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Effects of an "Active-Workstation" Cluster RCT on Daily Waking Physical Behaviors

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Abstract

Purpose: Evaluate the effects of sit-to-stand and treadmill desks on sedentary behavior during a 12-month, cluster-randomized multi-component intervention with an intent-to-treat design in overweight office workers.

Methods: Sixty-six office workers were cluster-randomized into a: control (N=21; clusters=8), sit-to-stand desk (N=23; clusters=9) or treadmill desk (N=22; clusters=7) group. Participants wore an activPAL™ accelerometer for 7 days at baseline, month-3, month-6 and month-12 and received periodic feedback on their physical behaviors. The primary outcome was total daily sedentary time. Exploratory outcomes included total daily and workplace sedentary, standing and stepping time, and the number of total daily and workplace sedentary, standing and stepping bouts. Intervention effects were analyzed using random intercept mixed-linear-models accounting for repeated measures and clustering effects.

Results: Total daily sedentary time did not significantly differ between- or within-groups after 12-months. Month-3 gains were observed in total daily and workplace standing time in both intervention groups (sit-to-stand desk: mean Δ±SD= 1.03±1.9 h/day and 1.10±1.87 h at work; treadmill desk: mean Δ±SD= 1.23±2.25 h/day and 1.44±2.54 h at work). At month-3 the treadmill desk users stepped more at the workplace than the control group (mean Δ±SD= 0.69±0.87 h). Month-6 gains in total daily stepping were observed within the sit-to-stand desk group (mean Δ ±SD= 0.82±1.62 h/day) and month-3 gains in stepping at the workplace were observed for the treadmill desk group (mean Δ±SD= 0.77±0.83 h). These trends were sustained through month-12 in only the sit-to-stand desk group.

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Conflicts of Interest
The authors report no conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study are an original investigation and do not constitute endorsement by ACSM.

Conclusions: Active-workstation interventions may cause short-term improvements in daily standing and stepping. Treadmill desk users engaged in fewer sedentary bouts but sit-to-stand desks resulted in more frequent transitions to upright physical behaviors.

Keywords

Sit-to-stand desks; treadmill desks; sedentary behavior; physical activity promotion; workplace wellness; seated office workers

Introduction

Prolonged sedentary behavior is associated with an increased susceptibility for disability, morbidity, and mortality from chronic disease (1). A substantial proportion of the US workforce is employed in full-time seated desk jobs (2, 3) and hence, at risk for these health hazards. As a result, the Centers for Disease Control and Prevention has recognized the workplace as a priority setting for health promotion (4). Active-workstations such as sit-to-stand and treadmill desks (3, 5) provide the opportunity for office workers to replace prolonged sitting at work with standing and/or light intensity physical activity. Thus, these active workstations have gained popularity as alternatives to traditional seated workstations.

Although popular, little is known about their long-term effects in reducing sedentary behavior and increasing standing and stepping physical behaviors. A recent review of experimental studies (n= 24) that implemented sit-to-stand desks at the workplace reported a wide range of the effects of these desks in reducing short-term sedentary behavior (range: 0.1 – 3.6 h/d) and in increasing standing (range: 0.5 – 3.1 h/d) and movement (range: 0 – 0.6 h/d) (6). Most of these studies lacked a robust study design and/or were of short duration (one day or up to 12 weeks) (6). There have been just two cluster-randomized sit-to-stand desk trials with a long-term follow-up of at least 12 months that have been published till date (7, 8). The first study reported significant short- and long-term reductions in overall sedentary behavior in the intervention group relative to the controls (i.e., 1.30 h/d at 3 months; 0.61 h/d at 12 months) with corresponding increases in overall standing time (i.e., 1.26 h/d at 3 months; 0.69 h/d after 12 months) (7). The second study reported significant medium- and long-term reductions in overall sedentary behavior in the intervention group relative to controls (i.e., 0.99 h/d after 6 months; 1.37 h/d after 12 months) with corresponding increases in overall standing time (i.e., 0.93 h/d after 6 months; 1.05 h/d after 12 months) (8). However, neither study found meaningful effects on stepping time (7).

Fewer studies have examined the effect of treadmill desks on sedentary behavior (n= 7) (9–15). Similar to sit-to-stand desks, studies on treadmill desk have reported high variability in reducing sedentary behavior (range: 0.1 – 2.1 h/d) (16) and in increasing stepping time (range: 0.1 – 1.3 h/d) (16). Only four studies had long-term follow-up (range: 9 – 13 months), and one study reported positive intervention effects on daily standing time (i.e., 1.8 h/d after 3 months; 1.5 h/d after 9 months) (9–11, 15). More long-term experimental studies are required to draw inferences on the effect of this intervention in improving daily waking physical behaviors.

This study analyzed physical behavior outcomes in a 12-month, three-arm cluster-randomized control trial to ‘sit less, stand and move more’ (17) using sit-to-stand and treadmill desks at the workplace among sedentary overweight or obese office workers. The primary outcome of this study was total daily sedentary behavior. Aim 1a. assessed the a priori hypothesis that decreases in total daily sedentary behavior would be greatest in the sit-to-stand desk group and lowest in the control group. Aim 1b was exploratory and analyzed the impact of sit-to-stand and treadmill desks on workplace sedentary behavior. Aims 2 and 3 analyzed the impact of sit-to-stand and treadmill desks on the following exploratory outcomes: total daily and workplace standing and stepping time, step counts and the number of total daily and workplace sedentary, standing and stepping bouts.

Methods

Study design and participants

Sixty-six office-workers were recruited from Massachusetts General Hospital and Northeastern University in Boston, MA. A total of 24 office clusters (i.e., Massachusetts General Hospital: 19 clusters, N=60; Northeastern University: five clusters, N= 6) were randomized to the seated-desk control (eight clusters, N=21), sit-to-stand desk (nine clusters, N= 23), or treadmill desk group (seven clusters, N= 22) (See figure, Supplemental Digital Content 1, enrollment, participation, attrition and analyses for total daily time). Participant clusters were identified based on office space such that clusters were separated by walls or were located on a different floor or building. Separations were aimed at not allowing participants in one cluster to be visible to other clusters during day-to-day office activities. Partners HealthCare and Northeastern University institutional review boards approved the study in March of 2014, and all participants provided written informed consent.

To be eligible for the trial, office workers had to be between 18 and 65 years of age, have a body mass index greater than 25 kg/m^2, not engage in any structured physical activity on more than two days/week, be employed in a seated desk job, and be free of limitations that prevented walking and standing in bouts lasting 40 to 60 min. An additional criterion for women was that they were not pregnant or planning to become pregnant in the next year. Subjects were also screened for hypertension, diabetes, cardiovascular disease, and musculoskeletal conditions (i.e., joint, bone or muscle conditions) using a medical history questionnaire at baseline.

Office workers who were enrolled in the study performed telephone and/or computer-based tasks in administrative and support roles. While no shift workers were enrolled in the study, neither institution enforced a standard 9 am to 5 pm work schedule for day-time workers. Additional details on the recruitment and eligibility of worksites can be found in supplemental material (See procedures, Supplemental Digital Content 2, subject selection and enrollment).

