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Evaluation of a Workplace Treadmill Desk Intervention: A Randomized Controlled Trial

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Evaluation of a Treadmill Desk Intervention

ABSTRACT

Objective: To evaluate the effectiveness of a 3-month treadmill desk intervention in eliciting changes in physical activity and sedentary behavior among overweight/obese office workers.

Methods: A randomized controlled trial was conducted among overweight/obese office workers (n=41, mean age = 40.1±10.1 years) at a private workplace. Participants were randomly assigned to a shared-treadmill desk intervention (n=21) or a usual working condition control group (n=20). Accelerometer-determined physical activity and sedentary behavior were measured before and following the intervention.

Results: Compared to the control group, the intervention group increased daily steps (1,622 steps/day, p=0.013) and light physical activity (1.6 min/hour, p=0.008), and decreased sedentary time (-3.6 min/hour, p=0.047) during working hours.

Conclusions: Shared-treadmill desks in the workplace can be effective at promoting favorable changes in light physical activity (specifically 40-99 steps/min) and sedentary behavior among overweight/obese office workers.

INTRODUCTION

Societal shifts to more sedentary occupations have reduced daily energy expenditure by more than 100 kcal/day over the past 50 years and this decline has been associated with population levels of weight gain tracked by the National Health and Nutrition Examination Survey (NHANES) over the same time period.[1] Time use studies[2] indicate that workers employed in sedentary occupations (< 1.6 METs) spend approximately 11 hours/day sedentary (including working and non-working time), leaving little time to achieve the recommended levels of physical activity considered important for overall health.[3] An analysis of 3,539 workers participating in the 1999-2004 NHANES indicated that those employed in low-activity occupations were 37% more likely to be abdominally obese (>102 cm in men and >88 cm in women) than workers in high-activity occupations.[4] Thus, determining effective strategies to increase physical activity levels in occupational settings may have public health and clinical significance.

Physical activity interventions in the workplace have primarily focused on promoting exercise (e.g. providing access to fitness facilities) during scheduled breaks, lunch, or before/after work and have met with modest success due to low adherence. Researchers in recent years have begun to consider how modern occupational practices and environments could be enriched to facilitate, rather than discourage, increased energy expenditure by replacing sedentary behaviors with opportunities for non-exercise physical activity without competing with time or attention committed to work tasks.[5] For example, Edelson and Danoff[6] first introduced the concept of walking while engaged in computer-based office work in 1989 while Levine and Miller[7] re-introduced the treadmill desk combination in 2007. Since that time, Thompson et al.[8] described a positive treadmill desk feasibility study with nurses, clinical assistants, and secretaries and John et al.[9] reported the pre-post impact of a 9-month treadmill desk intervention among 12 sedentary office workers. More recently, several publications have reported on the behavioral effects of a one-year quasi-experimental treadmill desk intervention,[10,11] a randomized cross-over study of physician's use of the treadmill desk during office work,[12] and a randomized controlled trial which implemented treadmill desks into a multicomponent participatory workplace intervention.[13] However, no other randomized controlled trials have been reported evaluating behavioral changes resulting from treadmill desk usage.

Therefore, the primary purpose of the present study was to evaluate the effectiveness of a 3-month treadmill desk intervention in eliciting changes in objectively monitored physical activity and sedentary behavior among overweight/obese office workers. Treadmill desk workstations were shared amongst workers in the intervention arm. The secondary purpose was to evaluate changes in body mass, body fat percentage, and body mass index (BMI) in response to the shared-treadmill desk intervention.

METHODS

Setting and Participants

The Workstation Pilot Study (ClinicalTrials.gov Identifier: NCT01587092) was conducted at a private health insurance company located in Baton Rouge, Louisiana. The Pennington Biomedical Research Center's Institutional Review Board approved all study protocols and procedures prior to the start of the study and all participants provided written informed consent. We have previously published the results of a process evaluation of this study focused on implementation issues including recruitment and adherence issues.[14] The results presented herein are focused on the primary outcomes of the trial and therefore are novel. The methods presented below are a summary of those presented previously with additional detail relevant specifically to study outcomes.

