Using sit-to-stand workstations in offices: is there a compensation effect?

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Short title: Sedentary behavior compensation

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Abstract

Purpose: Sit-to-stand workstations are becoming common in modern offices and are increasingly being implemented in sedentary behavior interventions. The purpose of this study was to examine whether the introduction of such a workstation among office workers leads to reductions in sitting during working hours, and whether office workers compensate for any reduction in sitting at work by increasing sedentary time and decreasing physical activity (PA) outside work.

Methods: Office workers (n=40; 55% female) were given a WorkFit-S, sit-to-stand workstation for 3 months. Participants completed assessments at baseline (prior to workstation installation), 1-week and 6-weeks after the introduction of the workstation, and again at 3-months (post-intervention). Posture and PA were assessed using the activPAL inclinometer and ActiGraph GT3X+ accelerometer, which participants wore for 7-days during each measurement phase.

Results: Compared to baseline, the proportion of time spent sitting significantly decreased (75±13% versus 52±16 - 56±13%), and time spent standing and in light activity significantly increased (standing: 19±12% versus 32±12 - 37±15%, light PA: 14±4% versus 16±5%) during working hours at all follow-up assessments. However, compared to baseline, the proportion of time spent sitting significantly increased (60±11% versus 66±12 - 68±12%) and light activity significantly decreased (21±5% versus 19±5%) during non-working hours across the follow-up measurements. No differences were seen in moderate-to-vigorous activity during non-working hours throughout the study.

Conclusion: The findings suggest that introducing a sit-to-stand workstation can significantly reduce sedentary time and increase light activity levels during working hours. However, these changes were compensated for by reducing activity and increasing sitting outside of working

hours. An intervention of a sit-to-stand workstation should be accompanied by an intervention outside of working hours to limit behavior compensation.

Key words: Standing desk, Sedentary behavior, Sedentary compensation, office workers, Physical activity, Occupational health

Introduction

Technological and social changes have significantly influenced the way we socialize, travel, work and spend our leisure time, and this has resulted in substantial proportions of the day spent in sedentary pursuits (i.e. sitting) (11). Sedentary behavior has recently been defined as "any waking behavior characterized by an energy expenditure of $\leq$1.5 METs while in a sitting or reclining posture" (p 540) (27). It refers to too much sitting rather than too little physical activity.

A growing body of epidemiological evidence has linked sedentary behavior to health risks including an increased risk of type 2 diabetes (3, 31), metabolic syndrome (12), cancer (3, 21), obesity (7) and all-cause and CVD mortality (3, 31). These associations have been shown to be at least partially independent of moderate-to-vigorous physical activity (MVPA). Recent reviews have noted that there is an inverse association between some sedentary behaviors (mostly TV viewing or screen time) and leisure-time physical activity in adults (22, 26), providing evidence for time displacement (where opportunities for physical activity are replaced by sedentary pursuits). Furthermore, using isotemporal substitution modelling, replacing sitting with standing, walking and/or MVPA has been shown to reduce the risk of all-cause mortality (28). Conversely the amount of light-intensity activity accumulated, for example during non-exercise related standing activities, has been linked to improved metabolic health, independent of MVPA (17).

Adults typically spend time sitting in three domains: the workplace, during leisure time (e.g. at home such as in front of a television) and for transport (8). Many adults in the UK are employed within sedentary occupations such as office work, and the majority of office workers' time is spent in sitting activities (10, 19). A recent study has shown that office workers typically sit for

>10 hours/day, with over half of their total daily sitting time occurring in the workplace (10). The workplace, therefore, represents a promising environment in which to undertake interventions to reduce sitting time.

The incorporation of sit-to-stand workstations may be an effective strategy for reducing sitting at work. Limited evidence has been published to date on the utility of sit-to-stand workstations although studies are now emerging (1, 6, 18, 24, 29). According to the ActivityStat hypothesis, when physical activity is increased or decreased in one domain, there will be a compensatory change in another domain, in order to maintain an overall stable level of physical activity or energy expenditure over time (15). However, studies examining compensation of sedentary behavior or physical activity with the use of sit-to-stand workstations in office workers are rare (1). The question remains therefore whether those using sit-to-stand workstations during working hours compensate by sitting for longer or being less active outside of work. This study investigated sedentary behavior and physical activity compensation outside working hours in a sample of office workers exposed to sit-to-stand desks in the workplace.

