five reported in studies using cycle ergometers<sup>46, 53</sup>.. A recent study suggested that a certain acclimatisation period may be necessary for the improvement of work-performance parameters when such activity-permissive workstations are used<sup>75</sup>. Notably, the studies reporting worsening of work-related outcomes were all of acute duration of either one<sup>41, 46, 51, 53</sup> or two days<sup>36, 48</sup>. Future studies using a longer-term follow-up should examine if a longer acclimatisation period will lead to an offset of these negative impacts.

Half of the studies included in our review assessed at least some aspect regarding the feasibility of the implementation of activity-permissive workstations in office-based workplaces, with predominantly positive feedback from participants reported. However, some studies identified some negative feedback from participants on aspects of workstation design, suggesting that a range of workstation models should be considered and tailored to individual needs and work tasks. In relation to this, it is notable that only a minority of included publications reported on the mechanisms (i.e. electric vs. non-electric) of the height-adjustable workstations used, or the time it takes to adjust their height.

Longer-term maintenance of health behaviour change has been challenging in the context of other prevalent health risk behaviours such as physical activity and diet and still not consistently measured and reported<sup>76</sup>. In this review, we identified only three studies in which an additional assessment of workplace sedentary time was included, beyond an initial intervention period. Extended follow-up (i.e. >1 year) in future studies will further enable evaluation of the impact of activity-permissive workstations on longer-term outcomes such as cardio-metabolic disorders, and productivity (including absenteeism and presenteeism), some of which are outcomes particularly relevant for informing the business case for their use.

The main strengths of this review include the extensive and cross-disciplinary literature search, the systematic summary of sedentary, health-related, work-related, and feasibility outcomes across several hundred outcome measures; and, the meta-analysis of sedentary time outcomes. However, when interpreting the results, the following limitations should be considered: 1) Non-English publications were excluded from review; the search was limited to peer-reviewed publications. 2) Twelve of 38 included publications were identified through the authors' libraries and cross-references rather than the database search. This speaks to the multi-disciplinary nature of the field and of the diverse and inconsistent use of terminology.

While an extensive search strategy was applied to address this challenge, other relevant

studies may have been missed. 3) Some relevant evidence is likely to exist in the grey literature (e.g., business reports<sup>77</sup>) and whilst not peer-reviewed, such evidence could provide further useful insights particularly into work-related and feasibility outcomes. 4) As most work-related outcomes were summarised as a compound category of ‘work-performance’, potential differences between aggregated outcomes may have been missed. 5) While four studies received the maximum quality score, the list of quality scoring categories was not comprehensive and items such as duration of follow up and generalisability of the study results were not explicitly scored. 6) As per inclusion criterion, all participants of included studies had to be engaged in administrative (i.e. not manufacturing, but with reliance on engagement with a computer) tasks while using the activity-permissive workstations. However, the work tasks performed may have slightly differed between laboratory-based studies (e.g., fine-motor skills test) and field studies (i.e. ‘typical’ administrative tasks), which may have influenced sedentary time as well as other outcomes. 7) Finally, as most work-related outcomes were summarised as a compound category of ‘work-performance’, potential differences between aggregated outcomes may have been missed.

Based on the findings from this review, the following recommendations are provided for future studies. 1) In relation to the second limitation above, the use of common terminology for the reporting of outcomes is needed to facilitate comparability of future studies. 2) Most studies including sedentary time measures reported on reductions in total sedentary time only. However, the pattern through which sedentary time is accrued throughout the day (i.e. through multiple smaller bouts and frequent posture changes) is also important for health-related outcomes<sup>4, 78</sup> and should be reported in future studies. 3) Larger-scale randomised controlled trials with long-term follow up ( $\geq 1$  year) assessments are needed to fully understand potential long-term impacts of activity-permissive workstations and related reductions in sedentary time on health-related and work-related outcomes. 4) Finally, a

number of different workstation types were included in this review, with models varying in both functionality and cost. Considering that the incorporation of activity-permissive workstations is likely to depend on both office design and work tasks undertaken, it is important for future studies to describe details on the make, model, target population, and typical work tasks conducted during workstation use.

## Conclusion

The installation of activity-permissive workstations in office-based workplaces is likely to be a feasible and acceptable means to reduce office workers' sedentary time, with mostly neutral or positive impacts on adiposity and other health- and work-related outcomes. Further intervention trials are required, particularly with more-rigorously controlled study designs, adequate statistical power, and longer term follow-ups to identify impacts on health-related outcomes as well as long-term maintenance of sedentary time reductions.

## References

- 1 Sedentary Behaviour Research Network. Letter to the editor: Standardized use of the terms “sedentary” and “sedentary behaviours”. *Applied Physiology, Nutrition, and Metabolism*. 2012; 37: 540–42.
- 2 Wilmot EG, Edwardson CL, Achana FA, *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. *American Journal of Preventive Medicine*. 2011; 41: 207-15.
- 4 Healy GN, Dunstan DW, Salmon J, *et al.* Breaks in sedentary time - beneficial associations with metabolic risk. *Diabetes Care*. 2008; 31: 661-66.
- 5 Gerr F, Marcus M, Ensor C, *et al.* A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. *American journal of industrial medicine*. 2002; 41: 221-35.
- 6 Chau JY, van der Ploeg HP, Merom D, Chey T, Bauman AE. Cross-sectional associations between occupational and leisure-time sitting, physical activity and obesity in working adults. *Preventive Medicine*. 2012; 54: 195-200.
- 7 Hu G, Tuomilehto J, Borodulin K, Jousilahti P. The joint associations of occupational, commuting, and leisure-time physical activity, and the Framingham risk score on the 10-year risk of coronary heart disease. *European Heart Journal*. 2007; 28: 492-98.
- 8 van Uffelen JGZ, Wong J, Chau JY, *et al.* Occupational sitting and health risks A systematic review. *American Journal of Preventive Medicine*. 2010; 39: 379-88.
- 9 Boyle T, Fritschi L, Heyworth J, Bull F. Long-term sedentary work and the risk of subsite-specific colorectal cancer. *American Journal of Epidemiology*. 2011; 173: 1183-91.
- 10 Zhang M, Xie X, Lee AH, Binns CW. Sedentary behaviours and epithelial ovarian cancer risk. *Cancer Causes & Control*. 2004; 15: 83-89.
- 11 Chau JY, Grunseit AC, Chey T, *et al.* Daily Sitting Time and All-Cause Mortality: A Meta-Analysis. *Plos One*. 2013; 8.
- 12 World Health Organization. Workers' health: global plan of action. WHO: Sixtieth World Health Assembly 2007.
- 13 Church TS, Thomas DM, Tudor-Locke C, *et al.* Trends over 5 Decades in US Occupation-Related Physical Activity and Their Associations with Obesity. *Plos One*. 2011; 6.
- 14 Straker L, Mathiassen SE. Increased physical work loads in modern work - a necessity for better health and performance? *Ergonomics*. 2009; 52: 1215-25.