The population targeted for this study was overweight/obese (BMI $\geq$ 25 kg/m^2) office workers whose job descriptions required continuous desk work. Working in collaboration with company management, an initial pool of 728 employees at a single office complex was targeted for recruitment. Recruitment efforts were initiated through in-house distribution of print and electronic media. Potential participants received an e-mail providing a link to an online survey that included a series of screening questions designed to assess participant eligibility. Exclusionary criteria included all of the following: 1) current participation in other Pennington Biomedical Research Center studies, 2) BMI < 25 kg/m^2, 3) self-reported type I diabetes, 4) existing cardiovascular disease, 5) diagnosed schizophrenia or bipolar disorder, 6) plans to move out of the area or leave their current job within the next 6 months, 7) self-reported pregnancy or breast feeding, 8) existence of any condition which would limit participation in a physical activity program, and 9) an inability to walk continuously for 45 minutes.

A list of potentially eligible employees identified from the initial online screening survey was forwarded to office management. Supervisors reviewed the list of identified employees and determined who would be permitted to participate in the study after considering potential work-related conflicts. Employees deemed eligible by office management were notified via telephone and invited by study staff to attend an orientation session held at the office complex. The intent of the orientation session was to present detailed information about the study, including the number and types of assessments, the length and nature of the treadmill desk intervention, time commitment required, and risks/benefits of study participation. All questions and concerns voiced by potential participants were addressed at the orientation session.

Design and Randomization

The WorkStation Pilot Study was designed as a randomized controlled trial with individual participants serving as the unit of randomization. Participants were randomized (1:1) to one of two study arms: 1) treadmill desk intervention group, or 2) usual working condition control group.

A total of 76 employees from the original pool of 728 responded to initial e-mail recruitment efforts. Of those, 20 employees were deemed ineligible following initial screening, and 26 employees did not receive supervisor approval to participate. Of the remaining 30 eligible employees, 23 attended an orientation session and consented, and 21 (recruitment cohort 1) were subsequently randomized following completion of the baseline assessment. In response to a lower than anticipated number of employees responding to our initial recruitment efforts, a second recruitment phase (recruitment cohort 2) was implemented three months after our first recruitment period. During the second recruitment phase, a further 47 employees responded to recruitment e-mails. Of those, 9 were deemed ineligible following initial screening, and 6 failed to receive supervisor approval to participate. Of the remaining 32 eligible employees, 21 attended an orientation session and consented, and 20 were ultimately randomized after completing the baseline assessment. Across both recruitment cohorts, 21 participants were randomly allocated to the treadmill desk intervention group and 20 to the usual working condition control group. The participant flow diagram detailed in Figure 1 displays the complete enrollment, allocation, follow-up, and analysis information for the Workstation Pilot Study (recruitment cohorts 1 and 2 combined) as outlined in the CONSORT Statement for reporting results of randomized controlled trials.[15]

Intervention

This study made use of treadmill desks in an effort to replace traditional seated office work with opportunities to accumulate light intensity non-exercise physical activity throughout the workday. The company purchased 8 treadmill desks for the study and these were placed throughout the office complex to be conveniently accessible to study participants. The primary components of the treadmill desk (The Walkstation – $4,000-$6,000 per unit; Steelcase Inc., Grand Rapids, MI) are an electronically controlled height adjustable desk (height adjustment range: 24.25 – 52”) and a low-speed treadmill (speed adjustment range: 0.3 – 2.0 mph). Each treadmill desk was equipped with a fully-functional desktop computer, keyboard, mouse, dual monitor display, all applications required to complete usual job tasks, and full access to network resources (e.g., intranet and internet). Only two shared workstations were equipped with telephones, as dedicated-use telephone lines were more the norm at the collaborating company.

Treadmill Desk Intervention: Participants randomized to the intervention group were asked to use the treadmill desk twice daily on workdays for up to 45 minutes/session (90 minutes/day) over a period of 3 months (12 weeks). Treadmill desks were shared and participants were required to schedule their sessions using a customized Microsoft Outlook calendar. Participants received an automated reminder 10 minutes prior to each of their scheduled sessions. Participants were able to self-select their preferred walking speed while on the treadmill desk. At the end of each session, participants were asked to complete a short electronic survey to document the duration and treadmill speed for each session using Research Electronic Data Capture (REDCap) software. Participants who failed to complete the daily sessions were also asked to fill out the survey and provide a reason why the session was not completed.

