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1 **Pre-Existing Low-Back Symptoms Impact Adversely on Sitting Time Reduction in Office Workers**

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45

46 **Abstract**

47 **Objectives:** Initiatives to reduce office-workplace sitting are proliferating, but the impact of pre-existing  
48 musculoskeletal symptoms on their effectiveness has not been determined. We assessed the influence of  
49 musculoskeletal symptoms on the outcomes of a workplace sitting intervention.

50 **Methods:** Baseline and three-month data from a cluster-randomized controlled trial of a workplace sitting  
51 intervention (*Stand Up Victoria*; trial registration number ACTRN12611000742976) were used. Office workers  
52 (n=231) from 14 work teams within one organisation were randomised (by worksite) to a multicomponent  
53 program with individual-, organisational-, and environmental-level (sit-stand workstations) change strategies;  
54 or, to a control condition (no intervention). Musculoskeletal symptoms in the low-back, upper- and lower-  
55 extremities (present/absent) were assessed through self-report. Linear regression models tested the  
56 moderation by baseline musculoskeletal symptoms of intervention effects on workplace sitting and standing  
57 time and on sitting and standing bout durations, assessed by the activPAL3™ activity monitor.

58 **Results:** There were significant reductions in sitting and increased standing at work ( $p < 0.05$ ). However, effects  
59 varied significantly by the presence of pre-existing low-back (but not other) symptoms, with greater benefit  
60 being seen in those without symptoms. Effects on sitting time and sitting bout duration were weaker in those  
61 with low-back symptoms compared to those without by 34.6 (95% CI: [0.9; 68.3]) min/8-h workday and 5.1  
62 (95% CI: [0.2; 9.9]) min, respectively. Comparable effects were seen for standing.

63 **Conclusion:** Low-back symptoms may impact on the extent to which office workers change their workplace  
64 sitting and standing time. A prudent next step to improve the effectiveness of workplace sitting-reduction  
65 initiatives such as *Stand Up Victoria* may be to assess and address the needs of those who displayed  
66 comparatively limited behaviour change, namely those with pre-existing low-back discomfort.

67

68 **Key words:** office work - musculoskeletal symptoms – sitting - standing - randomized controlled trial

69

70

**71 Introduction**

72 Excessive sitting is an emerging issue in current occupational safety and health research(Straker et al. 2016).  
73 There is now consistent evidence showing that high levels of overall sitting time are associated with adverse  
74 health outcomes, including type 2 diabetes and cardiovascular diseases(Biswas et al. 2015), some  
75 cancers(Schmid and Leitzmann 2014; Zhang et al. 2014) and depression(Teychenne et al. 2015; Zhai et al.  
76 2014). Moreover, over the last decades there has been a rapid shift from physically active to more sedentary  
77 work environments, with a large proportion of current workers now being employed in sitting jobs(Church et  
78 al. 2011). Office workers have been shown to spend on average three-quarters of their working hours  
79 sitting(Thorp et al. 2012) and workplace sitting is one of the largest contributors to overall daily sitting time in  
80 this group(Parry and Straker 2013). Due to its adverse health implications, and increasing levels of exposure at  
81 the workplace, excessive sitting has been identified as an emerging occupational safety and health  
82 issue(Straker et al. 2014) and office workers have been identified as a key target group(Healy et al. 2012).

83 There has been a rapid increase in reports from trials of targeting workplace sitting  
84 interventions(Neuhaus et al. 2014a; Prince et al. 2014; Shrestha et al. 2016), focussing on change through  
85 influencing attributes of the individual worker, the work organization, the work environment, or a combination  
86 of these(Shrestha et al. 2016). In particular, work environments with activity permissive (primarily sit-stand)  
87 workstations are becoming more common. Initial findings show that interventions are generally successful in  
88 reducing occupational sitting time(Neuhaus et al. 2014a; Shrestha et al. 2016), but the role that pre-existing  
89 health issues may have on the extent to which workers change their sitting time is not well understood.

90 Musculoskeletal symptoms such as neck, shoulder and back pain are commonly reported in office  
91 workers, with the annual prevalence of these symptoms estimated to be 67%, 71%, and 66%  
92 respectively(Griffiths et al. 2012). Although the evidence is equivocal, musculoskeletal symptoms have been  
93 shown to be associated with both excessive standing(Andersen et al. 2007; Waters and Dick 2014) and  
94 excessive sitting(Chen et al. 2009) at work. Postural variation has been proposed as a strategy to reduce  
95 musculoskeletal symptoms(Mathiassen 2006) and is also a feature of several sitting-reduction  
96 interventions(Dunstan et al. 2013; Parry et al. 2013). Therefore, pre-existing musculoskeletal symptoms could  
97 plausibly impact on the efficacy of a workplace sitting initiatives, beneficially or adversely. Such information is  
98 important to the development of future approaches. Therefore, we examined the influence of pre-existing

99 musculoskeletal symptoms on the outcomes of a workplace trial that targeted reduction in sitting among  
100 office workers.

101

## 102 **Study population and methods**

103

### 104 *Study population*

105 Data for this study were from the *Stand Up Victoria* study, a three-month cluster-randomized controlled trial  
106 aimed at reducing sitting time in office workers(Dunstan et al. 2013; Neuhaus et al. 2014b). Details on the  
107 methods(Dunstan et al. 2013), intervention development(Neuhaus et al. 2014b), sample size  
108 calculation(Dunstan et al. 2013) and main outcomes(Healy et al. 2016), have been described previously. Ethics  
109 approval was granted by Alfred Health Human Ethics Committee (Melbourne, Australia), with prospective trial  
110 registration with the Australian New Zealand Clinical Trials register (ACTRN12611000742976). In brief,  
111 participants were recruited in teams from 14 different sites (buildings  $\geq 1$ km apart) within the one organization  
112 in the state of Victoria, Australia. Worksites were randomly allocated to intervention (7 sites) or control (7  
113 sites). Office workers were eligible to take part in the study if, at the telephone screening, they were working  
114 at least 0.6 full time equivalent hours (FTE), aged 18–65 years, spoke English, had access to a telephone,  
115 internet and desk within the workplace, were not pregnant, and reported no physical or health problems  
116 (including musculoskeletal problems) that may limit their ability to regularly stand up for at least 10 minutes at  
117 a time. Initially, 246 workers expressed interest and appeared eligible from the telephone screening.  
118 Ultimately, 231 participants (136 intervention; 95 control) participated in the *Stand Up Victoria* trial. Physical,  
119 fasting blood, activity monitor, and questionnaire assessments occurred at baseline, at three months and after  
120 a nine-month follow-up period. The current study examines the 201 workers with complete data on baseline  
121 musculoskeletal symptoms and confounders; and, activity outcomes at the baseline and three-month  
122 assessment.