- 15 Thorp AA, Healy GN, Winkler E, *et al.* Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. *Int J Behav Nutr Phys Act* 2012; 9: 128.
- 16 Healy GN, Eakin EG, LaMontagne AD, *et al.* Reducing sitting time in office workers: Short-term efficacy of a multicomponent intervention. *Preventive Medicine*. 2013; 57: 43-48.
- 17 Parry S, Straker L. The contribution of office work to sedentary behaviour associated risk. *Bmc Public Health*. 2013; 13.
- 18 Alkhajah TA, Reeves MM, Eakin EG, Winkler EA, Owen N, Healy GN. Sit-stand workstations: a pilot intervention to reduce office sitting time. *American journal of preventive medicine*. 2012; 43: 298-303.
- 19 Ellegast R, Weber B, Mahlberg R. Method inventory for assessment of physical activity at VDU workplaces. *Work and Stress*. 2012; 41: 2355-59.
- 20 Roelofs A, Straker L. The experience of musculoskeletal discomfort amongst bank tellers who just sit, just stand or sit and stand at work. *Ergonomics Journal of South Africa*. 2002; 14: 11-29.
- 21 Tudor-Locke C, Schuna JM, Jr., Frensham LJ, Proenca M. Changing the way we work: elevating energy expenditure with workstation alternatives. *International journal of obesity*. 2013.
- 22 Carr L, Walaska K, Marcus B. Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace. *British Journal of Sports Medicine*. 2011; 46: 430-5.
- 23 Carr LJ, Karvinen K, Peavler M, Smith R, Cangelosi K. Multicomponent intervention to reduce daily sedentary time: a randomised controlled trial. *British Medical Journal Open*. 2013; 3.
- 24 Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. Edmonton, Alberta, Canada 2004.
- 25 DerSimonian R, Laird N. Meta-analysis in clinical trials. *Controlled Clinical Trials*. 1986; 7: 177-88.
- 26 Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal*. 1997; 315.
- 27 Aaras A, Fostervold K, Ro O, Thoresen M, Larsen S. Postural load during VDU work: a comparison between various work postures. *Ergonomics*. 1997; 40: 1255-68.
- 28 Alderman BL, Olson RL, Mattina DM. Cognitive function during low intensity walking: A test of the treadmill workstation. *J Phys Act Health*. 2013.
- 29 Chester MR, Rys MJ, Konz SA. Leg swelling, comfort and fatigue when sitting, standing, and sit/standing. *International Journal of Industrial Ergonomics*. 2002; 29: 289-96.

- 30 Cox RH, Guth J, Siekemeyer L, Kellems B, Brehm SB, Ohlinger CM. Metabolic cost and speech quality while using an active workstation. *Journal of Physical Activity & Health*. 2011; 8: 332-39.
- 31 Davis KG, Kotowski SE, Sharma B, Herrmann D, Krishnan AP. Combating the effects of sedentary work: Postural variability reduces musculoskeletal discomfort. San Antonio, TX 2009; 884-86.
- 32 Ebara T, Kubo T, Inoue T, *et al.* Effects of adjustable sit-stand VDT workstations on workers' musculoskeletal discomfort, alertness and performance. *Industrial Health*. 2008; 46: 497-505.
- 33 Gilson ND, Suppini A, Ryde GC, Brown HE, Brown WJ. Does the use of standing 'hot' desks change sedentary work time in an open plan office? *Preventive Medicine*. 2012; 54: 65-67.
- 34 Grunseit AC, Chau JY, van der Ploeg HP, Bauman A. "Thinking on your feet": A qualitative evaluation of sit-stand desks in an Australian workplace. *BMC Public Health*. 2013; 13: 365.
- 35 Husemann B, Mach CY, Borsotto D, Zepf KI, Scharnbacher J. Comparisons of musculoskeletal complaints and data entry between a sitting and a sit-stand workstation paradigm. *Human factors*: 2009; 310-20.
- 36 John D, Bassett D, Thompson D, Fairbrother J, Baldwin D. Effect of using a treadmill workstation on performance of simulated office work tasks. *Journal of Physical Activity and Health*. 2009; 6: 617-24.
- 37 John D, Thompson DL, Raynor H, Bielak K, Rider B, Bassett DR. Treadmill workstations: A worksite physical activity intervention in overweight and obese office workers. *Journal of Physical Activity and Health*. 2011; 8: 1034-43.
- 38 Koepp GA, Manohar CU, McCrady-Spitzer SK, *et al.* Treadmill desks: A 1-year prospective trial. *Obesity*. 2013; 21: 705-11.
- 39 McAlpine DA, Manohar CU, McCrady SK, Hensrud D, Levine JA. An office-place stepping device to promote workplace physical activity. *British Journal of Sports Medicine*. 2007; 41: 903-07.
- 40 Nerhood HL, Thompson SW. Adjustable sit-stand workstations in the office. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting*. The Human Factors and Ergonomics Society: Nashville, Tennessee 1994; 668-72.
- 41 Ohlinger CM, Horn TS, Berg WP, Cox RH. The effect of active workstation use on measures of cognition, attention, and motor skill. *Journal of Physical Activity and Health*. 2011; 8: 119-25.
- 42 Paul RD. Foot swelling in VDT operators with sitting and sit-stand workstations. *Designing for the Global Village: Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting*. The Human Factors and Ergonomics Society: San Diego, California 1995b; 568-72.

- 43 Paul RD. Effects of office layout and sit-stand adjustable furniture: A field study. *Designing for the Global Village: Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting*. The Human Factors and Ergonomics Society: San Diego, California 1995a; 422-26.
- 44 Paul RD, Helander MG. Effect of sit-stand schedule on spinal shrinkage in VDT operators. *Designing for the Global Village: Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting*. The Human Factors and Ergonomics Society: San Diego, California 1995; 563-67.
- 45 Pronk NP, Katz AS, Lowry M, Payfer JR. Reducing occupational sitting time and improving worker health: The take-a-stand project, 2011. *Preventing Chronic Disease*. 2012; 9: 110323.
- 46 Straker L, Levine J, Campbell A. The effects of walking and cycling computer workstations on keyboard and mouse performance. *Human Factors*. 2009; 51: 831-44.
- 47 Thompson WG, Foster RC, Eide DS, Levine JA. Feasibility of a walking workstation to increase daily walking. *British Journal of Sports Medicine*. 2007; 42: 225-28.
- 48 Thompson WG, Levine JA. Productivity of transcriptionists using a treadmill desk. *Work (Reading, Mass)*. 2011; 40: 473-77.
- 49 Beers EA, Roemmich JN, Epstein LH, Horvath PJ. Increasing passive energy expenditure during clerical work. *European journal of applied physiology*. 2008; 103: 353-60.
- 50 Fidler JL, MacCarty RL, Swensen SJ, *et al*. Feasibility of using a walking workstation during CT image interpretation. *American College of Radiology*. 2008; 5: 1130-36.
- 51 Funk RE, Taylor ML, Creekmur CC, Ohlinger CM, Cox RH, Berg WP. Effect of walking speed on typing performance using an active workstation. *Perceptual and Motor Skills*. 2012; 115: 309-18.
- 52 Hasegawa T, Inoue K, Tsutsue O, Kumashiro M. Effects of a sit-stand schedule on a light repetitive task. *International Journal of Industrial Ergonomics*. 2001; 28: 219-24.
- 53 Koren K, Pisot R, Simunic B. Get fit at the office. *Journal of the 3rd International Scientific Conference on EXERCISE AND QUALITY OF LIFE*: Novi Sad (Serbia) 2013; 377-82.
- 54 Parry S, Straler L, Gilson ND, Smith AJ. Participatory workplace interventions can reduce sedentary time for office workers—A randomised controlled trial. *PLOS ONE*. 2013; 8: e78957.
- 55 Hedge A, Ray EJ. Effects of an electronic height-adjustable worksurface on computer worker musculoskeletal discomfort and productivity. *Proceedings of the Human Factors and Ergonomics Society*. 2004; 48: 1091-95.
- 56 Neuhaus M, Healy GN, Dunstan DW, Owen N, Eakin EG. Workplace sitting and height-adjustable workstations: a randomized controlled trial. *American Journal of Preventive Medicine*. 2014; 46: 30-40.