To increase adherence to the intervention protocol throughout the study, behavioral support strategies were administered remotely by a trained interventionist who closely monitored daily reporting of treadmill desk sessions. Participants who failed to report a daily session were contacted by the interventionist to ascertain whether they missed their session(s) or merely failed to report it. Specifically, if a session was missed, the interventionist sent an e-mail to support the participant in making their next scheduled session. Telephone calls were placed to the participant if two consecutive days of scheduled treadmill desk sessions were missed. This allowed the interventionist to speak directly with the participant about potential barriers to completing the daily sessions. Additional contact was made for those participants who had recurring issues with participation, including face-to-face visits.

Usual Working Condition Control: Participants randomized to the usual working condition control group were asked to maintain their normal working and physical activity patterns throughout the duration of the study.

Measurements

Primary outcomes assessed during the study were objectively monitored physical activity and sedentary behavior. Secondary outcomes were body mass, body fat percentage, and BMI. Assessments of all primary and secondary outcomes were completed at baseline and 3 months (follow-up). Additional descriptive data were collected at baseline (demographic characteristics), while data pertaining to characteristics of the intervention were collected throughout the study.

Demographic Characteristics: Age, race/ethnicity, and biological sex were queried from each participant at baseline.

Intervention Characteristics: Session characteristics (adherence, daily treadmill desk usage, treadmill desk session duration, and walking speed) of participants in the treadmill desk intervention group were tracked throughout the study using the aforementioned electronic surveys.

Physical Activity and Sedentary Behavior: Physical activity and sedentary behavior were objectively assessed using the ActiGraph accelerometer (model GT3X+; ActiGraph LLC, Pensacola, FL). Participants were asked to wear the accelerometer on their right hip 24 hours/day for at least 4 working days (weekdays) at baseline and follow-up. An elastic belt was used to secure the accelerometer to the participant's body. They were explicitly asked to only remove the device for bathing/showering or other water-based activities.

Anthropometric Characteristics: Height, body mass, and body fat percentage were assessed without shoes for all participants. Height was measured using a portable stadiometer (Seca model 217; Seca GmbH & Co. KG., Hamburg, Germany). Body mass and body fat percentage were measured using an integrated scale and bioelectrical impedance analysis unit (Tanita SC-240 Body Composition Analyzer; Tanita Corporation, Tokyo, Japan). BMI was subsequently calculated by dividing body mass by height squared (kg/m^2).

Data Reduction and Aggregation

Intervention Characteristics: Details regarding the calculation of variables describing the intervention characteristics of this study have been previously reported.[14] In contrast to our previous report presenting summarizations of intervention characteristics at a monthly level,[14] data presented herein are summarized for each week of intervention. A metric for assessing adherence to the intervention protocol was calculated by summing the number of walking sessions attended each week and dividing by the total number prescribed (10 sessions/week). The resulting fraction was multiplied by 100 to express adherence as a percentage of sessions attended. Mean daily treadmill desk usage (minutes/day), treadmill desk session duration (minutes/session), and walking speed (miles/hour) while using the treadmill desk were also calculated for each week of intervention.

Physical Activity and Sedentary Behavior: For each participant, accelerometer data were downloaded using ActiLife software (version 6; ActiGraph LLC, Pensacola, FL) and integrated to 60 second epochs (recording intervals) in two separate files using both the manufacturer's low-frequency extension (LFE) and default filters. The two files were then merged on matched timestamps while retaining activity count data derived from the LFE filter and step data from the default filter. Activity count data from the LFE filter were retained to more closely approximate activity count outputs from a previous generation of ActiGraph (7164)[16] used in adult calibration studies identifying cut points for physical activity and sedentary behavior.[17,18] Step data from the default filter were retained due to the LFE filter's tendency to substantially overestimate step counts[16,19] and because step count values derived using the default filter have been shown to be congruent on the group level with those from pedometers.[20]