123

### 124 *Intervention*

125 *Stand Up Victoria* was a trial of a workplace intervention with individual, organisational and environmental  
126 components. Extensive formative research was used to develop the intervention(Neuhaus et al. 2014b). The

127 key intervention message was to “Stand Up, Sit Less, Move More”, both at work and outside of work.  
128 Specifically, the message encouraged participants to reduce their sitting time, particularly sitting for prolonged  
129 continuous periods of 30 minutes or more, and to replacing sitting with either standing or stepping. The  
130 environmental element of the intervention consisted of the installation of dual-screen desktop-mounted sit-  
131 stand computer workstations (Ergotron WorkFit-S; [www.ergotron.com](http://www.ergotron.com)). The workstations, which were  
132 provided to all intervention participants, enabled them to alternate their posture between sitting and standing  
133 regularly during computer based work. Upon installation of the workstation, the ergonomically correct heights  
134 for sitting and standing were determined for each individual by the research team and marked on the  
135 workstation via an adhesive label. In addition, written instructions were given regarding the appropriate  
136 postures for sitting and standing as provided by the workstation manufacturer  
137 ([www.ergotron.com/tabid/305/language/en-AU/Default.aspx](http://www.ergotron.com/tabid/305/language/en-AU/Default.aspx)), and participants were instructed to “listen to  
138 the body” and to alternate postures regularly. At the organisational level, strategies to support changes in  
139 workplace sitting included senior management consultation, representatives’ consultation workshops,  
140 participant information and brainstorming sessions and visible ongoing organisational support via tailored e-  
141 mails and role modelling by team champions. Individual-level support was delivered by a face-to-face health  
142 coaching session with subsequent telephone support. While the environmental component of the intervention  
143 (i.e., the sit-stand workstation) remained at the worksites during the nine-month follow up period, the  
144 organisational and individual components of the intervention were only delivered during the first three-month  
145 intervention period. Participants in control sites were told that they were taking part in a study on the  
146 association of physical activity and sitting with cardio-metabolic and anthropometric markers, and did not  
147 receive any of the intervention components.

148

#### 149 *Measures*

150 Changes in total workplace sitting and standing times, and usual bouts of sitting and standing (three-month vs  
151 baseline) and pre-existing musculoskeletal symptoms and other relevant factors (only at baseline) were  
152 examined.

153 Sitting-related outcomes were assessed objectively using the activPAL3™ activity monitor (PAL  
154 Technologies Limited, Glasgow, UK), worn on the thigh continuously (24 hours per day) for seven days at

155 baseline and at the three-month assessment(Healy et al. 2016). This monitor provides data with validity,  
156 reliability, and responsiveness to change, both for total time spent sitting, standing and stepping, and for  
157 transitions between a sitting and upright posture(Grant et al. 2006; Kozey-Keadle et al. 2011; Lyden et al.  
158 2012; Ryan et al. 2006). Self-completed daily logs were used to record wake and sleep times, any monitor  
159 removal periods, and work hours. Work hours were defined as all hours worked for the organisation at the  
160 primary worksite or other locations. As at every assessment nearly all work ( $\geq 98\%$ ) reported was for the  
161 organisation and very little of this work was reportedly conducted outside of the study worksite ( $< 5\%$ ) the  
162 terms “workplace” and “at work” are used interchangeably. Data were processed in SAS version  $\geq 9.3$  (SAS  
163 Institute Inc., Cary, NC), using a customised program that combined the activity monitor and log data. Details  
164 on the data processing have been reported on previously(Chen et al. 2009). Days with monitor removals of  
165  $< 20\%$  of work hours were deemed valid for workplace activity. Total workplace sitting and standing times were  
166 calculated as averages per valid day and standardised to an 8-hour workday (min/8-h workday). For each  
167 participant, ‘usual durations’ of sitting and standing bouts were calculated across all sitting or standing bouts  
168 at the workplace on valid days. Half of a participant’s workplace sitting or standing time is accumulated in  
169 bouts longer than his or her usual bout duration for workplace sitting or standing, respectively. As per  
170 established methods, usual bout duration for sitting at the workplace was estimated by fitting the sitting-bout  
171 accumulation curve using non-linear regression(Stephens et al. 2014). Although standing may be accumulated  
172 differently to sitting, we applied this same method as a generic curve-fitting technique to standing bouts to  
173 estimate their midpoint (Supplement 1).

174 At baseline, questionnaires were self-completed using an online Lime-Service tool  
175 ([www.limeservice.com](http://www.limeservice.com)). Musculoskeletal symptoms were measured using the 27-item Nordic Musculoskeletal  
176 Questionnaire(Dickinson et al. 1992). This questionnaire includes items on ‘trouble’ (such as ache, pain,  
177 discomfort, numbness) in the last seven days in various body parts, and has been shown to be repeatable and  
178 sensitive to changes(Palmer et al. 1999). Musculoskeletal symptoms (present/absent) in the following sites  
179 were assessed: neck, shoulders, elbows, wrists, low-back, hips, knees and ankles. Low-back symptoms, lower-  
180 extremity symptoms (hips, knees and ankles combined) and upper-extremity symptoms (neck, shoulder,  
181 elbows and wrists combined) were used for further analyses (all expressed as dichotomous variables).

182           The online questionnaire also assessed personal and lifestyle factors (i.e., age, gender and smoking  
183 behaviour); work productivity(Shikiar et al. 2004); presenteeism(Lerner et al. 2001); mental demands at  
184 work(Lerner et al. 2001), and physical health symptoms, including fatigue. Further details on the measures,  
185 including the reliability and validity of the scales, are available elsewhere(Dunstan et al. 2013). Physical  
186 assessment included measurement of waist circumference and standing height using standard measures.

187

### 188 *Statistical analyses*

189 All statistical analyses were conducted using STATA for Windows (StataCorp. 2013. Stata Statistical Software:  
190 Release 13. College Station, TX: StataCorp LP). Significance was set at  $p < 0.05$  (two-tailed) and linearized  
191 variance estimation was used (survey commands) to correct for the cluster-randomised design.

192           Multivariable linear regression models were used to test intervention effects (intervention – control  
193 difference) on changes in activities and the differences in these intervention effects by pre-existing  
194 musculoskeletal symptoms (i.e., interaction term for group allocation x symptom status). Each outcome and  
195 each symptom were assessed in separate models. Outcome values at the final assessment were modelled with  
196 adjustment for baseline values of the activity outcome variables (to control regression to the mean), and for  
197 age, gender, and other potential confounders selected in a backward stepwise selection procedure ( $p < 0.20$  for  
198 retention). Other confounding variables considered were smoking, height, waist circumference, work  
199 productivity, mental demands at work and fatigue (an overview of confounders can be found in Supplement  
200 2). We report on the changes within those with and without baseline symptoms allocated to intervention and  
201 control, using adjusted means (and 95% confidence intervals - CI). We also report from the regression models  
202 on intervention effects within each symptom group and the differences in intervention effects between  
203 symptom groups as regression coefficients with 95% CI.