- 57 Edelson N, Danoff J. Walking on an electric treadmill while performing VDT office work. *Special Interest Group on Computer-Human Interaction Bulletin*. 1989; 21: 72-77.
- 58 Seo A, Kakehashi M, Tsuru S, Yoshinaga F. Leg swelling during continuous standing and sitting work without restricting leg movement. *Journal of Occupational Health*. 1996; 38: 186-89.
- 59 Verweij LM, Proper KI, Weel ANH, Hulshof CTJ, van Mechelen W. The application of an occupational health guideline reduces sedentary behaviour and increases fruit intake at work: results from an RCT. *Occupational and Environmental Medicine*. 2012; 69: 500-07.
- 60 Kozey-Keadle S, Libertine A, Staudenmayer J, Freedson P. The feasibility of reducing and measuring sedentary time among overweight, non-exercising office workers. *Journal of Obesity*. 2012; 2012: 282303.
- 61 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. *American Journal of Preventive Medicine*. 2012; 43: 293-97.
- 62 de Wit L, van Straten A, Lamers F, Cuijpers P, Penninx B. Are sedentary television watching and computer use behaviors associated with anxiety and depressive disorders? *Psychiatry Research*. 2011; 186: 239-43.
- 63 Teychenne M, Ball K, Salmon J. Sedentary behavior and depression among adults: A review. *International journal of behavioral medicine*. 2010; ahead of print.
- 64 Paynev N, Kinman G, Jones F. Work, stress and health behaviors. In: Houdmont J, Leka SS, R. (eds.). *Contemporary occupational health psychology*. Wiley-Blackwell: Chichester, West Sussex, UK 2012; 239-55.
- 65 Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011; 32: 590-7.
- 66 De Troyer A. Mechanical role of the abdominal muscles in relation to posture. *Respiration Physiology*. 1983; 53: 341-54.
- 67 Sheeran L, Sparkes V, Caterson B, Busse-Morris M, van Deursen R. Spinal position sense and trunk muscle activity during sitting and standing in nonspecific chronic low back pain. *Spine*. 2012; 37: E486–E95.
- 68 Roebroek ME, Doorenbosch CAM, Harlaar J, Jacobs R, Lankhorst GJ. Biomechanics and muscular-activity during sit-to-stand transfer. *Clinical Biomechanics*. 1994; 9: 235-44.
- 69 Thorp AA, Kingwell BA, Sethi P, Hammond L, Owen N, Dunstan DW. Alternating bouts of sitting and standing attenuates postprandial glucose responses. *Med Sci Sports Exerc*. 2014.
- 70 Buckley JP, Mellor DD, Morris M, Joseph F. Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occupational and environmental medicine*. 2014; 71: 109-11.

- 71 Hansen L, Winkel J, Jorgensen K. Significance of mat and shoe softness during prolonged work in upright position: based on measurements of low back muscle EMG, foot volume changes, discomfort and ground force reactions. *Applied Ergonomics*. 1998; 29: 217-24.
- 72 Gregory DE, Callaghan JP. Prolonged standing as a precursor for the development of low back discomfort: An investigation of possible mechanisms. *Gait & Posture*. 2008; 28: 86-92.
- 73 German Federal Institute for Occupational Safety and Health. Up and Down – Up and Down. How dynamic sitting and standing can improve health in the office. 2008.
- 74 Dunstan DW, Wiesner G, Eakin EG, *et al.* Reducing office workers' sitting time: rationale and study design for the Stand Up Victoria cluster randomized trial. *BMC Public Health*. 2013; 13: 1057.
- 75 Robertson MM, Ciriello VM, Garabet AM. Office ergonomics training and a sit-stand workstation: Effects on musculoskeletal and visual symptoms and performance of office workers. *Applied Ergonomics*. 2013; 44: 73-85.
- 76 Fjeldsoe B, Neuhaus M, Winkler E, Eakin E. Systematic Review of Maintenance of Behavior Change Following Physical Activity and Dietary Interventions. *Health Psychology*. 2011; 30: 99-109.
- 77 Healy GN, Lawler S, Thorp A, *et al.* Reducing prolonged sitting in the workplace, An evidence review: full report. *Creating Healthy Workplace evidence review series*. Victorian Health Promotion Foundation (VicHealth): Carlton, Australia 2012; 88.
- 78 Dunstan DW, Kingwell BA, Larsen R, *et al.* Breaking Up Prolonged Sitting Reduces Postprandial Glucose and Insulin Responses. *Diabetes Care*. 2012; 35: 976-83.