Study procedures

Sedentary behavior interventions have been shown to be more efficacious when multi-faceted approaches such as individual education/behavioral strategies, social support, and environmental modification are integrated to promote behavior change (18). Hence, prior to randomization, all 66 participants received a 30-minute face-to-face counseling session with a trained researcher on the benefits of reducing daily sitting and increasing daily standing and movement. In addition, prior to modifying individual workspaces, supervisors of workers enrolled in the sit-to-stand and treadmill desk groups were provided with individual onsite training on the benefits of decreasing sedentary behavior at the workplace and provided verbal encouragement to employees. Supervisors reinforced the importance of decreasing sedentary behavior at regular department meetings during the intervention. Both individual counseling sessions and supervisor trainings were repeated after 3, 6 and 9 months for the sit-to-stand and treadmill desk clusters. During these sessions, participants were also given feedback on their measured physical behaviors (described below), using hourly pictorial breakdowns of workplace and daily behavior patterns.

Training to use workstations—The height-adjustable desks used in this study were the WorkFit-D from Ergotron® Inc. For the treadmill desk group, a WorkFit-D desk was retrofitted with a treadmill (TR1200 DT-3, LifeSpan Fitness Inc.) for each participant. The control panel for the treadmill was placed on the desktop of the WorkFit-D.

Treadmill desk group: Training pertaining to standing and sitting at the height-adjustable desk while working followed recommendations from the Occupational Safety and Health Administration (19). Briefly, training involved selecting the appropriate height of the work surface and maintaining proper posture (20) in the sitting and standing positions. The appropriate height of the work surface was selected by measuring and adjusting the height of the tabletop and the horizontal position of the keyboard, mouse and monitor and their angles relative to the horizontal plane to ensure a neutral posture that felt natural and comfortable and put minimal stress on the body (21). Participants were also trained on the use of the treadmill desk for walking while working, which was based on qualitative feedback from our previous work (22). These included: “i) acclimate to walking on the treadmill during the first week at a speed between 0.7 to 1.0 mph, ii) walk and stand for short bouts of 10-min during acclimation, iii) after acclimation, walk at a speed between 1.0 and 2.0 mph as this range allows you to simultaneously perform work and minimally affects work performance (22–25), and iv) after acclimation, accumulate periods of walking and standing during the course of the day in bouts lasting between 10 and 30 min.” Based on workstation use in our prior research, we recommended participants to accumulate at least two hours of walking and one hour of standing per day (10).

Sit-to-stand desk group: Training for the sit-to-stand desk group pertaining to sitting and standing postures while working was similar to that of the treadmill desk group. Similarly, we recommended participants to acclimate themselves to standing during the first week of using the sit-to-stand desk and to accumulate at least 3 hours of standing per day in bouts lasting 10 to 30 min after acclimation. The 3-hour recommendation aimed to ensure that the prescribed reduction in sedentary time for the sit-to-stand desk group matched the prescription for the treadmill desk group.

Control group: We recommended the control group to engage in three 10-min bouts of moderate-to-vigorous walking during the workday: one during each of the morning and afternoon sessions of work and during the lunch break. This recommendation aimed to enable the participants to meet the 2008 federal physical activity guidelines (26).

Activity monitoring—Participants wore an activPAL™ 3C activity monitor (PAL Technologies Ltd., Glasgow, UK) on their right thigh for a period of 7 days at baseline and after 3, 6, and 12 months during waking hours. The device used in this study has an 8-bit digital capacitive accelerometer (sampling rate: 20 Hz). Sensor data were processed using proprietary software (PALanalysis 7.0, PAL Technologies Ltd., Glasgow, UK) and algorithms to obtain various outcomes (described below) on volume and bouts of physical activity and sedentary behavior. Additionally, participants were asked to complete a daily log to self-report when the monitor was not worn (e.g., showering, sleep) and time spent at the workplace.

Activity monitor data processing and outcome variables—Sensor data were first processed to verify wake-wear intervals using a combination of the self-report logs and signal visualization (27). Wake-wear data were used to quantify total daily time spent sedentary (i.e., sitting/lying), standing, and stepping, and bout statistics of the same (described below). For inclusion in the primary analyses, there needed to be at least four valid days of sensor data consisting of at least ten hours of wake-wear/day from a participant (28).

There was poor compliance on self-report logs specific to reporting time spent at the workplace. In addition, both study sites did not follow the typical 9 am to 5 pm work schedule. While there was variability in schedules between individuals, intra-individual schedules were consistent in general. Therefore, unavailable log workhours were statistically predicted at an individual level by calculating the typical start and end times of a subject's workday (Monday-Friday) from compliant logs at other timepoints in the study. For inclusion in this prediction, subjects had to have at least four valid days of logged work time over the four physical behavior measurements of the study (See figure, Supplemental Digital Content 3, enrollment, participation, attrition and analyses for daily time at the workplace). Cases that did not meet this criterion were handled as missing data (described below) (See figure, Supplemental Digital Content 3, enrollment, participation, attrition and analyses for daily time at the workplace).

Outcome variables: The primary outcome variable was the average total daily hours of wake-time spent sedentary that was examined for intervention effects in Aim 1a. The study was powered to detect changes in the primary outcome, which was based on data from our previous pilot study (see sample size estimation details below). Aim 1b was an exploratory analysis of average sedentary hours at the workplace. Exploratory outcomes for aim 2 were the average total daily hours and daily time at the workplace spent standing and stepping, and average step counts for the total day and at the workplace. Exploratory outcomes for aim 3, which aimed to determine the frequency of transitioning from sedentary to upright physical behaviors, were the average number of total daily and workplace sedentary, standing and stepping bouts.

Sample size and statistical analyses—All analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC).

Sample size estimation: Sample size calculation was based on conservative power estimates derived using change in total daily sedentary behavior observed among participants (N=12) in our preliminary treadmill desk intervention (10). Study arms with at least 17/group was determined to provide 85% power (5% two-tailed significance) to detect an effect size of 1.06 between groups. Accounting for potential clustering effects, power estimates were based on an effective sample size of 51 subjects with an intraclass correlation coefficient of 0.01. A standard deviation of 2.7 h for change in total daily sedentary behavior observed in our pilot study corresponds to a mean detectable difference of 2.9 h between groups. The sample size of 66 accounts for an attrition rate of 20%.

Handling missing data: Losses to follow-up (See figures, Supplemental Digital Content 1 and 3, enrollment, attrition, participation and analyses for total daily time and at the workplace, respectively) were handled as intent-to-treat. Missing daily waking physical behavior outcomes attributable to unsystematic factors were imputed using joint multiple imputation (29, 30). Missingness was determined to be completely at random (i.e., varying subjects had missing physical behavior outcome data at varying time points of the study) and attributable to unsystematic factors, such as monitor malfunction, sickness, improper device placement, and forgetfulness to wear devices and/or log work hours. Multiple imputation is the gold standard for retaining lost statistical power arising from such missing data (29).

Analyses of outcome variables: We used random intercept mixed linear models that accounted for repeated measures and clustering effects to assess between and within group differences in the one-year study for all outcome variables. Data checks ensured that the underlying assumptions of the statistical modeling used on our data were not violated. Post-hoc pairwise comparisons for the primary outcome in aim 1 were adjusted for multiple comparisons using a Bonferroni correction, yielding a between-groups pairwise comparison α of 0.0042 (4 time points x 3 groups= 12 comparisons) with $(1 - 0.0042\ \alpha)$% confidence intervals, and a within-group pairwise comparison α of 0.0028 (6 comparisons/group = 18 comparisons) with $(1 - 0.0028\ \alpha)$% confidence intervals. Cluster effects for all outcomes were tested by calculating the intraclass correlation coefficients (ICCs) and their statistical significance ($p < 0.05$).