204           Since models excluded participants who lacked follow-up data, the findings represent the impact of  
205 symptoms on change and effectiveness for participants who remained in the study. To consider the potential  
206 impact of symptoms on effectiveness more broadly, we also report on the association of baseline symptoms  
207 with the odds of dropping out during the three-month intervention period (i.e., not participating in the three-  
208 month assessment, yes/no), using logistic regression models, and reporting associations as odds ratios (OR)  
209 with 95% CI.

**210 Results**

211 Baseline attributes of the study participants (n=201, average (mean±SD) age of 45.3±9.3 years, 138 (69%)  
212 women) are shown in Table 1. Within an 8-h workday, participants spent on average (mean±SD) 378.4±45.9  
213 minutes (i.e., 6.3±0.8 hours) sitting and 68.8±39.8 minutes (i.e., 1.1±0.7 hours) standing, with other activities  
214 (mainly stepping) comprising the rest of the work time. The means (±SD) of participants' usual bout durations  
215 for sitting and for standing were 31.6±15.2 and 1.7±1.3 minutes, respectively. At baseline, 52%, 54% and 69%  
216 of the participants respectively reported low-back, lower-extremity and upper-extremity symptoms during the  
217 last seven days.

218 In the participants remaining in the study for the three-month intervention period, adjusted mean  
219 changes (three months minus baseline) observed within intervention and control participants with and  
220 without musculoskeletal symptoms at baseline are shown in Tables 2 and 3. Intervention effects including  
221 difference in intervention effect in participants with and without pre-existing symptoms (i.e., interaction  
222 effects for group allocation x musculoskeletal symptom status) are shown in Table 4. The intervention  
223 significantly reduced workplace sitting and sitting bout duration and increased workplace standing and  
224 standing bout duration, relative to the control group (Table 4). In general, intervention effects were significant,  
225 within both those with and those without pre-existing symptoms.

226 Intervention effects [95% CI] on workplace sitting were large and significant for both those with and  
227 without low-back pain symptoms at baseline (-91.9 [-120.7; -63.1] min/8-h workday and -126.6 [-151.4; -101.7]  
228 min/8-h workday, respectively; Table 4). These effects were, however, significantly weaker for those with low-  
229 back symptoms at baseline compared to those without low-back symptoms, by just over half an hour per day  
230 (34.6 [0.9; 68.3] min/8-h workday). A similar effect was seen for workplace standing time, whereby the  
231 intervention effects were weaker for those with low-back symptoms at baseline compared to those without  
232 symptoms, by just over half an hour per 8-h workday (-34.3 [-64.5; -3.0] min/8-h workday). Relative to their  
233 asymptomatic counterparts, those with low-back symptoms had smaller sitting reductions (and reduced  
234 standing increases) when receiving the intervention and also slightly greater sitting reductions (and standing  
235 increases) when receiving the control condition (Table 2), thus explaining the weaker intervention effects.  
236 Intervention effects did not differ significantly by lower or upper-extremity symptoms. The size of the  
237 differences observed was very small for lower-extremity symptoms (<5 min/8-h workday), and modest for

238 upper-extremity symptoms (10–20 min/8-h workday), but also estimated with a wide margin of error that  
239 included potential differences of half an hour or more per day.

240 Intervention effects on the usual workplace sitting bout duration also varied significantly only by low-  
241 back symptoms (Table 4). Intervention effects were large and significant for those without pre-existing low-  
242 back symptoms (-8.9 [-12.5; -5.4] min), and were significantly larger by just over 5 minutes (5.1 [0.2; 9.9] min)  
243 than in those without symptoms (-3.8 [-8.0; 0.3] min). Significant intervention effects for standing bout  
244 duration, of approximately 3–5 minutes occurred. These were weaker within those with low-back symptoms  
245 than in those without low-back symptoms by approximately two minutes (-2.0 [-3.2; -0.8] min). Those without  
246 symptoms had the strongest intervention effects for sitting and standing bout duration, mostly due to greater  
247 intervention change and to a lesser extent differing control changes relative to their symptomatic counterparts  
248 (Table 3). The non-significant differences by lower-extremity and upper-extremity symptoms were small (<2  
249 minutes for sitting and <1 minute for standing) and with wide margins of error.

250 A total of 30 (13%) of the participants who participated in the *Stand Up Victoria* study dropped out of  
251 the study before the three-month assessment. There was a suggestion that (albeit not statistically significant)  
252 pre-existing symptoms (specifically in the upper extremities) increased the odds (OR [95% CI]) of dropping out  
253 of the study over the first three-months (2.3 [0.9; 6.1],  $p=0.08$ ), with drop-out rates being higher among  
254 participants with than without pre-existing symptoms in the upper extremities (Supplement 3). Differences in  
255 drop-out by baseline symptoms in the low-back (1.2 [0.5; 2.8],  $p=0.72$ ) and lower-extremities (0.9 [0.5; 1.6],  
256  $p=0.72$ ) were smaller and non-significant.

257

## 258 Discussion

259 The impact of the *Stand Up Victoria* intervention on workplace sitting and standing time, and sitting and  
260 standing bout duration varied significantly, depending on the presence or absence of pre-existing low-back  
261 symptoms. Specifically, for participants with complete data at the baseline and three-month assessments, the  
262 intervention was more effective for reducing sitting and increasing standing in those without pre-existing low-  
263 back symptoms compared to those with low-back symptoms, with a difference in effectiveness of more than  
264 half an hour per 8-h workday or several minutes in the duration of sitting and standing bouts. Notably, the  
265 intervention was still effective for reducing sitting time and increasing standing time in those with low-back

266 symptoms. Differences in effectiveness of the intervention by upper-extremity and lower-extremity symptom  
267 status were smaller and not statistically significant. However, relative to their asymptomatic counterparts,  
268 those with upper-extremity symptoms may have benefitted less from the intervention because of a greater  
269 tendency to drop out of the study.