Methods

Participants

A convenience sample of office workers from a range of administrative departments (including: engineering, finance, facilities and health sciences) from a UK university who had primarily desk-based jobs and the capacity to include a sit-to-stand workstation on their desk were recruited. Participants with the following conditions were excluded from the study: physical condition or illness which prevented full participation in the study, inability to communicate in spoken English, pregnant at baseline, planning relocation to another worksite or planning a holiday during the study period. The study received ethical approval from the Loughborough University Ethical Advisory Committee and participants provided written informed consent.

Familiarization visit and screening

Potential participants were invited to the laboratory at least 2 weeks before the main trial for a familiarization visit. During this visit, participants were screened for inclusion/exclusion into the study using a standard health screening tool. Following successful screening, eligible participants were shown the sit-to-stand workstation, ActiGraph and activPAL assessment devices and provided with an opportunity to try the workstation, familiarize themselves with the measurement devices and ask questions about the study protocol. During this visit, anthropometric measures were taken which included height (measured using a portable stadiometer, Seca UK), waist circumference (measured mid-way between the lower rib margin and the iliac crest using anthropometry tape), and body weight and composition (measured using a Tanita Body Composition Analyzer, model: BC-418 MA, Tanita, UK). Participants were asked to wear the ActiGraph and activPAL for the following 14-days to assess habitual physical activity and sedentary behavior prior to desk installation.

Objectively measured sitting time and physical activity

Participants wore an activPAL3 inclinometer (PAL Technologies, Glasgow, Scotland), which provides a direct measure of postural allocation (sitting/lying, standing, sit-to-stand transitions) and walking. The activPAL3 is a single-unit monitor based on a uniaxial accelerometer which is worn on the anterior aspect of the thigh (2). The monitor produces a signal related to thigh inclination and has been shown to be a valid and reliable measurement tool for determining posture during activities of daily living in a healthy population (16, 20). The activPAL was placed within a nitrile sleeve and attached to the leg using a waterproof hypoallergenic medical dressing (BSN Hypafix), enabling participants to wear the device continuously for 24 hour/day. Participants were asked to wear the activPAL continuously for two weeks following the familiarization and anthropometry screening visit at baseline, and for seven consecutive days on a further 3 separate occasions: one-week, 6-weeks and 3-months after receiving the sit-to-stand workstation. To be included in the analyses, participants were required to have provided at least four full days (>600 minutes of wear) of data (including at least 3 workdays and 1 non-workday) during each monitoring period.

Along with the activPAL, participants were also asked to wear an ActiGraph GT3X+ accelerometer throughout waking hours (ActiGraph, Pensacola, FL, USA) to assess free-living physical activity. In addition to the assessment of physical activity, the accelerometer also provided an *estimate* of sedentary time through a lack of movement counts (2). The widely used <100 counts/minute (cpm) cut-point was employed to estimate sedentary time (2) whilst the Freedson cut-points were used to estimate time spent in light intensity activity (100 – 1951 cpm) and MVPA (≥ 1952 cpm) (13). Accelerometer data were considered valid if there were more than 600 minutes of monitoring per day (excluding continuous strings of zero counts for 60 minutes or longer) recorded on at least three workdays and one non-workday on each measurement time point (23).

A two week monitoring period was initially chosen at baseline to examine any reactivity occurring in response to the measurement protocol (9). As no significant differences in any behavior measured occurred between these two weeks (data not shown), the data were averaged across weeks, and seven-day monitoring periods were applied during the follow-up periods. Participants were asked to complete an activity monitor log book over each monitoring period for both the activPAL and ActiGraph in order to document start and finish work times on working days, occurrences of monitor removal and sleep patterns (i.e. time in bed). Participants sleeping times, monitor removal and invalid days were excluded.