For exploratory outcomes examined in aims 1, 2 and 3, we present post hoc determination of treatment-effect trends for behavior change indicated by unidirectional 95% confidence intervals, which do not overlap the null value. This exploratory approach avoids confirmatory statistical significance conclusions based on p values and thus, does not require the application of Bonferroni corrections. Exploratory analyses are appropriate to use when the objective is to develop new hypotheses to further study observed phenomena (31).

To eliminate confounding of outcome analyses due to differences in activity monitor wear-time, mixed linear models were used to compare wear-time at different time points (i.e., average daily wear hours, and average number of valid wear days beyond minimum inclusion criteria). This testing did not detect any significant differences and hence, no adjustment of wear-time was necessary during mixed linear modeling of primary and exploratory outcomes. We also tested for statistically significant differences at baseline for all outcome variables and participant demographics (age, BMI, gender, ethnicity, and race) using mixed linear models for continuous variables and Chi-Square tests for categorical variables. A significant between-group difference was found for age. Thus, mixed linear models for outcome variables were adjusted for age. Cohen's D effect sizes were calculated for all between and within group comparisons and categorized using standardized thresholds (i.e., 0.01= very small, 0.2= small, 0.5= medium, 0.8= large, 1.2= very large, and 2.0= huge) (32).

Additionally, sensitivity analysis included a completers' analysis (N = 42) from baseline to month-12 performed for the primary outcome. This aimed to determine if the overall effect of the two interventions were altered when examining a less conservative and ideal scenario of intervention compliance and to evaluate the sensitivity of primary outcome findings to the handling of missing data (33). Post-hoc pairwise comparisons for the sensitivity analysis were adjusted for multiple comparisons using a Bonferroni correction, yielding a between-groups pairwise comparison α of 0.0083 (2 time points x 3 groups= 6 comparisons) with (1 – 0.0083 α)% confidence intervals, and a within-group pairwise comparison α of 0.0167 (1 comparison/group = 3 comparisons) with (1 – 0.0167 α)% confidence intervals.

Results

Participant characteristics

The control group comprised of 20 females and one male (eight African American/Black, 12 non-Hispanic Caucasians, and one Hispanic Caucasian; age= 41.9 ± 11.5 years; BMI= 33.3 ± 5.9 kg/m^2). The sit-to-stand desk group comprised of 21 females and two males (two African American/Black, 16 non-Hispanic Caucasians, three Hispanic Caucasians, one Asian, and one other race/ethnicity; age= 43.6 ± 12.2 years; BMI= 30.8 ± 6.0 kg/m^2). The treadmill desk group comprised of 18 females and four males (five African Americans/Black, 15 non-Hispanic Caucasians, one Hispanic Caucasian, and one other race/ethnicity; age= 50.4 ± 12.0 years; BMI= 33.5 ± 4.9 kg/m^2). Self-reporting of medical history showed a prior or current history of hypertension in 11 participants (eight sit-to-stand desk, two treadmill desk and one control), diabetes in five participants (three sit-to-stand desk and two treadmill desk), cardiovascular disease in two participants (two treadmill desk), and musculoskeletal conditions in 24 participants (six sit-to-stand desk, nine treadmill desk and nine controls). Sample sizes after losses to follow-up and mean activity monitor wear times for the total day and at the workplace are reported in Table 1.

Cluster effects

The cluster effect did not significantly (all p> 0.05) account for the variability in any of the outcome variables (See table, Supplemental Digital Content 4, ICCs for worksite clustering at baseline).

Aim 1a: Primary outcome analyses of total daily sedentary behavior

Mean total daily sedentary time did not significantly differ (all p> 0.0042) between-groups at 3, 6, or 12 months (Figure 1a and Table 2). Similarly, there were no significant changes (all p> 0.0028) observed in within-group comparisons (Table 2).

Aim 1b. Exploratory analyses of daily workplace sedentary behavior

No between- or within-group unidirectional trends were observed in mean daily workplace sedentary time after 3, 6 or 12 months (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace). The mean number of daily sedentary, standing, and stepping hours at the workplace (group * timepoint) are reported in supplemental material (See table, Supplemental Digital Content 6, summary of time spent in physical behaviors at the workplace).

Aim 2: Exploratory analyses of standing and stepping behavior

Standing behavior

Total Daily Time: No between-group unidirectional trends were observed in mean total daily standing time after 3, 6, or 12 months (Figure 1b and Table 3).

However, unidirectional within-group increasing trends in mean total daily standing time were observed from baseline to month-3 for both the sit-to-stand (Mean Δ ± SD: 1.03 ± 1.90 h/d; 95% CI: 0.10, 1.97; p= 0.0304; medium effect size= 0.55) and treadmill desk groups (Mean Δ ± SD: 1.23 ± 2.25 h/d; 95% CI: 0.16, 2.30; p= 0.0248; medium effect size= 0.55) (Table 3). Only the sit-to-stand desk group sustained this trend through month-12 (Mean Δ ± SD from baseline: 0.99 ± 1.88 h/d; 95% CI: 0.05, 1.94; p= 0.0394; medium effect size = 0.53) (Table 3).

Workplace: No between-group unidirectional trends were observed in mean daily standing time at the workplace after 3, 6 or 12 months (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace).

Similar to total daily time, unidirectional within-group increasing trends in daily workplace standing time were observed from baseline to month-3 for both the sit-to-stand (Mean Δ ± SD: 1.10 ± 1.87 h/d; 95% CI: 0.21, 1.99; p= 0.0151; medium effect size= 0.59) and treadmill desk groups (Mean Δ ± SD: 1.44 ± 2.54 h/d; 95% CI: 0.19, 2.69; p= 0.0242; medium effect size= 0.57) (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace). However, contrary to total daily time, only the treadmill desk group sustained this workplace trend through month-12 (Mean Δ ± SD from baseline: 1.61 ± 2.20 h/d; 95% CI: 0.56, 2.66; p= 0.0027; medium effect size= 0.73) (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace).

Stepping behavior

Total Daily Time: No between-group unidirectional trends were observed in mean total daily stepping time after 3, 6, or 12 months (Figure 1c and Table 4).

However, a unidirectional within-group increasing trend in mean total daily stepping time was observed from baseline to month-6 for the sit-to-stand desk group (Mean Δ ± SD: 0.82 ± 1.62 h/d; 95% CI: 0.17, 1.47; p= 0.0133; medium effect size= 0.50), which was sustained through month-12 (Mean Δ ± SD from baseline: 0.81 ± 1.64 h/d; 95% CI: 0.13, 1.49; p= 0.0191; medium effect size= 0.50) (Table 4).

Workplace: Between-group comparisons showed that after 3 months, the treadmill desk group had a unidirectional trend of spending more daily time stepping at the workplace relative to the control group (Mean Δ ± SD: 0.69 ± 0.87 h/d; 95% CI: 0.13, 1.25; p= 0.0165; medium effect size= 0.79) (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace).

Within-group comparisons showed that the treadmill desk group had increasing unidirectional trends in time spent stepping at the workplace from baseline to month-3 (Mean Δ ± SD: 0.77 ± 0.83 h/d; 95% CI: 0.34, 1.20; p= 0.0004; large effect size= 0.93), month-6 (Mean Δ ± SD: 0.89 ± 1.01 h/d; 95% CI: 0.30, 1.48; p= 0.003; large effect size= 0.88) and month-12 (Mean Δ ± SD: 0.54 ± 0.80 h/d; 95% CI: 0.11, 0.97; p= 0.014; medium effect size= 0.67) (See table, Supplemental Digital Content 5, post hoc comparisons of time spent in physical behaviors at the workplace). Contrary to total daily time, no such within-group trends were observed at the workplace for the sit-to-stand desk group.