Figure 1. Study selection process

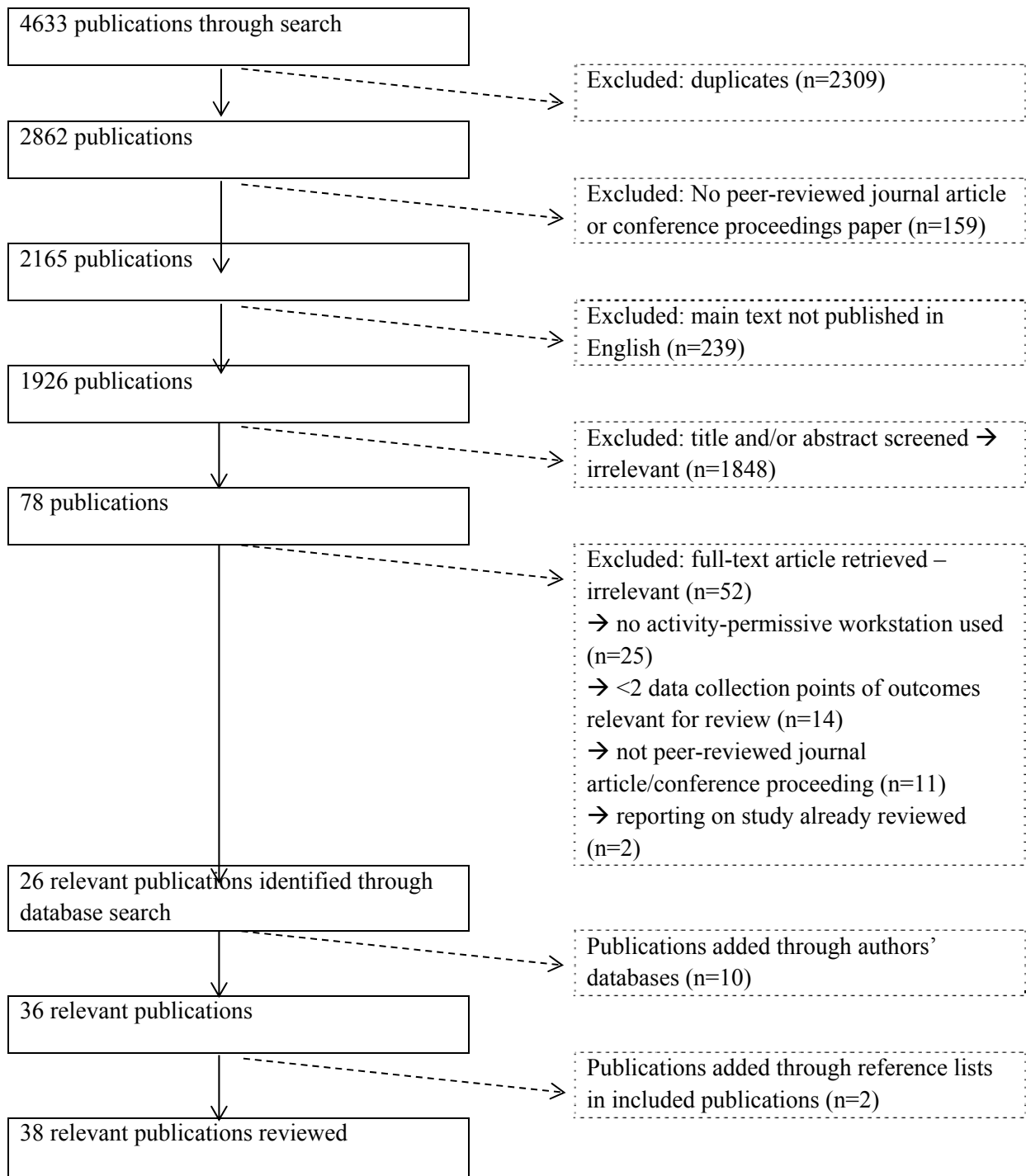


Table 1. Summary of included publications

| First author, year, country       | Sample (n; description; gender; age)   | APW, design, duration   | Overall findings   | Quality score (0-1) |
|-----------------------------------|--|---|--|---------------------|
| <i>Laboratory-based studies</i>   |  |   |  |                     |
| <sup>27</sup> Aaras, 1997; Norway | 20 experienced VDU workers aged 26-60 (15%F; mean age 52.5yrs)                   | Standing desks without access to height-adjustable chair; block-randomized; 1 day | <u>Sedentary</u> : NA<br><u>Health</u> : posture when using keyboard ns; muscle load when using keyboard ns; upper trapezius 10%le ns; lumbar erector spinae 10%le ns; 3x head flexion (10%le ns, 50%le ns, 90%le ns), 3x head side flexion (10%le ns, 50%le ns, 90%le ns); upper arm flexion 50%le +, upper arm abduction ns; low shoulder moment periods ns; back flexion ns; side flexion ns<br><u>Work</u> : work pace ns<br><u>Feasibility</u> : NA | 0.79                |
| <sup>28</sup> Alderman, 2013; USA | 66 students (59%F; 21.1yrs SD 1.6)   | Treadmill desks; cross-over; 2 days   | <u>Sedentary</u> : NA<br><u>Health</u> : NA<br><u>Work</u> : 2x cognitive performance: both ns; reading comprehension ns<br><u>Feasibility</u> : NA  | 0.86                |
| <sup>49</sup> Beers, 2008; USA    | 24 office workers (50%F: mean age 31.3yrs SD 9.1; 50%M: mean age 26.3yrs SD 6.2) | Standing desk without access to height-adjustable chair; cross-over; 1 day        | <u>Sedentary</u> : NA<br><u>Health</u> : musculoskeletal comfort -, fatigue +<br><u>Work</u> : work-performance ns<br><u>Feasibility</u> : choice -, liking -  | 0.83                |
| <sup>29</sup> Chester, 2002; USA  | 18 students (39%F; mean age 21.9yrs)   | Standing desk without access to height-adjustable chair; cross-over; 2 days       | <u>Sedentary</u> : NA<br><u>Health</u> : leg volume ns; leg circumference -; body comfort: upper back ns, lower back ns, hips -, upper legs -, knees -, lower legs -, ankles -, feet -; fatigue ns<br><u>Work</u> : NA<br><u>Feasibility</u> : NA  | 0.57                |
| <sup>30</sup> Cox, 2011; USA      | 31 adults (71%F; mean age 37yrs SD 2.5)  | Standing desk without access to height-adjustable chair; cross-over; 1 day        | <u>Sedentary</u> : NA<br><u>Health</u> : NA<br><u>Work</u> : 2x speech quality both ns<br><u>Feasibility</u> : NA  | 0.63                |
| <sup>30</sup> Cox,                | 31 adults (71%F;   | Treadmill desk; cross-  | <u>Sedentary</u> : NA  | 0.63                |

|   |   |  |  |               |
|---|---|--|--|---------------|
| 2011;<br>USA <sup>†</sup>                         | mean age 37yrs SD<br>2.5)   | over; 1 day  | <u>Health</u> : NA<br><u>Work</u> : 2x speech quality both ns<br><u>Feasibility</u> : NA   | -----         |
| <sup>31</sup> Davis,<br>2009;<br>USA              | 35 call centre<br>employees (77%F)  | HAD; pre-post; 2 weeks   | <u>Sedentary</u> : NA<br><u>Health</u> : body discomfort: overall ns, shoulders ns, hands and wrists +, upper<br>back ns, lower back +<br><u>Work</u> : work-performance: average number of calls/hour ns, average time until<br>call is answered ns, average time unavailable for calls ns<br><u>Feasibility</u> : NA       | 0.64          |
| <sup>31</sup> Davis,<br>2009;<br>USA <sup>†</sup> | 35 call centre<br>employees (77%F)  | HAD (plus software<br>reminder); pre-post; 2<br>weeks                              | <u>Sedentary</u> : NA<br><u>Health</u> : body discomfort: overall +, shoulders +, hands and wrists +, upper back<br>+, lower back +<br><u>Work</u> : work-performance: average number of calls/hour +, average time until<br>call is answered ns, average time unavailable for calls ns<br><u>Feasibility</u> : NA           | 0.64          |
| <sup>32</sup> Ebara,<br>2008;<br>Japan            | 24 adults aged 20-<br>29yrs and 60-69yrs<br>(50%F; mean age<br>21.2yrs SD 1.1 and<br>62.7yrs SD1.6) | Standing desk with<br>access to height-<br>adjustable chair; cross-<br>over; 1 day | <u>Sedentary</u> : NA<br><u>Health</u> : body discomfort: right forearm -, right wrist/hand -, both lower legs -,<br>neck both sides ns, shoulders ns, left forearm ns, left wrist/hand ns, upper and<br>lower back ns, hip/thighs both sides ns; fatigue ns<br><u>Work</u> : work-performance ns<br><u>Feasibility</u> : NA | 0.86          |
| <sup>57</sup> Edelson<br>, 1989;<br>USA           | 5 adults with<br>minimum typing<br>speed of 50 word/min<br>(80%F; mean age<br>26yrs)                | Treadmill desk; cross-<br>over; 2 weeks  | <u>Sedentary</u> : NA<br><u>Health</u> : stress +, body complaints ns<br><u>Work</u> : work-performance ns<br><u>Feasibility</u> : NA  | 0.64          |
| <sup>51</sup> Funk,<br>2012;<br>USA               | 24 university students<br>and staff (63%F;<br>mean age 23.2yrs SD<br>3.2)                           | Treadmill desk; cross-<br>over; 1 day  | <u>Sedentary</u> : NA<br><u>Health</u> : NA<br><u>Work</u> : typing performance: while walking at 1.3 km/hour -, while walking at<br>2.25 km/hour ns, while walking at 3.2 km/hour -<br><u>Feasibility</u> : NA  | 0.79          |
| <sup>52</sup> Hasega<br>wa,                       | 16 adults (0%F; aged<br>19-25yrs)   | Standing desk without<br>access to height-   | <u>Sedentary</u> : NA<br><u>Health</u> : fatigue: 2x dullness & drowsiness: + and ns, 2x body fatigue both ns  | -----<br>0.31 |