Experimental protocol

Following the 14 day baseline assessment, participants received a WorkFit-S, sit-to-stand workstation (Ergotron, Inc, St. Paul, MN, USA) for 3 months alongside a 6-page booklet including information about the advantages of sit-to-stand working. The booklet also contained some guidelines about the desk height adjustment and also introduced an online planning tool for comfortable computing (www.computingcomfort.org). Participants then undertook three, 7-day assessment phases: 1-week, 6-weeks, and 3-months after the desk had been installed. The 1-week follow-up took place 1–3 days after completion of the baseline assessment, with this assessment also corresponding with the first 7 days following workstation installation.

Data processing and analysis

As with any accelerometer worn on the hip, the ActiGraph is not capable of detecting sitting time due to its inability to directly measure posture (2). Therefore whilst the ActiGraph accelerometer provides an estimate of sedentary time, these data were included in the results for descriptive purposes only. activPAL-determined sitting, standing and stepping time data were used primarily to address the research question of whether the use of sit-to-stand workstations led to changes in these behaviors during and outside working hours. The ActiGraph data were primarily used to determine whether time in different physical activity intensities (light activity and MVPA) differed during and outside working hours over the intervention period.

All activPAL data were downloaded using manufacturer proprietary software (activPAL Professional v.7.2.29) in 15-s epochs and processed using a customized Microsoft Excel macro. The number of minutes that participants spent sitting, standing and stepping during waking hours (based on participants log book entries) were obtained for each working day. To enable the examination of the influence of the sit-to-stand desks on behavior during working and non-working hours, sitting, standing and stepping time were extracted for working and non-working hours (based on provided diary logs) from the daily weekday data. To account for differences in activPAL wear times between each segment of the day (working/non-working hours) and between the baseline and follow-up assessments, the proportions of wear time spent sitting, standing and stepping were calculated for each participant during each measurement period. These data were used in the analyses as opposed to the absolute minute data.

All ActiGraph data were downloaded using manufacturer proprietary software (ActiLife v.6.11.8) in 15-s epochs and processed using a customized Microsoft Excel. The number of minutes that participants spent in sedentary behavior, and in light-intensity activity and MVPA during waking hours was obtained for each working day. As with the activPAL data (and using the same procedures), times spent sedentary, and in light intensity activity and MVPA were calculated throughout waking hours, and during working and non-working hours on workdays. To control for differences in accelerometer wear time, the proportions of time spent in each type of behavior were used in the analyses. Absolute minute data derived from both the activPAL and ActiGraph are presented in the results for descriptive purposes. All participants complied to the monitoring protocol and provided at least 3 workdays and 1 non-workday of activPAL and ActiGraph data during each measurement period. Any days with missing data (due to monitor removal) were treated as missing data and the mean time, and proportion of time, spent in each behavior during and outside of working hours were calculated from the remaining data.

The Shapiro–Wilk test confirmed that all proportion and minute data from both devices were normally distributed. For the activPAL and ActiGraph data, the mean proportions of times spent in each behavior on workdays at baseline, 1-week, 6-weeks and 3-months follow-up were calculated for each domain (waking hours, working and non-working hours) and compared using repeated measures ANOVA's. In the event of a significant ANOVA result, Bonferroni-corrected post hoc comparisons were undertaken to determine where the significant differences occurred. $P < 0.05$ was considered significant, unless otherwise stated, and all tests were 2-sided. All statistical analyses were performed using SPSS v.22 (SPSS Inc., Chicago, IL, USA). Data are displayed as mean (± SD) in the text and tables.

Results

Forty male and female office workers age 18 - 65 years completed the study, representing a 100% retention and compliance rate. Participant characteristics are displayed in Table 1.

activPAL-determined sitting, standing and stepping time

Total sitting time on workdays significantly decreased from 605±83 mins/day at baseline to 517±70 mins/day at 1-week, 546±65 mins/day at 6-weeks and 561±65 mins/day at 3-months follow-up ($p<0.001$). Total standing time increased significantly from 289±80 mins/day at baseline to 383±85 min/day at 1-week, 350±70 min/day at 6-weeks and 344±68 min/day at 3-months follow-up ($p<0.001$). No differences were seen for total stepping time. At baseline participants spent 605±83 mins/day sitting on a workday, compared to 357±149 mins/day sitting on a non-workday ($p<0.001$). On workdays 49.3 % of daily sitting time was derived from sitting at work.