Step Counts: Mean total daily and workplace step counts (group * timepoint) are reported in Table 5.

Total daily steps: No between-group unidirectional trends were observed in mean total daily step counts after 3, 6, or 12 months.

However, unidirectional within-group increasing trends in mean total daily step counts were observed for both intervention groups after 3 and 6 months. The trend observed in the sit-to-stand desk group from baseline to month-3 (Mean Δ ± SD: 1811 ± 3876 steps/d; 95% CI: 247, 3375; p=0.0233; small effect size= 0.47), was sustained through month-6 (Mean Δ ± SD from baseline: 2390 ± 3853 steps/d; 95% CI: 835, 3944; p= 0.0026; medium effect size of 0.62). Similarly, the trend observed in the treadmill desk group from baseline to month-3 (Mean Δ ± SD: 2332 ± 4483 steps/d; 95% CI: 738, 3927 steps/d; p= 0.0042; medium effect size= 0.52), was sustained through month-6 (Mean Δ ± SD from baseline: 2087 ± 4493 steps/d; 95% CI: 236, 3938; p= 0.0272; small effect size= 0.46).

Steps at the workplace: Between-group comparisons showed that after 3 months, the treadmill desk group had unidirectional trends of higher daily step counts at the workplace relative to both the control (Mean Δ ± SD: 3054 ± 5780 steps/d; 95% CI: 605, 5502; p= 0.0145; medium effect size= 0.53) and sit-to-stand desk groups (Mean Δ ± SD: 2640 ± 4024 steps/d; 95% CI: 379, 4900; p= 0.0221; medium effect size= 0.66). This trend was sustained between the treadmill and sit-to-stand desk groups after 12 months (Mean Δ ± SD: 2013 ± 3053 steps/d; 95% CI: 117, 3908; p= 0.0375; medium effect size= 0.66).

Unlike total daily steps, within-group unidirectional increasing trends in mean daily step counts at the workplace were only observed for treadmill desk group from baseline to month-3 (Mean Δ ± SD: 3648 ± 3789 steps/d; 95% CI: 1549, 5748; p= 0.0007; large effect size= 0.96), and were sustained through month-6 (Mean Δ ± SD from baseline: 3440 ± 3848 steps/d; 95% CI: 1155, 5726; p= 0.0032; large effect size= 0.89) and month-12 (Mean Δ ± SD from baseline: 2653 ± 3048 steps/d; 95% CI: 954, 4351; p= 0.0022; large effect size= 0.87).

Aim 3: Exploratory analyses of the number of sedentary, standing and stepping bouts

The mean number of total daily and workplace sedentary, standing and stepping bouts (group * timepoint) are reported in Table 5.

Daily sedentary bouts

Total daily bouts: Between-group comparisons showed that after 12 months, the treadmill desk group had a unidirectional trend of engaging in fewer total daily sedentary bouts relative to both the control and sit-to-stand desk groups (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

A unidirectional within-group increasing trend in total daily sedentary bouts was observed from baseline to month-12 in the sit-to-stand desk group (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

Bouts at the workplace: Between-group comparisons showed that after 6 months, the treadmill desk group had a unidirectional trend of engaging in fewer daily sedentary bouts at the workplace relative to the control (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace). After 12 months, the treadmill desk group sustained this trend relative to the control, and also had a unidirectional trend of engaging in fewer daily sedentary bouts at the workplace relative to the sit-to-stand desk group (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

A unidirectional within-group decreasing trend in daily sedentary bouts at the workplace was observed from baseline to month-12 in the treadmill desk group (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

Daily Standing Bouts

Total daily bouts: Between-group comparisons showed that there were no unidirectional trends in both intervention groups relative to the control group after 3, 6, or 12 months. However, the sit-to-stand desk group had a unidirectional trend of engaging in a greater number of total daily standing bouts relative to the treadmill desk group after 6 months, which continued increasing through 12 months (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

A unidirectional within-group increasing trend in total daily standing bouts was observed from baseline to month 6 in the sit-to-stand desk group, which continued increasing through month 12 (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors). On the contrary, the treadmill desk group showed a unidirectional within-group decreasing trend in total daily standing bouts from months 6 to 12 (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

Bouts at the workplace: Between-group comparisons showed that the treadmill desk group had a unidirectional trend of engaging in fewer daily standing bouts at the workplace relative to the control at baseline, and the magnitude of this difference did not change through month-12 (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace). However, the sit-to-stand desk group showed a unidirectional trend of engaging in a greater number of daily standing bouts at the workplace relative to the treadmill group after 3 months, which continued to increase through month 12 (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

A unidirectional within-group increasing trend in daily standing bouts at the workplace was observed from baseline to month-12 in the sit-to-stand desk group (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

Daily Stepping Bouts

Total daily bouts: Between-group comparisons showed that the sit-to-stand desk group had a unidirectional trend of engaging in a greater number of total daily stepping bouts relative to the treadmill group after 12 months (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

A unidirectional increasing trend in total daily stepping bouts was observed from baseline to month 3 in the sit-to-stand desk group and continued increasing through months 6 and 12 (See table, Supplemental Digital Content 7, post hoc comparisons of the number of total daily bouts of physical behaviors).

Bouts at the workplace: Between-group comparisons showed that the sit-to-stand desk group had a unidirectional trend of engaging in a greater number of daily stepping bouts at the workplace relative to the treadmill group after 3 months (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

A unidirectional within-group increasing trend in daily stepping bouts at the workplace was observed from baseline to month-3 in the sit-to-stand desk group (See table, Supplemental Digital Content 8, post hoc comparisons of the number of daily bouts of physical behaviors at the workplace).

Sensitivity analyses

Similar to the intent-to treat analyses, sensitivity analyses involving complete cases only did not show intervention effects for total daily sedentary time (See table, Supplemental Digital Content 9, sensitivity analyses).

Discussion

Overall, we found that the use of both sit-to-stand and treadmill desks resulted in office workers reducing daily sedentary time in favor of increased standing and stepping time. Correspondingly, treadmill desks resulted in office workers engaging in fewer total daily and workplace sedentary bouts but sit-to-stand desk users transitioned to upright physical behaviors more frequently both over the whole day and at the workplace. Below, we discuss the effects of sit-to-stand and treadmill desks on total durations of behavior and the implications of our findings when compared to prior studies. This is followed by a discussion on the observed frequency of transitioning between types of physical behavior bouts when using these desks.