270 Our findings indicate that pre-existing musculoskeletal symptoms (in particular in the low-back) may  
271 impact on the effectiveness of workplace sitting interventions, especially interventions similar to *Stand Up*  
272 *Victoria* which include the introduction of sit-stand workstations to encourage more standing. Musculoskeletal  
273 symptoms should therefore be taken into account in workplace sitting interventions. Musculoskeletal  
274 symptoms are known to be highly prevalent among office workers(Griffiths et al. 2012) and have been shown  
275 to be associated with both excessive sitting(Chen et al. 2009) and excessive standing(Andersen et al. 2007;  
276 Waters and Dick 2014). On this basis, musculoskeletal symptoms might either facilitate or limit the capacity of  
277 office workers to substitute a standing posture for a sitting posture in the workplace. The results found in our  
278 study suggest that symptoms limit the capacity of workers to stand at work, at least at a group level. However,  
279 it could also be the case that different sub-groups may respond differently to sitting-reduction initiatives,  
280 suggesting that symptoms could facilitate standing for some workers. This is plausible for workers with low-  
281 back pain, as pain aggravated by spinal flexion (e.g., sitting) or extension (e.g., standing) is commonly observed  
282 in a clinical setting(O'Sullivan 2005). Identification of such groups in future studies might enhance knowledge  
283 on potential barriers to workplace sitting interventions and could thus improve efficiency by informing tailored  
284 interventions. For example, alternative (non-standing) initiatives, such as under-desk cycle  
285 workstations(Commissaris et al. 2014) or walk-and-talk meetings(Gilson et al. 2009) may be more suitable to  
286 those workers with low-back pain aggravated by static standing.

287 It is plausible that upper and lower limb symptoms pose a diminished hindrance to reducing and  
288 breaking up sitting than do low-back symptoms. However, the confidence intervals included potentially  
289 substantial differences, as large as those observed for low-back symptoms, and the study may have been  
290 underpowered to detect these. In addition to limiting the degree of posture change within those still in the  
291 study, there was some indication that symptoms, especially in the upper-extremities, may limit intervention  
292 effectiveness by predisposing participants to drop out of the study. There was a tendency for higher dropout  
293 for those with versus those without pre-existing upper-extremity symptoms (both in the intervention and the

294 control group). Moreover, self-reported adverse events arising from participation in the Stand Up Victoria  
295 study have been described previously(Healy et al. 2016). The 13 events reported on by 7 participants in the  
296 period from baseline to the first three months of the intervention included neck/shoulder (n=6), wrist (n=2),  
297 low-back/buttocks (n=2), thigh (n=2) and ankle (n=1) symptoms. Apart from musculoskeletal symptoms  
298 influencing the effect of occupational sitting time interventions, it can also be postulated that this association  
299 works the other way around (i.e., sitting interventions influencing the presence or severity of musculoskeletal  
300 symptoms). This direction should therefore be assessed in future research.

301

### 302 *Strengths and limitations*

303 The cluster-randomized controlled study design was well suited to examining the impact of symptoms on  
304 activity changes. Also, large behaviour changes occurred and total time and bout durations for sitting and  
305 standing were measured accurately and objectively(Grant et al. 2006; Kozey-Keadle et al. 2011; Ryan et al.  
306 2006), with self-report data used only to indicate work times and monitor removals. The cluster-randomised  
307 design covered a range of office settings (seven intervention and seven control sites) and a broad range of  
308 office workers with and without pre-existing symptoms. However, with the sample drawn from only one  
309 organisation (a government department) and not a population-based random sample, our findings need to be  
310 generalised with caution. The sample size was adequate for detecting intervention effects(Dunstan et al.  
311 2013), but was not chosen *a priori* for testing interactions with musculoskeletal symptoms. As many of the null  
312 findings included potentially meaningful effects, the study appeared underpowered for testing interaction  
313 effects and associations of symptoms with dropout. A study strength was the intervention recruited workers  
314 with any degree of symptom impairment that was less than a complete inability to stand for more than ten  
315 minutes. We cannot generalise beyond the severity levels we recruited; however, it is likely that an even  
316 greater difference in intervention effectiveness would be observed for workers with this very severe level of  
317 impairment. The intervention promoted the use of the sit-stand workstation, thus enabling participants to  
318 spend more time standing. The impact of symptoms on changes arising from other interventions targeting  
319 different movements (e.g., under-desk cycle or treadmill workstations) may be quite different.

320 Initiatives to reduce workplace sitting could be affected by health conditions other than  
321 musculoskeletal disorders, such as cardio-vascular disorders. Movement avoidance is a common phenomenon

322 among people with chronic venous insufficiency(Roaldsen et al. 2009) and cardiovascular disorders are  
323 associated with reduced levels of physical activity(Vanhees et al. 2012). This study tested only questions  
324 concerning musculoskeletal health and behaviour change. Other factors, such as the ones mentioned above,  
325 may however also be important and thus remain to be examined and considered in the development of  
326 occupational health and safety policy(Coenen et al. 2017). Also, our research question only concerned the  
327 impact of musculoskeletal symptoms on the extent to which workers initiate behaviour changes; it did not  
328 address maintenance. Findings should not be generalized to long-term interventions, maintenance, or  
329 interventions substantially different to Stand Up Victoria (such as those without sit-stand workstations).

330         The effectiveness of the *Stand Up Victoria* study overall was to reduce occupational sitting time by  
331 approximately 100 minutes per 8-h workday(Healy et al. 2016), with intervention effects in our study  
332 approximately half an hour (i.e., 30% of the overall effectiveness) greater for those without versus those with  
333 pre-existing musculoskeletal symptoms. Pre-existing symptoms may or may not be a critical factor in  
334 determining whether health benefits (such as to adiposity, glucose and lipid metabolism) can arise from such  
335 interventions. Although the relative difference in intervention effectiveness between those with and without  
336 musculoskeletal symptoms is large, it is not yet known how much change is required to produce benefits to  
337 these areas of cardio-metabolic health. Further, a better understanding of the mechanisms by which health  
338 conditions may influence occupational posture behaviours, and vice-versa, is needed. Qualitative process  
339 evaluations of barriers and facilitators to occupational behavioural change would also be valuable.

340

### 341 **Conclusions**

342 Although the *Stand Up Victoria* trial was generally effective in demonstrating reductions in workplace sitting  
343 and increasing standing, the intervention was significantly more efficacious in those without pre-existing low-  
344 back symptoms than in those with such symptoms: by approximately half an hour per 8-h workday and by  
345 several minutes for usual bout duration of sitting and standing. Moreover, there was some indication that  
346 symptoms (especially in the upper extremities) may have further pre-disposed participants to withdraw from  
347 the study and thereby benefit less from the intervention. The presence of musculoskeletal symptoms,  
348 especially in these regions, should therefore be considered in future workplace sitting initiatives.