During working hours, compared to baseline, the proportion of time spent sitting significantly decreased at 1-week, 6-weeks and 3-months follow-up ($p<0.01$), while the proportion of time spent standing and stepping significantly increased at all follow-up periods ($p<0.01$) (Table 2). During non-working hours, compared to baseline, the proportion of time spent sitting significantly increased at 6-weeks and 3-months follow-up while the proportion of time spent stepping significantly decreased at 1-week, 6-weeks and 3-months follow-up ($p<0.01$). No differences were seen in standing time during non-working hours (Table 2).

ActiGraph-determined physical activity and sedentary time

At baseline participants spent 148±31 mins/day in light intensity activity, equating to 16.7% of waking hours. During week 1 of workstation use, daily time in light activity increased to 157±25 mins/day (17.6% of waking hours). There were no significant changes in the overall proportions of times participants spent in light activity on workdays at 6-weeks and 3-months follow-up. At baseline, participants spent 47±16 mins/day in MVPA (5.4% of waking hours) on workdays. There were no significant changes in the overall proportion of times spent in MVPA on workdays at each follow-up period.

During working hours, compared to baseline, the proportion of time spent in light activity significantly increased at 1-week, 6-weeks and 3-months follow-up ($p<0.01$). The proportion of time spent in MVPA during working hours also increased significantly at 1-week and 6-weeks. During non-working hours, compared to baseline, the proportion of time in light activity significantly decreased at 1-week and 6 weeks follow-up. No significant differences were seen in MVPA during non-working hours. Small, but significant decreases in ActiGraph-determined sedentary time were seen during working hours, relative to baseline, in weeks 1 and 6. Correspondingly, small increases in ActiGraph-determined sedentary time were seen outside working hours in weeks 1 and 6 (Table 3).

Discussion

This study provides novel evidence of the presence of sedentary behavior compensation outside working hours in office workers utilizing sit-to-stand workstations. At baseline participants were sedentary for ~10 hrs/day on a workday, with ~50% of this total daily sedentary time coming from sitting at work. This is in line with previous research (10, 11) and confirms the importance of the workplace as a site highly suitable for interventions to reduce sitting time (19). Results from the current study showed that using sit-to-stand workstations is an effective way of reducing sedentary time during working hours. This result is consistent with other studies (1, 6, 18, 24). However, for the first time, this study examined compensation of sedentary behavior outside working hours and findings indicated that participants were more sedentary during non-working hours at 1-week, 6-weeks and 3-months after workstation installation, compared to baseline.

Despite the compensation effect observed in the present study, overall sedentary time across the day was still reduced when participants were using sit-to-stand desks at work. Total daily sedentary times fell to approximately 8.5 hours/day during week 1 of desk use, and gradually rose to 9 hours/day at week 6 and to 9 hours 20 minutes/day at 3-months. Evidence has demonstrated an increased risk of coronary heart disease and mortality in individuals sitting for over 10 hours/day (25). The reductions in daily sitting times observed in the present study, if maintained, could therefore have meaningful health benefits. Our knowledge of a specific duration of sitting time that represents an increased risk of disease is incomplete however, with other research demonstrating that chronic disease risk is increased with sitting durations of over 8 hours/day (14).

The findings also demonstrate that using sit-to-stand workstations are an effective way of increasing standing and stepping time during working hours. These findings are consistent with other studies (1, 6, 18, 24). Thus as a result of the intervention, participants time in light intensity activity significantly increased during working hours. Slight increases in MVPA were also observed during working hours during the early weeks of the intervention. A recent study has shown that reallocating just 30 minutes of sedentary time per day to light movement is associated with a 2–4% improvement in cardio-metabolic biomarkers (5). Also there is evidence which suggests replacing sedentary time with light-intensity physical activity or MVPA is associated with positive influences on insulin sensitivity (32) and plasma glucose (30). Such changes observed in light intensity activity during working hours could lead to important health benefits in previously sedentary office workers.