|   |   |   |  |                        |
|---|---|---|--|------------------------|
| 2001;<br>Japan                                    |   | adjustable chair; cross-over; 1 day                             | <u>Work:</u> Work-performance: 2x mental concentration: + and ns, 2x work load: + and ns, 2x error rate: + and ns; 2x miss rate both ns; 2x working motivation both ns<br><u>Feasibility:</u> NA   | -----                  |
| <sup>35</sup> Husemann, 2009;<br>Germany          | 60 students aged 18-35yrs (100%F; IG mean age 25.1yrs SD2.7; KG mean age 24.7yrs SD3.8) | HAD; RCT; 5 days  | <u>Sedentary:</u> NA<br><u>Health:</u> physical well-being +, psychological well-being ns<br><u>Work:</u> work-performance ns<br><u>Feasibility:</u> NA  | 0.69                   |
| <sup>36</sup> John, 2009;<br>USA                  | 20 students (45%F; mean age 26.4yrs SD4.0)  | Treadmill desks; cross-over; 2 days                             | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: mouse clicking test -, drag-and-drop test -, typing speed -, math -, selective attention ns, processing speed ns, reading comprehension ns<br><u>Feasibility:</u> NA | 0.79                   |
| <sup>53</sup> Koren, 2013;<br>Slovenia            | 13 office workers (100%F; mean age 30.6yrs SD3.8)                                       | Cycle-ergometer; cross-over; 1 day                              | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: typing speed -, typing errors ns<br><u>Feasibility:</u> preference +   | 0.67                   |
| <sup>39</sup> McAlpine, 2007;<br>USA              | 19 'sedentary' adults (42%F; mean age 27yrs SD9)  | Stepping device; pre-post; 1 day                                | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> NA<br><u>Feasibility:</u> adverse events: none, tolerance +  | 0.75                   |
| <sup>41</sup> Ohlinger, 2011;<br>USA              | 50 university staff (mean age 43.2yrs SD9.3)  | HAD; cross-over; 1 day  | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: fine motor ns, 2x cognitive performance both ns<br><u>Feasibility:</u> NA  | 0.83                   |
| <sup>41</sup> Ohlinger, 2011;<br>USA <sup>†</sup> | 50 university staff (mean age 43.2yrs SD9.3)  | Treadmill desk; cross-over; 1 day                               | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: fine motor -, 2x cognitive performance both ns<br><u>Feasibility:</u> NA   | 0.83                   |
| <sup>58</sup> Seo, 1996;<br>Japan                 | 12 adults (33%F; mean age 24.1yrs SD1.2)  | Standing desk without access to height-adjustable chair; cross- | <u>Sedentary:</u> NA<br><u>Health:</u> musculoskeletal symptoms: leg swelling +, lower leg dullness -, low back pain ns, whole body fatigue -  | -----<br>0.75<br>----- |

|   |  |   |  |      |
|---|--|---|--|------|
|   |  | over; 1 day   | <u>Work:</u> NA<br><u>Feasibility:</u> NA  |      |
| <sup>46</sup> Straker, 2009; Australia              | 30 office workers (53%F aged 22-64yrs) | Standing desk without access to height-adjustable chair; cross-over; 1 day          | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: typing speed ns, typing errors ns; mouse pointing speed ns; mouse pointing errors ns; combined keyboard and mouse task speed ns; combined keyboard and mouse task errors ns<br><u>Feasibility:</u> user perception + (83% of participants thought it was feasible); adverse events: 3 reports of leg discomfort  | 0.93 |
| <sup>46</sup> Straker, 2009; Australia <sup>†</sup> | 30 office workers (53%F aged 22-64yrs) | Treadmill desks with participants walking at 1.6km/h and 3.2km/h; cross-over; 1 day | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: typing speed - (in both conditions), typing errors ns (in both conditions); mouse pointing speed - (in both conditions); mouse pointing errors - (in both conditions); combined keyboard and mouse task speed - (in both conditions); combined keyboard and mouse task errors ns (in both conditions)<br><u>Feasibility:</u> user perception: 50% of participants thought it was feasible; adverse events: 3 reports of dizziness, 2 reports of discomfort, 2 reports of leg discomfort  | 0.93 |
| <sup>46</sup> Straker, 2009; Australia <sup>†</sup> | 30 office workers (53%F aged 22-64yrs) | Cycle ergometers with participants cycling at 5 and 30 watts; cross-over; 1 day     | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: typing speed – (when cycling at 5 watts) and ns (when cycling at 30 watts), typing errors ns (in both conditions); mouse pointing speed - (in both conditions); mouse pointing errors ns (when cycling at 5 watts) and – (when cycling at 30 watts); combined keyboard and mouse task speed ns (in both conditions); combined keyboard and mouse task errors ns (in both conditions)<br><u>Feasibility:</u> user perception: 63% of participants thought it was feasible; adverse events: 9 reports of hip or gluteal discomfort | 0.93 |
| <sup>48</sup> Thompson, 2011; USA                   | 11 medical transcriptionists           | Treadmill desks; cross-over; 2 days   | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance: tape completion ns, transcription errors ns, transcription time -, self-reported quality ns<br><u>Feasibility:</u> Preference for APW used 100%; 9/11 participants disagreed/  | 0.67 |

strongly disagreed that they were more tired using the APW; no one agreed that the workstation was too noisy; mixed feedback on productivity levels, no one agreed that the workstation interfered with work quality