Total daily and workplace sedentary, standing, and stepping time

Compared to Healy et al. (7), where office workers using sit-to-stand desks over a 12-month period were able to considerably replace sedentary time with standing time at both the workplace and over the total-day, our study demonstrated smaller short-term reductions in total sedentary behavior in the sit-to-stand group relative to the control group. I.e., after 3-months sit-to-stand desk users in Healy et al. reduced total daily and workplace sedentary behavior by an additional 30.0 min and 36.1 min over those observed in our study, respectively. Compared to Healy et al. (7), long-term sedentary behavior reduction in our study was smaller at the workplace, but greater over the total-day. I.e., after 12 months, sit-to-stand desk users in Healy et al. reduced sedentary behavior by an additional 4.6 min at the workplace over what was observed in our study, but over the total day, sit-to-stand desk users in our study demonstrated improved reduction by an additional 29.7 min/total-day over what was observed by Healy et al. These dissimilarities may be attributable to a higher level of sedentariness (~20%) among participants at baseline and a larger sample size (N=231) in Healy et al. (7) Compared to our study, a more recent trial by Edwardson et al. (8) reported smaller short-term reductions in sedentary behavior in the sit-to-stand group relative to the control, but larger long-term reductions. I.e., after 3-months sit-to-stand desk users in our study reduced total daily and workplace sedentary behavior by an additional 13.9 min and 12.4 min over those observed by Edwardson et al., respectively. However, after 12-months, sit-to-stand desk users in Edwardson et al. reduced total daily and workplace sedentary behavior by an additional 35 min and 20.3 min over those observed in our study, respectively. Compared to Healy et al. (7), Edwardson et al. (8) and our study may have been successful in enabling larger long-term reductions in daily sedentary behavior due to more periodic feedback on measured workplace and daily behavior patterns throughout the study. Participants in Healy et al. (7) received no researcher input or feedback on their physical behaviors between months 3 and 12. Taking the findings from the three studies, it would seem that a practical estimate of long-term reductions in workplace sedentary behavior among users of sit-to-stand desk, may be approximately 60 min/day on average.

Similar to Edwardson et al. (8), users of sit-stand desks in our study increased short- (3-months) and long-term (12-months) workplace and total daily standing time by about an hour. Relative to our trial, standing time gains by sit-to-stand desk users in Healy et al. (7) were greater in the short-term both at the workplace (36.2 min) and over the total-day (13.7 min), but were similar in the long-term.

While the impact of sit-to-stand and treadmill desks on the accumulation of stepping time was variable in our study, increasing trends in accumulated daily stepping time were suggestive of positive effects. Sit-to-stand desk users demonstrated short- and long-term increases in total daily stepping time (i.e., about an hour at both 3- and 12-months) while the treadmill desk users demonstrated short- and long-term stepping time increases at the workplace (i.e., about 45 min at 3-month and 30 min at 12-months). Notably, although the concept of a sit-to-stand desk does not specifically encourage increased physical activity, having an intervention along with periodic counseling during the study to encourage participants to ‘sit less, stand and move more’ may enable users to be more active (17). In a 13-month RCT study by Bergman et al. (15) that exclusively examined the effect of treadmill desks in office workers, there were no significant reductions in total daily sitting or standing time but a significant increase in steps/day. Compared to Bergman et al. (15), treadmill desk users in our study demonstrated greater short- and long-term reductions in sedentary behavior relative to the control group. I.e., In the short-term (i.e., 3 months in our trial and 2 months in Bergman et al.) treadmill desk users in our study reduced total daily sedentary behavior by 27 more min/day over that observed in Bergman et al. In the long-term (i.e., 12 months in our trial and 13 months in Bergman et al.) treadmill desk users in our study reduced total daily sedentary behavior by an additional 40 min/day over that observed by Bergman et al. While users of treadmill desks in our study increased daily steps/day after six months, similar to Bergman et al. (15), gains in steps/day were not sustained in the long-term. Gains in daily steps counts ranging from ≈1800–2400 steps/d in both intervention groups after 3 and 6 months in our study, represent a relative increase of 25–35% in step volume. This aligns with the 2018 Physical Activity Guidelines Advisory Committee’s viewpoint that any gain in the overall volume of active movement among sedentary individuals contributes to health benefits (34).

Since all other intervention components were similar for both the sit-to-stand and treadmill desk groups in our study, findings suggest that sit-to-stand and treadmill desks may elicit a different behavior change response among users. Access to a sit-to-stand desk may enable gains in positive behavior to be accrued both at and outside the workplace. It seems that the availability of a treadmill desk at work may encourage office workers to accumulate most of the gains in standing and stepping time at the workplace. We are unable to determine the reason for this variable response in our study, which may be explored in future work. Thus, interventions using treadmill desks may need specific messaging that also promote overall daily movement to ensure that users avoid prolonged sedentary bouts when they are not at the workplace.

Number of total daily and workplace sedentary, standing and stepping bouts

In summary: (i) Compared to controls and sit-to-stand desks, treadmill desks enabled positive long-term reductions in the number of total daily and workplace sedentary bouts (i.e., at 12 months by 16 and 19 bouts over the whole day and by 15 and 16 bouts at the workplace, respectively). (ii) Compared to treadmill desks, sit-to-stand desks facilitated greater increases in the number of total daily standing bouts (i.e., at 12 months: by 34 bouts) and workplace standing bouts (i.e., at 3 and 12 months by 18 and 30 bouts, respectively). (iii) Compared to treadmill desks, sit-to stand desks also facilitated greater increases in the total number of total daily stepping bouts (i.e., at 12 months by 16 bouts) and workplace stepping bouts (i.e., at 3 months by 11 bouts).

The findings above suggest that sit-to-stand desks may be more successful than treadmill desks in breaking up daily sedentary behavior more frequently and in sustaining this pattern for a longer period of time; this needs to be explored in future larger studies. Thus, sit-to-stand desks may allow users to meet the 2018 Physical Activity Guidelines Advisory Committee Scientific Report's recommendation to frequently break and replace daily sedentary behavior with light intensity physical activity. The report considers standing during work tasks as light intensity activity (34) and states that individuals who perform no or little moderate-to-vigorous physical activity could reduce their risks for cardiovascular disease and diabetes and that for all-cause mortality by replacing sedentary behavior with light intensity activity (34).

Conclusions

In addition to increasing short-term standing at the workplace, our findings suggest the use of sit-to-stand desks may also translate into increased medium- (6 months) and long-term (12 months) overall daily stepping. Our findings among users of treadmill desks suggested that stepping gains did not extend outside the workplace. More work is required to investigate the reasons for observed discrepancies between sit-to-stand and treadmill desks. In addition, translating short-term sedentary behavior reductions attributable to the initial novelty factor of the interventions to habitual behavior may require a higher frequency of motivation, support, and coaching than what was provided in this study.

Our work may serve as a foundation to develop new hypotheses to test: (1) strategies that leverage desk-based behavior change at the workplace to positively impact overall daily behavior (2) if both sit-to-stand and treadmill desks enable office workers to engage in fewer daily sedentary bouts and helps them engage in upright physical behaviors more frequently; and (3) if users of sit-to-stand desks sustain potentially beneficial behavior patterns to a greater extent than users of treadmill desks.

Strengths and Limitations

Strengths of our study included a cluster randomized controlled intervention design with a 1-year follow-up and a head-to-head comparison of sit-to-stand and treadmill desks.