Results from the activPAL, in terms of stepping time, and findings from the ActiGraph, in terms of time in light intensity activity, both confirmed that the proportion of time in these behaviors reduced outside of working hours during sit-to-stand workstation use. These findings suggest that in order for originally sedentary workers to achieve optimum benefits from sit-to-stand working, interventions and public health messages should also target the promotion of light intensity activities outside of the workplace. Of interest, time in MVPA did not change outside of working hours in the present sample, suggesting that the use of sit-to-stand desks in the workplace may not have a detrimental effect on leisure time MVPA.

Findings of the current study lend partial support to the ActivityStat hypothesis which proposes that as physical activity is increased or decreased in one domain, there will be a compensatory change in another domain (15). Whilst we saw reductions in sedentary time and increases in light intensity activity during working hours and compensatory changes in these behaviors outside working hours, the magnitude of the compensatory changes were not as great as the changes in sitting and light activity seen during working hours, suggesting that participants did not fully compensate for the beneficial changes made during working hours.

Participants' standing time during working hours increased from 91 minutes (~1.5 hours) at baseline to 237 minutes (~4 hours, an increase of 146 minutes) in week 1, dropping to ~3.5 hours during the subsequent follow-up measurement periods. Whilst direct comparisons with other sit-to-stand workstation interventions are difficult, due to differences in procedures adopted for data processing, the magnitude of the changes in standing time seen in the present study is similar to those observed in other interventions. For example, when normalizing their data to an 8-hour workday, Healy et al.(18) and Alkhajah et al.(1) reported increases in standing time of 121 and 130 minutes/day, in their intervention groups, relative to baseline. According to a recent expert statement, office workers should set their goal to achieve 2 hours/day of standing and light activity (light walking) during working hours, eventually progressing to a total accumulation of 4 hours/day (4). It is recommended in the statement that sit-to-stand desks could be a useful tool in which to support office workers in achieving these goals. The present study supports this statement. The findings indicate however that sit-to-stand desks may not be sufficient over the long term and therefore in order to keep participants motivated, interventions may need to go beyond simply installing sit-to-stand desks. For example, additional strategies such as educational material on the negative health effects of prolonged sitting, and/or office activities to encourage standing or stepping may need to be adopted in order for office workers to achieve and sustain the recommendations in this expert statement. It should be noted that these recommendations were not based on a comprehensive review of the literature, and further interventions are required to assess their feasibility, adherence and impact on health.

Whilst the activPAL provided the primary measure of sitting in the present study, ActiGraph-determined sedentary time (using the <100 cpm cut-point) was also presented for descriptive purposes. Discrepancies between these two common measures were observed. During working hours at baseline, participants spent 76% of their time sitting according to the activPAL, while the proportion of time spent sedentary according to the ActiGraph was 82%. In week one of the intervention, according to the activPAL the proportion of time spent sitting at work decreased to 52% (representing a reduction of 24%), while the proportion of time spent sedentary at work decreased to only 78% (a reduction of 4%) when assessed by the ActiGraph. These observations suggest that the ActiGraph cut-point approach is not sensitive enough to measure changes in sedentary behavior in interventions, supporting earlier observations (20).

This study provides novel information on how sedentary behavior and physical activity are compensated outside working hours in a sample of office workers from the UK exposed to sit-to-stand desks. The objective measurement of posture and physical activity using the activPAL ActiGraph are strengths of this study as such measures overcome the limitations of bias and recall, common with self-report measures. Limitations of this study include the small and relatively homogenous convenience sample and relatively short term follow-up (3 months). The 100% compliance rates to all measurement phases and the relatively large changes seen in sitting and standing during working hours suggest the present sample may have been a highly motivated group. Similarly high compliance and follow-up rates have been observed however in other workplace sit-to-stand desk interventions, with reported follow-up rates ranging from 81-100% (1, 6, 18, 24). Further research should examine the impact of sit-to-stand workstations on sedentary time during and outside working hours in diverse groups to extend the generalizability of the present and existing studies. This study did not employ a process evaluation or any qualitative components. Further research would benefit from the inclusion of such components to help further our understanding of whether participants consciously or sub-consciously change their behaviors outside of the working environment.