*Field-based studies*

|   |  |  |   |      |
|---|--|--|---|------|
| <sup>18</sup> Alkhaja<br>h, 2012;<br>Australia<br>* | 32 office workers (18 IG: 94.4%F, mean age 33.5yrs SD 8.7; 14 CG: 85.7%F, mean age 39.9yrs SD 7.2) | HADM; CT; 3 months                             | <u>Sedentary (ActivPAL)</u> : 1 week: -143 minutes/8-hour workday (95% CI=- 184, -102); 3months: -137 minutes/8-hour workday (95% CI= -179, -95)<br><u>Health</u> : at 3 months: BMI ns; weight ns; body composition: fat-free mass ns, fat mass ns; waist ns; blood profile: total cholesterol ns, HDL +, triglycerides ns, glucose ns; fatigue ns, eye strain ns, headache ns, digestion ns, sleep problems ns, musculoskeletal symptoms ns<br><u>Work</u> : at 3 months: absenteeism ns, work-performance ns<br><u>Feasibility</u> : at 3 months: positive feedback on ease of use, comfortable, enjoyable; majority of participants agreed or strongly agreed that the workstations were easy to use (94%); enjoyable (94%); comfortable (83%); 83% disagreed/disagreed strongly that they would like rather return to their original workspace setup; some negative feedback on elements of workstation design | 1    |
| <sup>22</sup> Carr,<br>2011;<br>USA                 | 18 full-time office workers (88%F; mean age 40.2yrs SD 10.7)                                       | portable pedal machines; pre-post; 4 weeks     | <u>Sedentary (workstation software)</u> : participants pedalled on 12.2/20 days (SD 6.6) on average for 23.4 minutes (SD20.4)<br><u>Health</u> : NA<br><u>Work</u> : NA<br><u>Feasibility</u> : majority of participants reported positive feedback (i.e. median $\geq 4/5$ ) regarding preference, ease of use, comfort; no visual disturbance, no interference with work-tasks  | 0.83 |
| <sup>23</sup> Carr,<br>2013;<br>USA*                | 49 overweight and non-active uni staff working in desk-based jobs                                  | portable pedal machines; blinded RCT; 12 weeks | <u>Sedentary (workstation software)</u> : -58.7 minutes/day; participants pedalled for approx. 32 minutes in total on days they had access to pedal machines, with an average of 16 mins per pedalling bout<br><u>Health</u> : waist +; weight ns; BMI ns; blood profile: total cholesterol ns, HDL ns, LDL ns, triglycerides ns<br><u>Work</u> : NA<br><u>Feasibility</u> : Majority of participants (i.e. median $\geq 4/5$ ) rated the pedal machines as helpful in reducing their workplace sedentary time  | 1    |
| <sup>19</sup> Ellegast                              | 25 office workers  | HAD; RCT; 12 weeks                             | <u>Sedentary (CUELA)</u> : -80 minutes/8-hour workday (95%CI= -123, -37)  | 0.56 |



|   |  |  |   |      |
|---|--|--|---|------|
| , 2012;<br>Germany<br>*                         | (24%F)   |  | <u>Health:</u> BMI +, 2x emotional wellbeing both +, fatigue +, musculoskeletal health: maximum trunk strength: flexion ns, extension ns; muscle endurance: shoulders ns, back ns, abdomen ns<br><u>Work:</u> NA<br><u>Feasibility:</u> NA  |      |
| <sup>50</sup> Fidler,<br>2008;<br>USA           | 2 radiologists<br>(100%F)  | Treadmill desk; cross-<br>over; 8 months | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> work-performance +<br><u>Feasibility:</u> NA  | 0.75 |
| <sup>33</sup> Gilson,<br>2012;<br>Australia     | 11 office workers<br>(64%F; mean age<br>46.9yrs SD 9.8)                        | HAD (shared 4/11); pre-<br>post; 1 week  | <u>Sedentary (wrist-worn accelerometer):</u> ns<br><u>Health:</u> NA<br><u>Work:</u> NA<br><u>Feasibility:</u> NA   | 0.83 |
| <sup>34</sup> Grunse<br>t, 2013;<br>Australia   | 19 office workers<br>(53%F; 27-59yrs;<br>median age 46 yrs)                    | HAD; pre-post; 3<br>months               | <u>Sedentary (self-report):</u> -102 minutes during workplace time (95% CI= -192, -14)<br><u>Health:</u> NA<br><u>Work:</u> NA<br><u>Feasibility:</u> main outcome; overall high usability and acceptability  | 0.83 |
| <sup>16</sup> Healy,<br>2013;<br>Australia<br>* | 43 office workers<br>(56%F, mean age<br>43.2 yrs SD 10.3)                      | HADM; CCT; 4 weeks                       | <u>Sedentary (ActivPAL):</u> -125 minutes/8-hour workday (95% CI= -161, -89 minutes)<br><u>Health:</u> weight ns; body composition: fat mass ns, fat free mass ns; waist ns; blood profile: glucose +, cholesterol ns, triglycerides ns; fatigue ns, eye strain ns; headache ns; digestion ns; sleep problems ns; musculoskeletal symptoms ns<br><u>Work:</u> work-performance: overall ns, absenteeism ns, presenteeism ns<br><u>Feasibility:</u> no adverse outcomes                                    | 1    |
| <sup>55</sup> Hedge,<br>2004;<br>USA            | 33 office workers<br>(42%F; mean age<br>38.6yrs SD2.1 across<br>two companies) | HAD; RCT and cross-<br>over; 4-6 weeks   | <u>Sedentary (self-report):</u> -16.5% during work hours<br><u>Health:</u> 8x time-of-day and mean discomfort: home morning ns, start work ns, late morning ns, all other +; 28-item musculoskeletal symptoms scale: right eye ns, left neck ns, hip both sides ns, right thigh ns, both lower legs ns, both feet ns, both upper arms ns, left elbow ns, all other +<br><u>Work:</u> Productivity +<br><u>Feasibility:</u> workstation ratings: keyboard +, mouse +, chair +, workstation +; preference + | 0.5  |
| <sup>37</sup> John,                             | 12 overweight/ obese   | Treadmill desks; pre-                    | <u>Sedentary (ActivPAL):</u> 3 months: -182 minutes during total waking hours; 9  | 0.79 |

|   |  |                                       |  |      |
|---|--|---------------------------------------|--|------|
| 2011;<br>USA                                      | office workers<br>(58%F; mean age<br>46.2yrs SD9.2)                    | post; 9 months                        | months: -88 (from baseline) during total waking hours<br><u>Health</u> : 3 months: weight ns; BMI ns; waist +; body composition: body fat (%) ns, fat mass (kg) ns, fat free mass ns, truncal fat ns; blood profile: LDL ns, VLDL ns, HDL ns, total cholesterol +, triglycerides ns, glucose ns, insulin ns, glycosylated haemoglobin +; 9 months (in comparison to outcomes at 3 months): weight ns; BMI ns; waist +; body composition: body fat (%) ns, fat mass (kg) ns, fat free mass ns, truncal fat ns; blood profile: LDL +, VLDL ns, HDL ns, total cholesterol +, triglycerides ns, glucose ns, insulin ns, glycosylated haemoglobin +)<br><u>Work</u> : NA<br><u>Feasibility</u> : NA   |      |
| <sup>38</sup> Koepp,<br>2013;<br>USA              | 36 employees with<br>sedentary jobs<br>(69%F; mean age<br>42yrs SD9.9) | Treadmill desks; pre-<br>post; 1 year | <u>Sedentary (hip-worn accelerometer)</u> : 6 months: -91 minutes (SD66) during total waking hours; 12 months: -43 minutes (SD 67; from baseline) during total waking hours<br><u>Health</u> : 6 months: weight +; waist +; body composition: body fat ns, fat mass ns, fat free mass +; blood profile: glucose ns, haemoglobin A1c +, total cholesterol ns, triglycerides ns, HDL ns, LDL ns; 12 months (in comparison to outcomes at baseline): weight +, waist +; body composition: body fat ns, fat mass ns, fat free mass ns; blood profile: glucose ns, haemoglobin A1c ns, total cholesterol ns, triglycerides ns, HDL +, LDL ns<br><u>Work</u> : 6 months: work-performance: 2x overall both ns, 2x quality both ns, 2x quantity both ns; 2x interaction both ns; 12 months: work-performance: 2x overall both ns, 2x quality both ns, 2x quantity both ns; 2x interaction both ns<br><u>Feasibility</u> : adverse events: none, tolerance + | 0.79 |
| <sup>40</sup> Nerhood,<br>1994;<br>USA            | Office workers at<br>UPS   | HAD; pre-post; 9<br>months            | <u>Sedentary</u> : NA<br><u>Health</u> : body part discomfort: eyes ns, neck ns, shoulders ns, upper back +, upper arm ns, middle back +, lower back ns, lower arms/elbows +, wrists ns, hands ns, buttocks +, thighs +, knees +, legs +, feet +<br><u>Work</u> : absenteeism ns; productivity +<br><u>Feasibility</u> : injuries +; cost of injuries +  | 0.21 |
| <sup>56</sup> Neuhaus,<br>2014;<br>Australia<br>* | 44 office workers<br>(84% female; mean<br>age 42.6yrs SD11.5)          | HADM; RCT; 3 months                   | <u>Sedentary (ActivPAL)</u> : -33 minutes/8-hour workday (95% CI= -74, 7)<br><u>Health</u> : weight ns; musculoskeletal ns<br><u>Work</u> : work-performance: overall ns, absenteeism ns, presenteeism ns<br><u>Feasibility</u> : adverse events: 1 (body pain); acceptability +; feasibility +  | 1    |