While losses to follow-up are unlikely to have biased the results given that data was determined to be missing at random, the generalizability of this study's findings may be limited by the fact that some attrition rates (See figures, Supplemental Digital Content 1 and 3, enrollment, participation, attrition and analyses for total daily time and at the workplace, respectively) were higher than what the study was powered to handle (i.e., 20%). Relatedly, a smaller sample in comparison to the few other long-term active workstations intervention studies that are currently available, may have resulted in a reduced ability to detect intervention effects. Another limitation of this study is the inability to provide an analysis of the '24-hour activity cycle' because we did not measure sleep. Additionally, a higher number of women in our study limits the generalizability of our findings with regards to male seated office workers. While there were several intervention components, the specific contributions of each component on the observed effects were not determined. Furthermore, our study did not employ a pre-investigation educational approach (7, 8) of assessing participant's baseline knowledge of the risks of sedentary behavior to enhance the acceptability and responsiveness of the intervention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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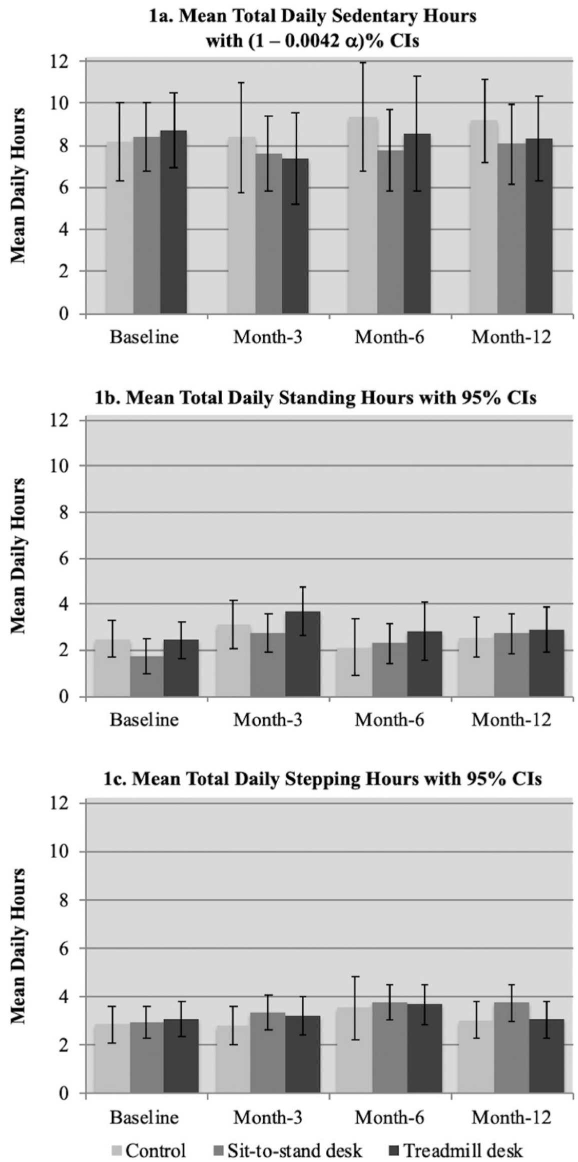

Figure 1. Mean total daily waking time spent in physical behaviors by randomization group * timepoint, adjusted for age.

There were no significant between group differences at the multiple comparison Bonferroni adjusted rejections α of 0.0042 for daily sedentary behavior volume. There were also no unidirectional between group trends for daily standing and stepping behavior volume. Sample sizes after loss to follow-up: baseline (21 control, 23 sit-to-stand desk, 22 treadmill desk), month-3 (15 control, 21 sit-to-stand desk, 22 treadmill desk), month-6 (14 control, 20 sit-to-stand desk, 19 treadmill desk), and month-12 (18 control, 20 sit-to-stand desk, 20 treadmill desk).

Table 1.

Sample sizes after losses to follow-up and activity monitor weartimes by group*timepoint

Group	Timepoint	N	Mean Activity Monitor Wear Time			
			Total Time		Workplace	
			Days ± SD	Daily Hours ± SD	Days ± SD	Daily Hours ± SD
Control	Baseline	21	5.79 ± 2.57	14.15 ± 2.13	4.08 ± 1.82	7.83 ± 1.39
Sit-to-stand desk		23	6.18 ± 1.76	12.96 ± 2.00	3.87 ± 1.62	7.46 ± 1.37
Treadmill desk		22	6.59 ± 1.01	13.98 ± 1.36	3.64 ± 1.61	7.41 ± 0.82
Control	Month-3	15	5.92 ± 2.60	14.62 ± 1.97	5.11 ± 1.32	8.46 ± 1.21
Sit-to-stand desk		21	6.25 ± 2.44	13.67 ± 1.69	4.91 ± 2.14	7.91 ± 1.33
Treadmill desk		22	5.74 ± 2.71	13.97 ± 2.83	3.64 ± 2.09	8.30 ± 1.66
Control	Month-6	14	7.77 ± 2.80	15.51 ± 1.71	6.43 ± 5.79	8.06 ± 1.85
Sit-to-stand desk		20	5.99 ± 2.62	13.49 ± 3.48	4.28 ± 1.49	6.76 ± 1.96
Treadmill desk		19	7.74 ± 3.22	14.68 ± 1.76	5.05 ± 4.42	7.89 ± 1.83
Control	Month-12	18	6.65 ± 1.20	14.94 ± 1.84	3.86 ± 2.82	8.40 ± 1.96
Sit-to-stand desk		20	6.68 ± 1.90	14.37 ± 1.69	4.56 ± 1.24	7.79 ± 1.28
Treadmill desk		20	6.01 ± 2.56	14.17 ± 2.78	4.18 ± 2.22	8.32 ± 1.55

Table 2.

Between and within group comparisons of mean total daily sedentary time, adjusted for age

	Comparison	Sample Sizes		Mean Difference ± SD [(1 − α)% CI] (Hours)	Cohen's D Effect Size	p value
		N1	N2			
Between Group Comparisons	B: Sit-to-stand desk - Control	23	21	0.27 ± 2.79 [−2.05, 2.60]	0.10	0.7462
	B: Treadmill desk - Control	22	21	0.54 ± 2.86 [−1.88, 2.96]	0.19	0.5394
	B: Treadmill desk - Sit-to-stand desk	22	23	0.27 ± 2.77 [−2.01, 2.55]	0.10	0.7470
	M3: Sit-to-stand desk - Control	21	15	−0.79 ± 3.04 [−3.66, 2.09]	0.26	0.4488
	M3: Treadmill desk - Control	22	15	−1.01 ± 3.41 [−4.20, 2.19]	0.29	0.3796
	M3: Treadmill desk - Sit-to-stand desk	22	21	−0.22 ± 3.17 [−2.90, 2.46]	0.07	0.8201
	M6: Sit-to-stand desk - Control	20	14	−1.60 ± 3.06 [−4.60, 1.40]	0.52	0.1352
	M6: Treadmill desk - Control	19	14	−0.78 ± 3.60 [−4.34, 2.79]	0.22	0.5319
	M6: Treadmill desk - Sit-to-stand desk	19	20	0.82 ± 3.54 [−2.33, 3.98]	0.23	0.4672
	M12: Sit-to-stand desk - Control	20	18	−1.10 ± 2.84 [−3.67, 1.47]	0.39	0.2331
	M12: Treadmill desk - Control	20	18	−0.83 ± 2.92 [−3.47, 1.82]	0.28	0.3823
	M12: Treadmill desk - Sit-to-stand desk	20	20	0.27 ± 2.96 [−2.33, 2.88]	0.09	0.7712
Within Group Comparisons	Control: Δ B to M3	21	15	0.22 ± 3.09 [−2.87, 3.31]	0.07	0.8001
	Control: Δ B to M6	21	14	1.19 ± 3.01 [−1.88, 4.27]	0.40	0.1860
	Control: Δ B to M12	21	18	0.99 ± 2.84 [−1.69, 3.67]	0.35	0.1709
	Control: Δ M3 to M6	15	14	0.97 ± 3.21 [−2.62, 4.56]	0.30	0.3552
	Control: Δ M3 to M12	15	18	0.77 ± 3.05 [−2.40, 3.95]	0.25	0.3830
	Control: Δ M6 to M12	14	18	−0.20 ± 2.97 [−3.35, 2.96]	0.07	0.8281
	Sit-to-stand desk: Δ B to M3	23	21	−0.84 ± 2.73 [−3.24, 1.57]	0.31	0.2016
	Sit-to-stand desk: Δ B to M6	23	20	−0.68 ± 2.85 [−3.23, 1.86]	0.24	0.3436
	Sit-to-stand desk: Δ B to M12	23	20	−0.38 ± 2.79 [−2.87, 2.12]	0.13	0.5885
	Sit-to-stand desk: Δ M3 to M6	21	20	0.16 ± 2.88 [−2.48, 2.80]	0.05	0.8325
	Sit-to-stand desk: Δ M3 to M12	21	20	0.46 ± 2.82 [−2.13, 3.05]	0.16	0.5201
	Sit-to-stand desk: Δ M6 to M12	20	20	0.30 ± 2.94 [−2.43, 3.03]	0.10	0.6956
	Treadmill desk: Δ B to M3	22	22	−1.32 ± 3.21 [−4.15, 1.50]	0.41	0.0742
	Treadmill desk: Δ B to M6	22	19	−0.12 ± 3.48 [−3.32, 3.07]	0.04	0.8929
	Treadmill desk: Δ B to M12	22	20	−0.37 ± 2.94 [−3.03, 2.29]	0.13	0.5902
	Treadmill desk: Δ M3 to M6	22	19	1.20 ± 3.78 [−2.27, 4.67]	0.32	0.2320
	Treadmill desk: Δ M3 to M12	22	20	0.95 ± 3.30 [−2.03, 3.93]	0.29	0.2365
	Treadmill desk: Δ M6 to M12	19	20	−0.25 ± 3.56 [−3.60, 3.11]	0.07	0.7985