349

350 **Conflicts of interest**

351 The authors declare that they have no conflict of interest.

352 Table 1. Baseline characteristics of the study sample.

Variable	Total	Control	Intervention
Number of participants, n	201	83	118
Sex, number of females (%)	138 (69%)	61 (73%)	77 (65%)
Age (years)	45.3 (9.3)	46.1 (9.7)	44.8 (8.9)
Height (cm)	167.2 (9.2)	166.8 (9.7)	167.5 (8.9)
Waist circumference (cm)	93.9 (14.7)	93.4 (13.9)	94.2 (15.3)
Smokers, number of smokers (%)	36 (18%)	16 (19%)	20 (17%)
Sitting at work (minutes/8-h workday)	378.4 (45.9)	373.4 (41.4)	381.9 (48.7)
Standing at work (minutes/8-h workday)	68.8 (39.8)	70.8 (32.6)	67.3 (44.3)
Sitting bout duration at work (minutes) <sup>1</sup>	31.6 (15.2)	31.0 (16.3)	32.1 (14.5)
Standing bout duration at work (minutes) <sup>1</sup>	1.7 (1.3)	1.6 (0.8)	1.8 (1.5)
Work productivity <sup>2</sup>	7.2 (1.3)	7.4 (1.3)	7.1 (1.3)
Mental work demands <sup>3</sup>	16.6 (16.2)	16.0 (15.6)	17.0 (16.8)
Fatigue <sup>4</sup>	13.8 (5.3)	13.5 (4.7)	13.9 (5.7)
Low-back symptoms (last 7 days), number (%)	105 (52%)	44 (53%)	61 (52%)
Lower-extremity symptoms (last 7 days), number (%)	109 (54%)	44 (53%)	65 (55%)
Upper-extremity symptoms (last 7 days), number (%)	139 (69%)	57 (69%)	82 (69%)

Adjusted mean values with standard deviation and adjusted prevalence are presented, using linearized variance estimation to account for workplace clustering.

<sup>1</sup>Ascertained for each individual as the midpoint of the sitting bout accumulation curve(Stephens et al. 2014) with the same method applied to standing bouts.

<sup>2</sup>Productivity score composed of 11 items, ranging from 1 (low productivity) to 10 (high productivity).

<sup>3</sup>Mental-interpersonal demands score composed of 9 items, ranging from 0% (least demanding) to 100% (most demanding).

<sup>4</sup>Fatigue score, ranging from 0 (least fatigue) to 28 (most fatigue).

Table 2. Baseline workplace sitting and standing time and change (three months versus baseline) of these behaviours, observed within intervention and control participants with and without musculoskeletal symptoms at baseline.

Musculoskeletal symptoms		Group	n	Baseline sitting time (minutes/8-hr workday) <sup>a</sup>	Change in sitting time (minutes/8-hr workday) <sup>b</sup>	p	Baseline standing time (minutes/8-hr workday) <sup>a</sup>	Change in standing time (minutes/8-hr workday) <sup>c</sup>	p
Low-back symptoms	No symptoms	Control	39	377.5 [354.8 400.2]	-1.1 [-6.7 4.6]	0.683	65.7 [47.8 83.6]	0.6 [-6.6 7.7]	0.869
		Intervention	57	384.7 [373.1 396.3]	-127.7 [-153.9 -101.4]	<0.001	64.3 [52.0 76.6]	126.0 [104.2 147.8]	<0.001
	Symptoms	Control	44	369.8 [347.4 392.1]	-12.3 [-27.6 3.0]	0.107	75.4 [59.9 90.9]	11.3 [-3.0 25.7]	0.112
		Intervention	61	379.4 [353.7 405.1]	-104.2 [-128.5 -79.9]	<0.001	70.1 [50.7 89.5]	102.5 [78.9 126.0]	<0.001
Lower extremity symptoms	No symptoms	Control	39	373.9 [358.2 389.7]	-5.7 [-15.2 3.9]	0.223	70.8 [58.7 82.9]	6.2 [-4.5 16.8]	0.234
		Intervention	53	390.1 [369.1 411.1]	-115.8 [-133.6 -97.9]	<0.001	60.8 [44.4 77.3]	114.1 [95.5 132.7]	<0.001
	Symptoms	Control	44	373.0 [349.1 396.8]	-8.3 [-18.3 1.7]	0.095	70.9 [51.5 90.3]	6.4 [-3.5 16.3]	0.186
		Intervention	65	375.3 [355.7 394.9]	-115.3 [-143.5 -87.1]	<0.001	72.6 [55.2 90.0]	113.6 [88.8 138.3]	<0.001
Upper extremity symptoms	No symptoms	Control	26	369.3 [352.1 386.5]	6.6 [-1.9 15.2]	0.118	72.6 [59.6 85.5]	-4.8 [-13.5 4.0]	0.262
		Intervention	36	384.7 [359.9 409.5]	-112.8 [-138.3 -87.2]	<0.001	62.3 [42.7 81.9]	109.6 [86.2 133.0]	<0.001
	Symptoms	Control	57	375.3 [357.7 392.8]	-13.4 [-24.4 -2.4]	0.021	70.1 [56.0 84.1]	11.4 [0.2 22.7]	0.046
		Intervention	82	380.7 [368.5 392.9]	-116.6 [-141.6 -91.7]	<0.001	69.5 [59.6 79.4]	115.6 [91.8 139.3]	<0.001

<sup>a</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering.

<sup>b</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering and adjusted for gender, age, sitting at work at baseline and mental work demands as confounders.

<sup>c</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering and adjusted for gender, age, standing at work at baseline and mental work demands as confounders.

Table 3. Baseline usual workplace sitting and standing bout durations and changes (three months versus baseline) in these behaviours, observed within intervention and control participants with and without musculoskeletal symptoms at baseline.

Musculoskeletal symptoms		Group	n	Baseline usual sitting bout duration (minutes) <sup>a</sup>	Change in usual sitting bout duration (minutes) <sup>b</sup>	p	Baseline usual standing bout duration (minutes) <sup>a</sup>	Change in usual standing bout duration (minutes) <sup>c</sup>	p
Low-back symptoms	No symptoms	Control	39	31.4 [22.4 40.5]	-0.2 [2.6 2.2]	0.852	1.4 [1.2 1.7]	-0.3 [-0.8 0.2]	0.232
		Intervention	57	34.4 [31.6 37.2]	-9.13[-11.6 -6.6]	<0.001	1.7 [1.2 2.2]	4.9 [4.2 5.7]	<0.001
	Symptoms	Control	44	30.6 [20.7 40.4]	-2.1 [-4.9 0.7]	0.129	1.7 [1.4 2.0]	0.4 [0.0 0.8]	0.043
		Intervention	61	30.0 [23.8 36.2]	-5.9 [-9.2 -2.7]	0.002	1.8 [1.2 2.4]	3.7 [3.0 4.3]	<0.001
Lower extremity symptoms	No symptoms	Control	39	31.3 [21.1 41.5]	-0.8 [-2.2 0.6]	0.250	1.7 [1.2 2.1]	0.34[-0.1 0.9]	0.131
		Intervention	53	33.4 [27.3 39.6]	-7.8 [-10.4 -5.1]	<0.001	1.6 [1.0 2.3]	4.5 [3.9 5.2]	<0.001
	Symptoms	Control	44	30.7 [23.8 37.5]	-1.6 [-5.5 2.2]	0.374	1.5 [1.2 1.7]	-0.2 [-0.5 0.2]	0.291
		Intervention	65	31.1 [26.1 36.1]	-7.2 [-10.6 -3.9]	<0.001	1.9 [1.3 2.4]	4.0 [3.1 5.0]	<0.001
Upper extremity symptoms	No symptoms	Control	26	33.1 [20.5 45.8]	-0.7 [-2. 8 1.3]	0.462	1.6 [1.4 1.8]	0.0 [-0.6 0.7]	0.876
		Intervention	36	33.4 [27.1 39.7]	-8.2 [-11.0 -5.4]	<0.001	1.6 [1.2 2.0]	4.5 [3.2 5.9]	<0.001
	Symptoms	Control	57	30.0 [25.5 34.5]	-1.5 [-4.1 1.1]	0.240	1.6 [1.2 1.9]	0.1 [-0.3 0.5]	0.599
		Intervention	82	31.6 [27.9 35.3]	-7.1 [-9.9 -4.4]	<0.001	1.8 [1.3 2.4]	4.2 [3.6 4.7]	<0.001

<sup>a</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering

<sup>b</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering and adjusted for gender, age, sitting bout at baseline and body height as confounders.