|   |  |   |  |      |
|---|--|---|--|------|
| <sup>56</sup> Neuhaus, 2014; Australia *† | 44 office workers (84% female; mean age 42.6yrs SD11.5)                                  | HADM (plus additional strategies); RCT; 3 months  | <u>Sedentary (ActivPAL)</u> : -89 minutes/8-hour workday (95% CI= -130, -47)<br><u>Health</u> : weight ns; musculoskeletal ns<br><u>Work</u> : work-performance: overall ns, absenteeism ns, presenteeism ns<br><u>Feasibility</u> : no adverse events; acceptability +; feasibility +   | 1    |
| <sup>54</sup> Parry, 2013; Australia *    | 62 office workers (80.6%F; mean age 43.5yrs SD6.4)                                       | Treadmill desk or treadmill desk with cycle-ergometer (shared 1/9, 1/6, and 1/4); Cluster RCT; 12 weeks | <u>Sedentary (hip-worn accelerometer)</u> : -1.7% during work hours<br><u>Health</u> : NA<br><u>Work</u> : NA<br><u>Feasibility</u> : no adverse events  | 0.88 |
| <sup>43</sup> Paul, 1995a; USA            | 12 office workers (75%F; mean age 37yrs)   | HAD; pre-post; 3 months   | <u>Sedentary</u> : NA<br><u>Health</u> : psychological well-being: feeling bored ns, sluggish +, alert +, energetic +; fatigue +<br><u>Work</u> : NA<br><u>Feasibility</u> : NA  | 0.5  |
| <sup>42</sup> Paul, 1995b; USA            | 13 VDT operators   | HAD; pre-post; 1 day  | <u>Sedentary</u> : NA<br><u>Health</u> : spinal shrinkage -<br><u>Work</u> : NA<br><u>Feasibility</u> : NA   | 0.64 |
| <sup>44</sup> Paul, 1995; USA             | 6 office workers (84%F; mean age 39yrs)  | HAD; pre-post; 6 weeks  | <u>Sedentary</u> : NA<br><u>Health</u> : foot swelling: at 12 pm +, at 1pm ns, at 5pm +<br><u>Work</u> : NA<br><u>Feasibility</u> : NA   | 0.42 |
| <sup>45</sup> Pronk, 2012; USA*           | 34 office workers (IG: 96%F, mean age 38.4yrs SD11.4; CG: 80%F, mean age 44.2yrs SD11.9) | HADM; CT; 4 weeks   | <u>Sedentary (self-report)</u> : -83 minutes during work hours (95%CI= -173, 7)<br><u>Health</u> : musculoskeletal symptoms: upper back +, neck +, lower back ns; psychological wellbeing: vigour+, tension+, confusion+, depression+, total mood disturbance+, anger ns, self-esteem ns; fatigue+<br><u>Work</u> : organisational-cultural: time spent in face-to-face interactions ns<br><u>Feasibility</u> : no adverse events; overall positive feedback: 87% felt more comfortable, 87% more energised, 75% healthier, 7% more focused, 66% more productive, 62% happier, 33% less stressed | 0.63 |
| <sup>20</sup> Roelofs, 2002; Australia    | 30 bank tellers (80F; mean age 27yrs)  | Standing desk without access to height-adjustable chair; cross-   | <u>Sedentary</u> : NA<br><u>Health</u> : musculoskeletal symptoms: body discomfort -, back ns, lower limb -, upper limb ns   | 0.79 |

|  |  |  |  |      |
|--|--|--|--|------|
|  |  | over; 3 days   | <u>Work:</u> NA<br><u>Feasibility:</u> sit/stand preferred by 70%, just sit 20%, just stand 10%  |      |
| <sup>20</sup> Roelofs, 2002; Australia | 30 bank tellers (80F; mean age 27yrs)        | Standing desk with access to height-adjustable chair; cross-over; 3 days | <u>Sedentary:</u> NA<br><u>Health:</u> musculoskeletal symptoms: body discomfort ns, back ns, lower limb ns, upper limb ns<br><u>Work:</u> NA<br><u>Feasibility:</u> sit/stand preferred by 70%, just sit 20%, just stand 10%  | 0.79 |
| <sup>47</sup> Thompson, 2007; USA      | 25 employees in the executive health program | Treadmill desks; pre-post; 6 weeks                                       | <u>Sedentary:</u> NA<br><u>Health:</u> NA<br><u>Work:</u> NA<br><u>Feasibility:</u> no adverse events; overall positive feedback: workstation is too noisy (mean score 1.8/5), productivity improved (mean score 2.9/5), increased fatigue at end of day (mean score 3.0/5), workstation did not interfere with patient care (mean score 3.9/5), preference for APW (mean score 4.4/5) | 0.64 |

\* publications included in meta-analysis; † same study population as above; F= female; M= male; CT= controlled trial; RCT= randomised controlled trial; APW= Activity-permissive workstation; HAD= fully height-adjustable desk; HADM= Height-adjustable desk mount for computer only; %le= percentile; BMI= body mass index; LDL= low-density lipoprotein; VLDL= very low-density lipoprotein; HDL= high-density lipoprotein; NA= not applicable; + = statistically significant improvement in outcome; - = statistically significant worsening in outcome; ns=statistically non-significant