Key: B= Baseline, M3= Month-3, M6= Month-6, M12= Month-12 follow-ups, N1= sample size of 1st comparison group, N2= sample size of 2nd comparison group

Bonferroni adjusted rejection α's: between-group comparisons= 0.0042, within-group comparisons= 0.0028

Table 3.

Between and within group comparisons of mean total daily standing time, adjusted for age

	Comparison	Sample Sizes		Mean Difference ± SD [(1 − α)% CI] (Hours)	Cohen's D Effect Size	p value	U Trend ↗
		N1	N2				
Between Group Comparisons	B: Sit-to-stand desk - Control	23	21	−0.76 ± 1.85 [−1.85, 0.34]	0.41	0.1755	----
	B: Treadmill desk - Control	22	21	−0.05 ± 1.90 [−1.19, 1.09]	0.03	0.9294	----
	B: Treadmill desk - Sit-to-stand desk	22	23	0.70 ± 1.87 [−0.39, 1.80]	0.38	0.2081	----
	M3: Sit-to-stand desk - Control	21	15	−0.33 ± 2.03 [−1.69, 1.02]	0.16	0.6293	----
	M3: Treadmill desk - Control	22	15	0.56 ± 2.32 [−0.93, 2.06]	0.24	0.4607	----
	M3: Treadmill desk - Sit-to-stand desk	22	21	0.90 ± 2.27 [−0.46, 2.25]	0.40	0.1943	----
	M6: Sit-to-stand desk - Control	20	14	0.16 ± 2.17 [−1.34, 1.66]	0.07	0.8337	----
	M6: Treadmill desk - Control	19	14	0.71 ± 2.62 [−1.07, 2.49]	0.27	0.4358	----
	M6: Treadmill desk - Sit-to-stand desk	19	20	0.55 ± 2.45 [−1.00, 2.09]	0.22	0.4879	----
	M12: Sit-to-stand desk - Control	20	18	0.19 ± 1.92 [−1.04, 1.41]	0.10	0.7666	----
	M12: Treadmill desk - Control	20	18	0.38 ± 2.06 [−0.93, 1.68]	0.18	0.5700	----
	M12: Treadmill desk - Sit-to-stand desk	20	20	0.19 ± 2.08 [−1.10, 1.48]	0.09	0.7700	----
Within Group Comparisons	Control: Δ B to M3	21	15	0.61 ± 1.99 [−0.52, 1.74]	0.31	0.2898	----
	Control: Δ B to M6	21	14	−0.36 ± 2.13 [−1.69, 0.97]	0.17	0.5934	----
	Control: Δ B to M12	21	18	0.05 ± 1.89 [−0.93, 1.04]	0.03	0.9175	----
	Control: Δ M3 to M6	15	14	−0.97 ± 2.23 [−2.46, 0.52]	0.44	0.2009	----
	Control: Δ M3 to M12	15	18	−0.56 ± 2.00 [−1.73, 0.61]	0.28	0.3495	----
	Control: Δ M6 to M12	14	18	0.41 ± 2.14 [−0.94, 1.77]	0.19	0.5501	----
	Sit-to-stand desk: Δ B to M3	23	21	1.03 ± 1.90 [0.10, 1.97]	0.55	0.0304	↗
	Sit-to-stand desk: Δ B to M6	23	20	0.56 ± 1.89 [−0.39, 1.51]	0.29	0.2518	----
	Sit-to-stand desk: Δ B to M12	23	20	0.99 ± 1.88 [0.05, 1.94]	0.53	0.0394	↗
	Sit-to-stand desk: Δ M3 to M6	21	20	−0.48 ± 1.96 [−1.50, 0.54]	0.24	0.3582	----
	Sit-to-stand desk: Δ M3 to M12	21	20	−0.04 ± 1.96 [−1.05, 0.97]	0.02	0.9361	----
	Sit-to-stand desk: Δ M6 to M12	20	20	0.44 ± 1.95 [−0.58, 1.46]	0.22	0.3997	----
	Treadmill desk: Δ B to M3	22	22	1.23 ± 2.25 [0.16, 2.30]	0.55	0.0248	↗
	Treadmill desk: Δ B to M6	22	19	0.40 ± 2.43 [−0.92, 1.71]	0.16	0.5537	----
	Treadmill desk: Δ B to M12	22	20	0.48 ± 2.07 [−0.53, 1.49]	0.23	0.3516	----
	Treadmill desk: Δ M3 to M6	22	19	−0.83 ± 2.70 [−2.30, 0.64]	0.31	0.2686	----

	Comparison	**Sample Sizes**		**Mean Difference ± SD [(1 − α)% CI] (Hours)**	**Cohen's D Effect Size**	**p value**	**U Trend** ⊘
		N1	**N2**				
	Treadmill desk: Δ M3 to M12	22	20	−0.75 ± 2.38 [−1.95, 0.46]	0.31	0.2252	----
	Treadmill desk: Δ M6 to M12	19	20	0.08 ± 2.55 [−1.34, 1.51]	0.03	0.9079	----

Key: B= Baseline, M3= Month-3, M6= Month-6 and M12= Month-12 follow-ups,

N1= sample size of 1st comparison group, N2= sample size of 2nd comparison group, U Trend= unidirectional trend:

⊘= yes, ---- = no

Table 4.