<sup>c</sup> Adjusted mean and 95% confidence interval (95%CI), using linearized variance estimation to account for workplace clustering and adjusted for gender, age, standing bout at baseline, smoking, mental work demands and general fatigue as confounders.

Table 4. Intervention effects at three months on time at the workplace spent sitting and standing, and on usual sitting and standing bout duration at the workplace by the presence or absence of musculoskeletal symptoms at baseline (n=201).

Outcome	Musculoskeletal symptom group	Low-back		Lower-extremity		Upper-extremity	
		Intervention effect (95% CI) <sup>a</sup>	p	Intervention effect (95% CI) <sup>a</sup>	p	Intervention effect (95% CI) <sup>a</sup>	p
Sitting time (minutes/8-hr workday) <sup>b</sup>	No symptoms	-126.6 [-151.4 -101.7]	<0.001	-110.1 [-130.5 -89.6]	<0.001	-119.4 [-148.2 -90.6]	<0.001
	Symptoms	-91.9 [-120.7 -63.1]	<0.001	-107.0 [-136.0 -78.0]	<0.001	-103.2 [-132.1 -74.4]	<0.001
	Difference (Symptoms – No symptoms) <sup>f</sup>	34.6 [0.9 68.3]	0.040	3.1 [-28.8 35.0]	0.838	16.2 [-28.3 60.7]	0.446
Standing time (minutes/8-hr workday) <sup>c</sup>	No symptoms	125.4 [104.7 146.2]	<0.001	108.0 [86.9 129.1]	<0.001	114.3 [87.3 141.4]	<0.001
	Symptoms	91.1 [63.3 118.9]	<0.000	107.1 [80.6 133.7]	<0.001	104.1 [76.3 131.9]	<0.001
	Difference (Symptoms – No symptoms) <sup>f</sup>	-34.3 [-65.5 -3.0]	0.034	-0.8 [-32.8 31.2]	0.957	-10.2 [-55.2 34.8]	0.632
Usual workplace sitting bout duration (mins) <sup>d</sup>	No symptoms	-8.9 [-12.5 -5.4]	<0.001	-7.0 [-9.9 -4.1]	<0.001	-7.5 [-10.9 -4.1]	<0.001
	Symptoms	-3.8 [-8.0 0.3]	0.067	-5.6 [-10.9 -0.3]	0.040	-5.7 [-9.7 -1.7]	0.009
	Difference (Symptoms – No symptoms) <sup>f</sup>	5.1 [0.2 9.9]	0.042	1.4 [-5.0 7.8]	0.643	1.9 [-3.1 6.8]	0.433
Usual workplace standing bout duration (mins) <sup>e</sup>	No symptoms	5.2 [4.4 6.1]	<0.001	4.2 [3.4 5.0]	<0.001	4.5 [3.0 5.9]	<0.001
	Symptoms	3.2 [2.5 3.9]	<0.001	4.2 [3.2 5.2]	<0.001	4.1 [3.3 4.8]	<0.001
	Difference (Symptoms – No symptoms) <sup>f</sup>	-2.0 [-3.2 -0.8]	0.003	0.0 [-1.4 1.5]	0.938	-0.4 [-2.2 1.4]	0.642

<sup>a</sup> Intervention effect is change (three months - baseline) for the intervention minus the control group, adjusting for confounders, using linear regression models with a linearized variance estimator to account for workplace level clustering.

<sup>b</sup> Using linearized variance estimation to account for workplace clustering and adjusted for gender, age, sitting at work at baseline and mental work demands as confounders.

<sup>c</sup> Using linearized variance estimation to account for workplace clustering and adjusted for gender, age, standing at work at baseline and mental work demands as confounders.

<sup>d</sup> Using linearized variance estimation to account for workplace clustering and adjusted for gender, age, sitting bout at baseline and body height as confounders.

<sup>e</sup> Using linearized variance estimation to account for workplace clustering and adjusted for gender, age, standing bout at baseline, smoking, mental work demands and general fatigue as confounders.

<sup>f</sup> Depicting the interaction term for group allocation x baseline musculoskeletal symptoms

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## Calculation of 'usual' bout durations

The appropriate distributions to assume for standing are not known. Active (non-sitting) bouts have been argued to follow a log-normal distribution<sup>38</sup>. The distribution of standing bouts (with duration rounded up to the nearest second) are plotted in Figure A1, alongside a log-normal distribution. The approach used to calculate usual sitting bout duration ( $W_{50}$ ) was as the midpoint of the cumulative distribution function for sitting bouts, which have been shown to follow a power-law distribution<sup>28 38 39</sup>. In this approach, the outcome ( $y$ , cumulative proportion of standing time accrued in bouts of duration  $\leq t$ ) is modelled in a non-linear regression (Marquadt method) as a function of bout duration ( $t$ ), usual bout duration ( $W_{50}$ ) and the free parameter ( $n$ ) in the form of:

$$y = \frac{t^n}{t^n + (W_{50})^n}$$

The same approach to determining the accumulation midpoint was used to estimate the standing accumulation midpoint, as a generic curve fitting method. We evaluated the appropriateness of the curve-fitting technique as an approximation for the midpoint by plotting observed data against the predicted curve and its 95% confidence intervals. The observed data closely followed the fitted curve, especially around the midpoint. The method appeared to perform acceptably in approximating the mid-point of standing time accumulation (just over one minute). All bouts are shown in Figure A2 and only the short bouts of less than five minutes in Figure A3.

Figure A1: Frequency distribution of standing bouts (log-log plot).