Table 2. Summary of health and work outcomes stratified by study duration

| Outcome (n)                         | Number of studies |          | Worsening (n) |          | No change (n) |           | Improvement (n) |           |
|-------------------------------------|-------------------|----------|---------------|----------|---------------|-----------|-----------------|-----------|
|                                     | short             | long     | short         | long     | short         | long      | short           | long      |
| <i>Health-related</i>               |                   |          |               |          |               |           |                 |           |
| Musculoskeletal (n=127)             | 13                | 4        | 16            | 0        | 56            | 15        | 32              | 8         |
| Weight (n=9)                        | 1                 | 5        | 0             | 0        | 1             | 6         | 0               | 2         |
| Body mass index (n=5)               | 0                 | 4        | -             | 0        | -             | 4         | -               | 1         |
| Waist circumference (n=6)           | 1                 | 3        | 0             | 0        | 1             | 0         | 0               | 5         |
| Body composition (n=19)             | 1                 | 3        | 0             | 0        | 2             | 16        | 0               | 1         |
| Blood profile (n=34)                | 1                 | 4        | 0             | 0        | 2             | 23        | 1               | 8         |
| Fatigue (n=10)                      | 6                 | 3        | 0             | 0        | 4             | 1         | 3               | 2         |
| Psychological well-being (n=15)     | 3                 | 2        | 0             | 0        | 2             | 1         | 7               | 5         |
| Leg/Foot swelling (n=5)             | 2                 | 0        | 1             | -        | 2             | -         | 2               | -         |
| Other (n=9)                         | 2                 | 1        | 0             | 0        | 4             | 4         | 1               | 0         |
| <b>Total health-related (n=239)</b> | <b>15</b>         | <b>8</b> | <b>17</b>     | <b>0</b> | <b>74</b>     | <b>70</b> | <b>46</b>       | <b>32</b> |
| <i>Work</i>                         |                   |          |               |          |               |           |                 |           |
| Work-performance (n=99)             | 17                | 5        | 21            | 0        | 56            | 15        | 5               | 2         |
| Absenteeism (n=5)                   | 1                 | 3        | 0             | 0        | 1             | 4         | 0               | 0         |
| Presenteeism (n=3)                  | 1                 | 1        | 0             | 0        | 1             | 2         | 0               | 0         |
| Cultural-organisational (n=5)       | 1                 | 1        | 0             | 0        | 1             | 4         | 0               | 0         |
| <b>Total work (n=112)</b>           | <b>18</b>         | <b>5</b> | <b>21</b>     | <b>0</b> | <b>59</b>     | <b>25</b> | <b>5</b>        | <b>2</b>  |

\*Study duration was defined as: short= < 12 weeks; long= ≥12weeks; ‘-’ indicates that the outcome was not measured in any study of that particular duration;

Supplementary Table 2. Quality scores of included publications.

| Study          | Recruit. | Participants | Allocation | Measure | Sample size | Variance | Confounding | Results | TOTAL |
|----------------|----------|--------------|------------|---------|-------------|----------|-------------|---------|-------|
| Aaras, 1997    | 1        | 2            | 1          | 2       | 1           | 2        | N/A         | 2       | 0.79  |
| Alderman, 2013 | 2        | 2            | 1          | 2       | 1           | 2        | N/A         | 2       | 0.86  |
| Alkhajah, 2012 | 2        | 2            | N/A        | 2       | 2           | 2        | 2           | 2       | 1.00  |
| Beers, 2008    | 1        | 2            | 1          | 2       | 1           | 2        | N/A         | 1       | 0.83  |
| Carr, 2011     | 2        | 2            | N/A        | 1       | 2           | 2        | N/A         | 1       | 0.83  |
| Carr, 2013     | 2        | 2            | 2          | 2       | 2           | 2        | 2           | 2       | 1.00  |
| Chester, 2001  | 1        | 2            | 1          | 1       | 1           | 0        | N/A         | 2       | 0.57  |
| Cox, 2011      | 1        | 1            | 1          | 2       | 1           | 2        | 0           | 2       | 0.63  |
| Davis, 2009    | 2        | 1            | 1          | 1       | 1           | 1        | N/A         | 2       | 0.64  |
| Ebara, 2008    | 2        | 2            | 1          | 1       | 2           | 2        | N/A         | 2       | 0.86  |
| Edelson, 1989  | 2        | 2            | 1          | 2       | 0           | 0        | N/A         | 2       | 0.64  |
| Ellegast, 2012 | 1        | 1            | 1          | 2       | 1           | 1        | 0           | 2       | 0.56  |
| Fidler, 2008   | 1        | 2            | N/A        | 2       | 1           | 1        | N/A         | 2       | 0.75  |
| Funk, 2012     | 1        | 2            | 1          | 2       | 1           | 2        | N/A         | 2       | 0.79  |
| Gilson, 2012   | 2        | 2            | N/A        | 2       | 0           | 2        | N/A         | 2       | 0.83  |
| Grunseit, 2013 | 2        | 2            | N/A        | 1       | 1           | 2        | N/A         | 2       | 0.83  |
| Hasegawa, 2001 | 0        | 1            | 0          | 1       | 1           | 0        | 0           | 2       | 0.31  |
| Healy, 2013    | 2        | 2            | N/A        | 2       | 2           | 2        | 2           | 2       | 1.00  |
| Hedge, 2004    | 1        | 2            | 1          | 1       | 1           | 0        | 0           | 2       | 0.50  |
| Husemann, 2009 | 1        | 1            | 1          | 2       | 1           | 2        | 1           | 2       | 0.69  |
| John, 2009     | 1        | 2            | 1          | 2       | 1           | 2        | N/A         | 2       | 0.79  |
| John, 2011     | 2        | 2            | N/A        | 2       | 1           | 2        | 0           | 2       | 0.79  |
| Koepp, 2013    | 2        | 2            | N/A        | 2       | 1           | 2        | 0           | 2       | 0.79  |
| Koren, 2013    | 1        | 2            | N/A        | 1       | 1           | 2        | N/A         | 1       | 0.67  |
| McAlpine, 2007 | 1        | 2            | N/A        | 1       | 1           | 2        | N/A         | 2       | 0.75  |
| Nerhood, 1994  | 1        | 0            | N/A        | 1       | 0           | 0        | 0           | 1       | 0.21  |
| Neuhaus, 2014  | 2        | 2            | 2          | 2       | 2           | 2        | 2           | 2       | 1.00  |
| Ohlinger, 2011 | 1        | 2            | N/A        | 2       | 1           | 2        | N/A         | 2       | 0.83  |
| Parry, 2013    | 2        | 2            | 2          | 1       | 2           | 2        | 1           | 2       | 0.88  |
| Paul, 1995a    | 1        | 2            | N/A        | 0       | 1           | 0        | N/A         | 1       | 0.42  |
| Paul, 1995b    | 1        | 2            | 0          | 2       | 1           | 1        | N/A         | 2       | 0.64  |

|                |             |             |             |             |             |             |             |             |      |
|----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------|
| Paul, 1995     | 1           | 1           | 0           | 2           | 1           | 1           | 0           | 2           | 0.50 |
| Pronk, 2012    | 2           | 2           | 1           | 2           | 1           | 0           | 0           | 2           | 0.63 |
| Roelofs, 2002  | 2           | 2           | 1           | 1           | 1           | 2           | N/A         | 2           | 0.79 |
| Seo, 1996      | 1           | 2           | N/A         | 1           | 1           | 2           | N/A         | 2           | 0.75 |
| Straker, 2009  | 2           | 2           | 2           | 2           | 1           | 2           | N/A         | 2           | 0.93 |
| Thompson, 2011 | 2           | 0           | 1           | 2           | 2           | 0           | N/A         | 2           | 0.64 |
| Thompson, 2007 | 2           | 0           | N/A         | 2           | 1           | 1           | N/A         | 2           | 0.67 |
| <b>TOTAL</b>   | <b>0.74</b> | <b>0.84</b> | <b>0.55</b> | <b>0.80</b> | <b>0.57</b> | <b>0.71</b> | <b>0.33</b> | <b>0.93</b> |      |