In conclusion, the findings suggest that introducing sit-to-stand workstations can significantly reduce sedentary time and increase light activity levels during working hours. However, it appears that the changes in sedentary behavior and physical activity during working hours were compensated for by reducing activity and increasing sedentary behavior outside of working hours. Nonetheless, despite this compensation effect, overall sedentary time was still reduced when office workers used the sit-to-stand workstations relative to their traditional seated desk. Such overall reductions in sedentary time and increases in light activity could lead to substantial health benefits in traditionally sedentary workers. Further research is required to examine the long-term use of sit-to-stand desks on changes in sedentary time, and resultant effects on markers of health. Further studies investigating the notion of behavior compensation are also warranted.

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Conflict of Interest

The desks used in this study were supplied via an in-kind donation from Ergotron Inc, USA. The company played no role in the study design, analyses, or in the preparation of this manuscript. The results of the present study do not constitute endorsement by ACSM.

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Table 1. Demographic characteristics of the study sample (data are presented as the mean±SD)

	Males (n = 18)	Females (n = 22)
Age (years)	31.5±8.6	32.3±7.9
Height (cm)	177.4±7.4	165.3±6.2
Weight (kg)	81.5±12	66.6±15.1
BMI (kg/m^2)	25.9±3.5	24.3±4.9
Percent body fat	25.9±3.5	29±10.2
Waist circumference (cm)	85.5±8.7	75.9±10.8

Table 2. activPAL-determined time spent sitting, standing and stepping during and outside working hours on workdays at baseline, 1-week, 6-weeks and 3-months follow-up following sit-to-stand workstation use. Data are presented as the mean±SD. To control for wear time, the proportion data were used in the primary analyses, however the absolute time data (in minutes) are provided for descriptive purposes.

	Working hours on workdays				Non-working hours on workdays			
	Baseline	Week 1	Week 6	3 Months	Baseline	Week 1	Week 6	3 Months
% of wear time spent sitting	76±13	52±16*	56±13*	56±13*	60±11	64±11	66±12*	68±12*
Time spent sitting (mins)	299±85	254±81*	259±63	266±66	307±82	264±59*	287±66	295±62
% of wear time spent standing	19±12	37±15*	33±12*	32±12*	26±8	24±8	24±9	23±9
Time spent standing (mins)	92±50	238±92*	207±71*	208±66*	198±69	146±47*	144±55*	136±50*
% of wear time spent stepping	5±3	11±5*	12±5*	12±4*	14±5	12±5*	11±4*	9±4*
Time spent stepping (mins)	19±8	52±22*	54±24*	58±17*	71±31	48±23*	45±20*	40±17*
Wear time (mins)	409±69	544±58	519±45	532±47	574±117	457±58	475±73	471±67

*Significantly different to baseline.

Table 3. ActiGraph-determined time spent sedentary, in light activity and MVPA during and outside working hours on workdays at baseline, 1-week, 6-weeks and 3-months follow-up following sit-to-stand workstation use. Data are presented as the mean±SD. To control for wear time, the proportion data were used in the primary analyses, however the absolute time data (in minutes) are provided for descriptive purposes.

	Working hours on workdays				Non-working hours on workdays			
	Baseline	Week 1	Week 6	3 Months	Baseline	Week 1	Week 6	3 Months
% of wear time spent sedentary	82±5	78±7*	79±6*	80±6	70±7	73±8*	74±8*	72±7
Time in sedentary behavior (mins)	333±40	374±43*	366±41*	366±47*	316±42	299±40*	253±49*	321±56
% of wear time in light activity	14±4	16±6*	16±5*	16±5	21±5	19±5*	19±5*	20±6
Time in light activity (mins)	53±18	79±27*	73±22*	72±24*	96±29	79±23*	78±24*	72±23*
% of wear time in MVPA	4±1	6±3*	5±3*	5±2	9±5	8±6	7±5	8±6
Time in MVPA (mins)	16±8	24±12*	21±10*	17±7	32±19	26±21	24±16*	31±21
Wear time (mins)	440±44	482±34	464±33	458±40	451±63	410±36	412±57	445±67

*Significantly different to baseline.