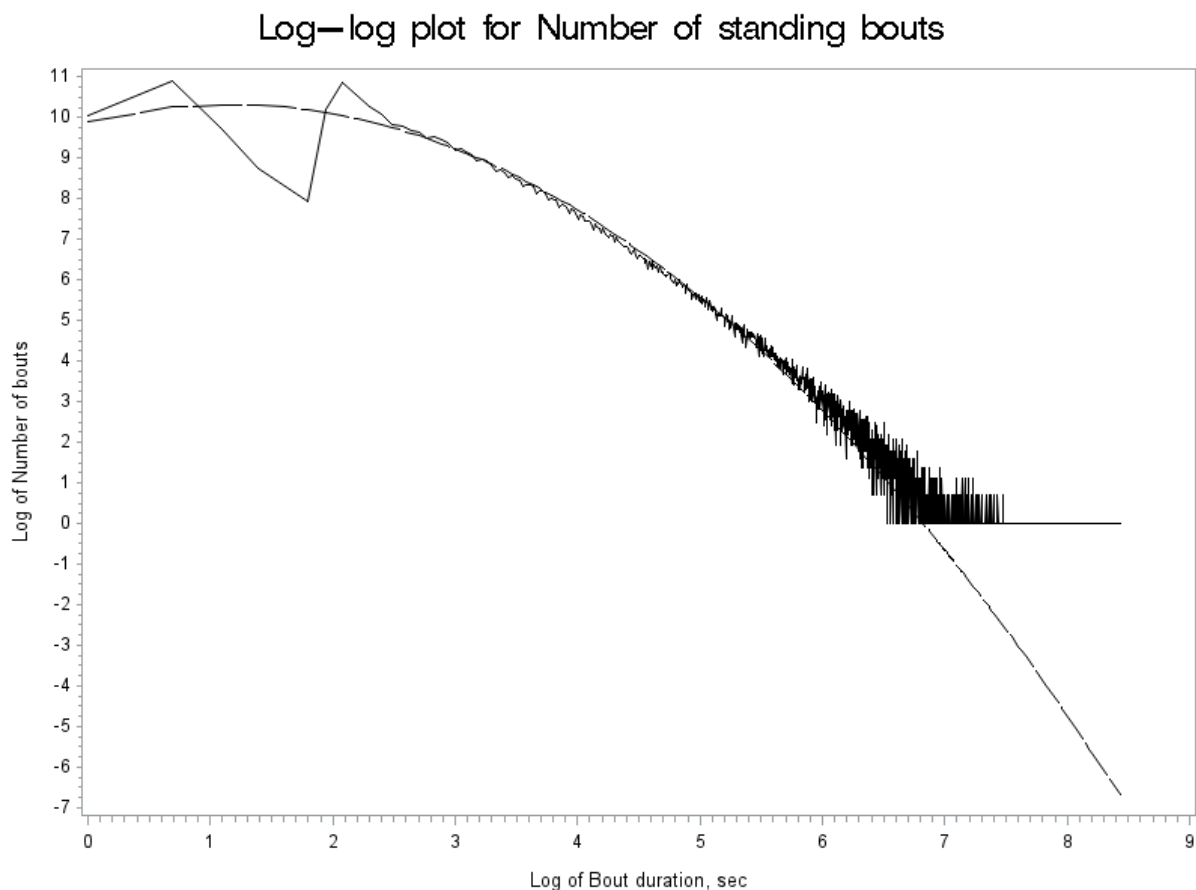


Figure A2: Standing time accumulation in bouts of each duration and shorter: observed and as estimated by the curve fitting method

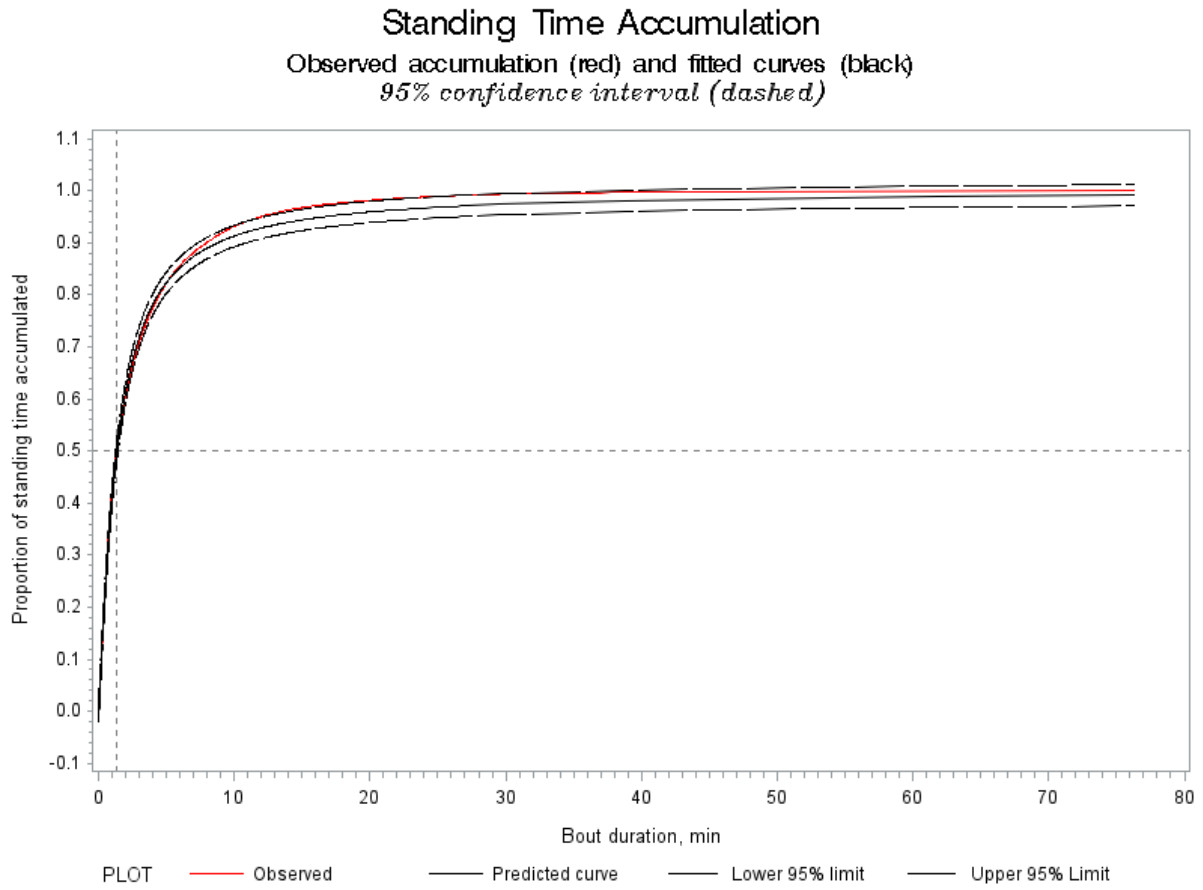
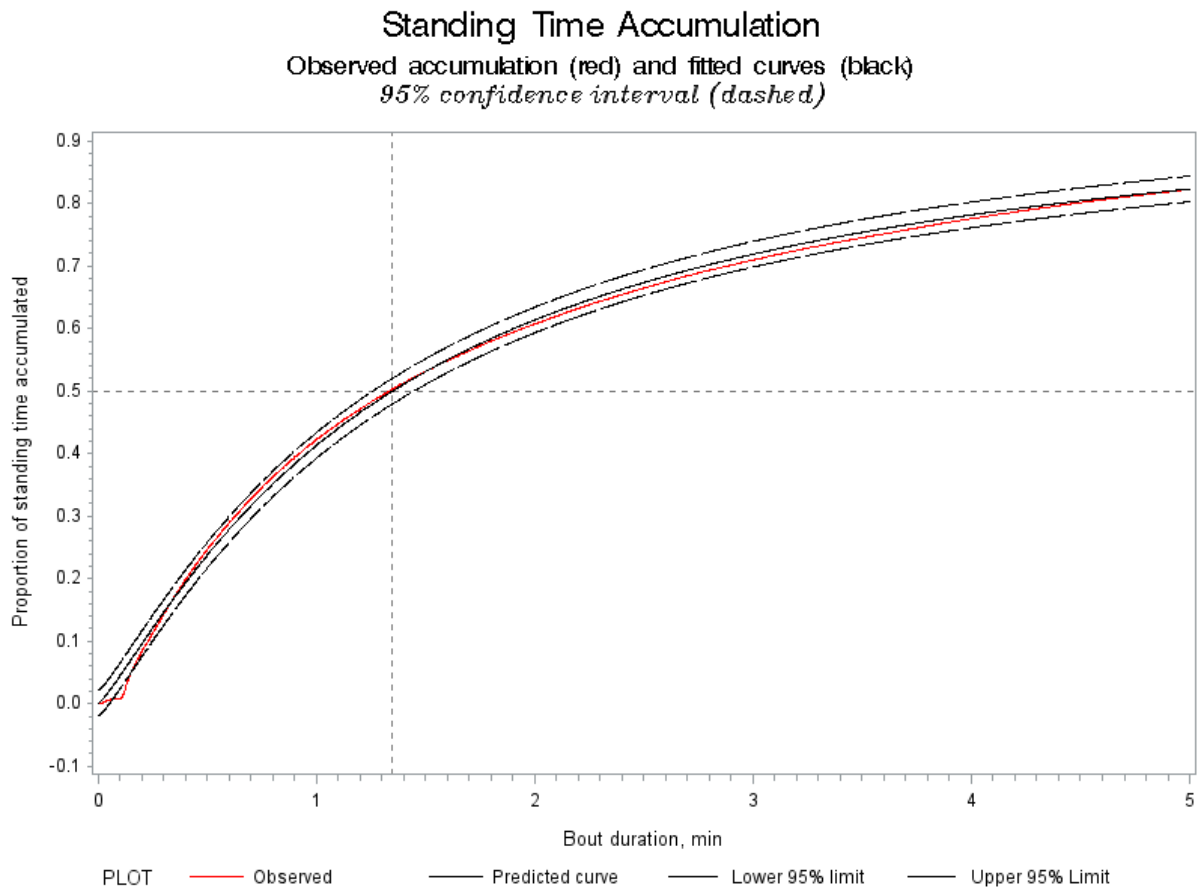