Accelerometer data were then processed in two-steps using R (version 3.0.1; R Foundation for Statistical Computing, Vienna, Austria) and SAS® (version 9.3; SAS Institute Inc., Cary, NC). First, accelerometer wear and non-wear time were identified using the algorithm proposed by Choi et al.[21] (non-wear identified as ≥ 90 consecutive minutes of zero activity counts, with allowance for 2 minutes of non-zero activity counts if no activity counts were detected both 30 minutes upstream and downstream from that interval) and implemented in R's "PhysicalActivity" package. Daily wear time was calculated by subtracting non-wear time from 1,440 minutes. Only those days with at least 10 hours of wear time were considered valid and retained for further analyses.[17] Following wear time identification, data were scored and aggregated in SAS® to derive a series of physical activity and sedentary behavior indicator variables using a modified version of publically available SAS® code developed by the National Cancer Institute (http://riskfactor.cancer.gov/tools/nhanes_pam/). A full listing of the derived accelerometer variables and their definitions are presented in Table 1. Values for each variable were averaged over valid days and calculated for the full-day (12:00 a.m. – 11:59 p.m.) and for scheduled working hours only (8:00 a.m. – 4:30 p.m.). To account for the influence of accelerometer wear time on absolute estimates of physical activity, all variables were expressed relative to accelerometer wear time (except steps/day and sedentary bout length) and presented in units consistent with previous research (i.e., steps/min, min/hr). Only participants with a minimum of 3 days of valid accelerometry data at baseline and follow-up were retained for primary analyses.

Analytic Sample: Of the original 41 participants randomized and measured at baseline, 31 (intervention: n = 15, control: n = 16) were retained in the final analytic sample (Figure 1). The number of valid accelerometry monitoring days was similar at baseline (M ± *SE*; intervention: 4.2 ± 0.1 valid days, control: 3.9 ± 0.2 valid days) and follow-up (intervention: 4.3 ± 0.2 valid days, control: 4.1 ± 0.2 valid days). In general, accelerometer wear time was high for both groups at baseline (intervention: full-day = 19.9 ± 0.6 hours/day, working hours = 8.2 ± 0.1 hours/day; control: full-day = 19.9 ± 0.4 hours/day, working hours = 8.3 ± 0.1 hours/day) and follow-up (intervention: full-day = 20.5 ± 0.8 hours/day, working hours = 8.3 ± 0.1 hours/day; control: full-day = 18.9 ± 0.8 hours/day, working hours = 8.2 ± 0.1 hours/day).

Data Analysis

Descriptive statistics were calculated to summarize baseline and intervention characteristics. Differential between group changes in objectively monitored physical activity and sedentary behavior, body mass, body fat percentage, and BMI were assessed using a series of ANCOVA models. For each outcome measure, a separate model was fitted with change score (Δ = Month 3 – Baseline) as the dependent variable, treatment group (intervention vs. control) as a fixed effect, and baseline value as a covariate. Separate analyses were conducted to test for differential changes between groups in each objectively monitored physical activity and sedentary behavior variable across the full-day and during scheduled working hours only.

All statistical analyses were conducted using SAS® (version 9.3; SAS Institute Inc., Cary, NC). Statistical significance was defined as $p < 0.05$ (two-tailed).

RESULTS

Baseline Demographic and Anthropometric Characteristics

Baseline characteristics for each group and the overall sample are presented in Table 2. Participants were on average approximately 40 years of age and generally obese (73%; BMI $\geq$ 30). A large proportion of participants were African-American (76%) and nearly all were female (98%).

Intervention Characteristics

Mean values for adherence, daily treadmill desk usage, treadmill desk session duration, and walking speed while using the treadmill desk are depicted in Figure 2. Adherence during week 1 was approximately 65%, before falling to a low of 31% in week 3, and reaching a maximum of 66% in week 11. Daily treadmill desk usage largely mirrored intervention adherence and was approximately 54 minutes/day during week 1, before falling to a low of 24 minutes/day in week 3, and reaching a maximum of 58 minutes/day in week 11. Mean treadmill desk session duration varied from 38-44 minutes/session throughout the intervention. Mean walking speed while using the treadmill desk was lowest at week 1 (1.6 miles/hour), before increasing to 1.8 miles/hour by week 4, and stayed relatively stable near 1.8 miles/hour for the remainder of the intervention.