Between and within group comparisons of mean total daily stepping time, adjusted for age

	Comparison	Sample Sizes		Mean Difference ± SD [(1 − α)% CI] (Hours)	Cohen's D Effect Size	p value	U Trend ⊘
		N1	N2				
Between Group Comparisons	B: Sit-to-stand desk - Control	23	21	0.07 ± 1.65 [−0.91, 1.05]	0.04	0.8830	----
	B: Treadmill desk - Control	22	21	0.21 ± 1.72 [−0.82, 1.24]	0.12	0.6892	----
	B: Treadmill desk - Sit-to-stand desk	22	23	0.14 ± 1.64 [−0.81, 1.09]	0.08	0.7792	----
	M3: Sit-to-stand desk - Control	21	15	0.58 ± 1.59 [−0.48, 1.63]	0.36	0.2834	----
	M3: Treadmill desk - Control	22	15	0.44 ± 1.72 [−0.67, 1.54]	0.25	0.4384	----
	M3: Treadmill desk - Sit-to-stand desk	22	21	−0.14 ± 1.77 [−1.19, 0.91]	0.08	0.7928	----
	M6: Sit-to-stand desk - Control	20	14	0.21 ± 2.13 [−1.31, 1.73]	0.10	0.7838	----
	M6: Treadmill desk - Control	19	14	0.14 ± 2.18 [−1.41, 1.70]	0.07	0.8555	----
	M6: Treadmill desk - Sit-to-stand desk	19	20	−0.07 ± 1.73 [−1.15, 1.01]	0.04	0.9014	----
	M12: Sit-to-stand desk - Control	20	18	0.70 ± 1.64 [−0.35, 1.74]	0.42	0.1905	----
	M12: Treadmill desk - Control	20	18	0.03 ± 1.66 [−1.02, 1.07]	0.02	0.9626	----
	M12: Treadmill desk - Sit-to-stand desk	20	20	−0.67 ± 1.72 [−1.73, 0.39]	0.39	0.2156	----
Within Group Comparisons	Control: Δ B to M3	21	15	−0.06 ± 1.64 [−0.76, 0.64]	0.04	0.8656	----
	Control: Δ B to M6	21	14	0.68 ± 2.15 [−0.66, 2.02]	0.31	0.3198	----
	Control: Δ B to M12	21	18	0.19 ± 1.65 [−0.49, 0.87]	0.12	0.5794	----
	Control: Δ M3 to M6	15	14	0.74 ± 2.08 [−0.61, 2.09]	0.35	0.2838	----
	Control: Δ M3 to M12	15	18	0.25 ± 1.56 [−0.44, 0.94]	0.16	0.4738	----
	Control: Δ M6 to M12	14	18	−0.49 ± 2.10 [−1.81, 0.84]	0.23	0.4706	----
	Sit-to-stand desk: Δ B to M3	23	21	0.44 ± 1.61 [−0.18, 1.06]	0.27	0.1634	----
	Sit-to-stand desk: Δ B to M6	23	20	0.82 ± 1.62 [0.17, 1.47]	0.50	0.0133	⊘
	Sit-to-stand desk: Δ B to M12	23	20	0.81 ± 1.64 [0.13, 1.49]	0.50	0.0191	⊘
	Sit-to-stand desk: Δ M3 to M6	21	20	0.38 ± 1.66 [−0.32, 1.07]	0.23	0.2895	----
	Sit-to-stand desk: Δ M3 to M12	21	20	0.37 ± 1.68 [−0.35, 1.09]	0.22	0.3103	----
	Sit-to-stand desk: Δ M6 to M12	20	20	0.00 ±1.69 [−0.75, 0.74]	0.00	0.9921	----
	Treadmill desk: Δ B to M3	22	22	0.17 ± 1.79 [−0.44, 0.77]	0.09	0.5895	----
	Treadmill desk: Δ B to M6	22	19	0.61 ± 1.75 [−0.03, 1.26]	0.35	0.0619	----
	Treadmill desk: Δ B to M12	22	20	0.01 ± 1.72 [−0.58, 0.59]	0.00	0.9819	----
	Treadmill desk: Δ M3 to M6	22	19	0.45 ± 1.84 [−0.25, 1.15]	0.24	0.2109	----
	Treadmill desk: Δ M3 to M12	22	20	−0.16 ± 1.81 [−0.81, 0.49]	0.09	0.6336	----
	Treadmill desk: Δ M6 to M12	19	20	−0.61 ± 1.76 [−1.29, 0.08]	0.34	0.0827	----

Key: B= Baseline, M3= Month-3, M6= Month-6 and M12= Month-12 follow-ups,

N1= sample size of 1st comparison group, N2= sample size of 2nd comparison group, U Trend= unidirectional trend:

⊘= yes, ---- = no

Table 5.

Summary of mean daily step counts and the number of waking physical behavior bouts for the total day and at the workplace by randomization group*timepoint, adjusted for age

Group	Timepoint	N	Mean Daily Step Counts (Steps ± SD)		Mean Daily Sedentary Bouts (N ± SD)		Mean Daily Standing Bouts (N ± SD)		Mean Daily Stepping Bouts (N ± SD)	
			Total Time	At-Work	Total Time	At-Work	Total Time	At-Work	Total Time	At-Work
Control	Baseline	21	6522 ± 4000	3182 ± 2798	44.28 ± 15.63	30.23 ± 16.99	99.39 ± 31.97	63.88 ± 35.04	54.82 ± 19.03	35.13 ± 19.65
Sit-to stand desk		23	6476 ± 3745	3270 ± 2494	41.17 ± 15.21	24.02 ± 13.08	96.51 ± 31.43	54.05 ± 24.62	54.29 ± 18.65	29.82 ± 13.56
Treadmill desk		22	6725 ± 4129	2683 ± 2526	36.25 ± 15.53	21.31 ± 13.41	89.96 ± 32.75	44.63 ± 25.51	52.94 ± 19.75	23.76 ± 13.96
Control	Month-3	15	6691 ± 3764	3277 ± 2869	43.06 ± 15.06	26.04 ± 14.73	96.91 ± 30.53	57.63 ± 28.54	55.56 ± 17.88	30.26 ± 16.78
Sit-to-stand desk		21	8287 ± 4002	3692 ± 2507	42.35 ± 15.62	26.68 ± 14.07	106.49 ± 31.83	64.01 ± 27.12	62.51 ± 18.95	37.58 ± 15.54
Treadmill desk		22	9057 ± 4810	6331 ± 4725	32.43 ± 18.29	18.59 ± 15.86	84.74 ± 37.75	45.97 ± 32.40	51.14 ± 21.76	26.96 ± 17.06
Control	Month-6	14	8010 ± 4940	4822 ± 6602	48.59 ± 16.36	32.18 ± 13.97	103.26 ± 29.35	63.85 ± 33.33	55.47 ± 20.33	31.74 ± 19.70
Sit-to-stand desk		20	8866 ± 3958	4188 ± 3026	48.75 ± 17.08	28.13 ± 16.72	114.06 ± 34.80	65.06 ± 28.38	64.39 ± 19.93	35.15 ± 14.95
Treadmill desk		19	8812 ± 4829	6124 ± 4819	37.76 ± 19.97	19.09 ± 17.75	103.62 ± 41.73	47.17 ± 36.73	62.38 ± 28.34	29.37 ± 18.28
Control	Month-12	18	6613 ± 3782	3936 ± 3121	47.27 ± 15.64	29.18 ± 15.56	103.75 ± 32.01	59.06 ± 29.41	57.79 ± 18.48	29.49 ± 15.36
Sit-to-stand desk		20	8063 ± 4038	3323 ± 2539	50.56 ± 17.52	30.40 ± 14.39	119.06 ± 36.17	67.83 ± 28.84	66.94 ± 21.01	35.38 ± 14.98
Treadmill desk		20	7794 ± 4244	5336 ± 3492	31.50 ± 16.26	14.18 ± 13.48	84.60 ± 33.83	38.20 ± 25.64	51.40 ± 20.63	26.19 ± 15.34