Figure A3: Standing time accumulation in bouts of each duration and shorter: observed and as estimated by the curve fitting method, only bouts  $\leq 5$  minutes shown.



Overview of confounding variables

Independent variable used in the model	Dependent variable used in model	Table in which the model is presented	A priori selection of confounders	A posteriori adjustment of confounders
Low-back, lower extremity and upper extremity symptoms, respectively	Change in sitting time at work	2 and 4	<u>Fixed</u> Baseline sitting time at work, age and gender <u>Step-wise selection</u> Smoking, height, waist circumference, work productivity, mental demands at work and fatigue	Age, gender, baseline sitting time at work and mental work demands
Low-back, lower extremity and upper extremity symptoms, respectively	Change in standing time at work	2 and 4	<u>Fixed</u> Baseline standing time at work, age and gender <u>Step-wise selection</u> Smoking, height, waist circumference, work productivity, mental demands at work and fatigue	Age, gender, baseline standing time at work and mental work demands
Low-back, lower extremity and upper extremity symptoms, respectively	Change in usual sitting bout duration at work	3 and 4	<u>Fixed</u> Baseline sitting bout duration at work, age and gender <u>Step-wise selection</u> Smoking, height, waist circumference, work productivity, mental demands at work and fatigue	Age, gender, baseline sitting bout duration at work and body height
Low-back, lower extremity and upper extremity symptoms, respectively	Change in usual standing bout duration at work	3 and 4	<u>Fixed</u> Baseline standing bout duration at work, age and gender <u>Step-wise selection</u> Smoking, height, waist circumference, work productivity, mental demands at work and fatigue	Age, gender, baseline standing bout duration at work, smoking, mental work demands and general fatigue

Association of pre-existing symptoms with the odds of dropping out during the three-month intervention period. Associations were performed on the total group of participants eligible to participate (n=231), those randomized into the control group (n=95) and those randomised in the intervention group (n=136).

		Total (n=231)				Control group (n=95)			Intervention group (n=136)				
		Drop out (n=30)	In study (n=201)	OR [95% CI] <sup>a</sup>	p	Drop out (n=12)	In study (n=83)	OR [95% CI] <sup>a</sup>	p	Drop out (n=18)	In study (n=118)	OR [95% CI] <sup>a</sup>	p
Low-back symptoms	No symptoms	11 (10%)	96 (90%)	1.16 [0.47 2.85]	0.72	4 (9%)	39 (91%)	1.11 [0.25 4.99]	0.87	7 (11%)	57 (89%)	1.20 [0.29 4.96]	0.76
	Symptoms	14 (12%)	105 (88%)			5 (10%)	44 (90%)			9 (13%)	61 (87%)		
Lower extremity symptoms	No symptoms	12 (12%)	92 (88%)	0.91 [0.54 1.56]	0.72	4 (9%)	39 (91%)	1.11 [0.48 2.57]	0.78	8 (13%)	53 (87%)	0.82 [0.35 1.91]	0.58
	Symptoms	13 (11%)	109 (89%)			5 (10%)	44 (90%)			8 (11%)	65 (89%)		
Upper extremity symptoms	No symptoms	4 (6%)	62 (94%)	2.34 [0.90 6.11]	0.08	1 (4%)	26 (96%)	2.11 [0.89 15.00]	0.07	3 (8%)	36 (92%)	1.90 [0.40 8.94]	0.35
	Symptoms	21 (13%)	139 (87%)			8 (12%)	57 (88%)			13 (14%)	82 (86%)		

% = row percent within intervention / control arm.

<sup>a</sup> Using linearized variance estimation to account for workplace clustering