Intervention-Related Changes in Physical Activity and Sedentary Behavior

Full-Day Results: Baseline and follow-up values, and baseline-adjusted changes in ambulatory behavior during the full-day are depicted in Figure 3. The baseline-adjusted increase in steps/day among the intervention group was significantly greater than that observed for the control group (intervention vs. control pairwise difference = 1,622 steps/day, 95% CI: 364-2,880, $p = 0.013$). However, after expressing daily steps relative to accelerometer wear time, baseline-adjusted changes in mean steps/minute (intervention vs. control pairwise difference = 1.1 steps/min, 95% CI: -0.1-2.2, $p = 0.059$) were not significantly different between groups.

Baseline and follow-up values, and baseline-adjusted changes for all other measured physical activity and sedentary behavior variables during the full-day are presented in Table 3. Baseline-adjusted changes in non-movement, incidental movement, sporadic movement, brisk walking, and all faster locomotion were not significantly different between the intervention and control groups. However, baseline-adjusted increases in purposeful steps, slow walking, and medium walking were significantly greater among the intervention group in comparison to the control group. These categories represent steps accumulated at 40-99 steps/min.

Baseline-adjusted changes in low-intensity physical activity, and moderate-to-vigorous physical activity across the full-day were not significantly different between groups. However, the baseline-adjusted increase in light physical activity among the intervention group was significantly greater than that observed for the control group. No significant differential changes in full-day sedentary time, sedentary bout length, or transitions (breaks in sedentary time) were observed between groups.

Working Hours Results: Baseline and follow-up values, and baseline-adjusted changes in ambulatory behavior during working hours (8:00 a.m. – 4:30 p.m.) are depicted in Figure 4. The baseline-adjusted increase in steps/day among the intervention group was significantly greater than that observed for the control group (intervention vs. control pairwise difference = 1,001 steps/day, 95% CI: 200-1,803, $p = 0.016$). In addition, after representing steps relative to accelerometer wear time (steps/minute), the significant differential effect remained as increases in steps/minute for the intervention group were greater than those observed for the control group (intervention vs. control pairwise difference = 2.1 steps/min, 95% CI: 0.4-3.8, $p = 0.019$).

Baseline and follow-up values, and baseline-adjusted changes for all other measured physical activity and sedentary behavior variables during working hours are presented in Table 4. Baseline-adjusted changes in incidental movement, sporadic movement, brisk walking, and all faster locomotion were not significantly different between groups. However, baseline-adjusted decreases in non-movement, and increases in purposeful steps, slow walking, and medium walking were significantly greater among the intervention group in comparison to the control group.

Baseline-adjusted changes in low-intensity physical activity, and moderate-to-vigorous physical activity during working hours were not significantly different between groups. However, the baseline-adjusted increase in light physical activity among the intervention group was significantly greater than that observed for the control group. Additionally, the baseline-adjusted decrease in sedentary time among the intervention group was significantly greater than that observed for the control group. No significant differential changes in sedentary bout length or breaks in sedentary time during working hours were observed between groups.

Intervention-Related Changes in Anthropometric Characteristics

Baseline and follow-up values, and baseline-adjusted changes in body mass, body fat percentage, and BMI are presented in Table 5. No significant differential changes in any measured anthropometric variables were observed between the intervention and control groups.

DISCUSSION

This study presents detailed results evaluating objectively monitored physical activity and sedentary behavior during a randomized controlled trial of shared-treadmill desk use in a real world office workplace. Among the intervention group, treadmill desk use in the workplace was associated with increases in ambulatory behavior during the full-day (steps/day) and working hours only (steps/day and steps/min) relative to the control group. Differential group changes in ambulatory behavior appeared to be driven by an increase in time spent at stepping rates of 40-99 steps/min (described as purposeful steps, slow walking, and medium walking) in the intervention group. In terms of time spent in different intensities of activity count-defined physical activity, significant differential group changes were only noted for light physical activity with observed increases apparent for the intervention group relative to control. Changes in markers of sedentary behavior (sedentary time, sedentary bout length, and transitions) were generally non-significant, with sedentary time during working hours being the only variable to demonstrate a statistically significant differential between group change (≈ 3.5 min/hr decrease among intervention group relative to control). No significant changes in any measured or calculated anthropometric variables (body mass, body fat percentage, and BMI) were observed during the intervention period.

In general, treadmill desk use during the intervention reached only half of the target prescription (originally 2 sessions/day, 90 minutes/day) with an average of 1.1 walking sessions/day and a total of 45 min/day spent walking on the treadmill. This level of use was half of the observed 90 min/day reported by Thompson et al.[12] among physicians participating in a cross-over treadmill desk trial. The week-by-week depictions in Figure 2 clearly show substantial variability in treadmill desk usage throughout the 12-week intervention. Herein mean walking time per session on the treadmill desk remained relatively stable throughout the intervention, only ranging from 38-44 min/session. Participants in the intervention group self-selected an average walking speed of approximately 1.8 miles/hour, a value faster than the 1.5 miles/hour reported by John et al.[9] during a 9-month quasi-experimental treadmill desk study. This average speed (1.8 miles/hour) was also considerably faster than the 1.0 miles/hour reported by Thompson and colleagues during a short-term feasibility study[8] and a 24-week cross-over trial[12] using treadmill desks.

Observed increases in ambulatory behavior were significant among the intervention group, with approximately 66% (≈ 1,000 steps/day) of the daily increase (≈ 1,500 steps/day) attributable to more steps taken during scheduled working hours. Mean levels of daily ambulatory behavior for both groups at baseline can be interpreted as “low active” (5,000 – 7,499 steps/day).[22] At follow-up, mean steps/day for the control group remained indicative of the “low active” classification, while higher steps/day values among the intervention group can be characterized as “somewhat active” (7,500 – 9,999 steps/day).[22] Although increases in steps/day were statistically significant, they are substantially less than the 3-month increases in steps/day (median increase of 6,111 steps/day) reported in the quasi-experimental treadmill desk trial conducted by John et al.[9] Considering average speed on the treadmill was 1.8 miles/hour, observed changes in ambulatory behavior at stepping rates of 40-99 steps/min (purposeful steps, slow walking, and medium walking) are consistent with previous data detailing the relationships between cadence and walking speed,[23-25] suggesting that such velocities (< 2.0 mph) are typically associated with cadences of < 100 steps/min. Increases in time spent between 40-99 steps/min appear to be reflective of light physical activity (500-1,951 activity counts/min), the only activity count-defined intensity of physical activity which demonstrated a significant differential group change between baseline and follow-up. Increases in light physical activity observed in this study are in contrast to results presented by Parry et al.[13] which demonstrated that a multi-component intervention with shared access to a treadmill desk did not elicit significant changes in light physical activity.

Similar to results presented by Parry et al.,[13] reductions in accelerometer-determined sedentary time among intervention group participants were generally of a small-to-moderate magnitude (≈ 22 min/day reduction relative to baseline during the full-day and ≈ 19 min/day reduction relative to baseline during working hours) and only the reduction in work-related sedentary time was statistically significant relative to the control group. The clinical relevance of these findings remain unknown as the dose-response relationships between free-living sedentary behavior and beneficial/harmful effects have yet to be adequately elucidated.[26] Regardless, the observed declines in sedentary time in this study were of a substantially lesser magnitude than in the treadmill desk investigations conducted by Koepp et al.[10] and John et al.[9] However, comparing results in regard to sedentary time from this investigation with the aforementioned studies is problematic due to the differing intervention protocols, participant samples, and choice of assessment instruments. Previous epidemiological evidence has linked shorter sedentary bout lengths and more numerous breaks in sedentary time with lower BMI values.[27,28] However, neither of these accelerometer-based variables (sedentary bout length or breaks in sedentary time) was significantly impacted by this treadmill desk intervention.

Previous studies have attempted to quantify the potential health effects of using a treadmill desk, often focusing on weight loss, by calculating the expected increase in energy expenditure associated with its usage.[7,8,12] The 12-week treadmill desk intervention described herein did not appear to provide a sufficient stimulus to reduce body mass, body fat percentage, or BMI. Results from an acute observational study, quantifying energy expenditure via indirect calorimetry while using a treadmill desk,[7] suggested that workplace energy expenditure could be increased by 100 kcal/hour if typical workplace sedentary behaviors were replaced with treadmill desk walking at 1.1 miles/hour. A subsequent investigation by Thompson et al.[12] reported that overweight and obese physicians increased their accelerometer-estimated energy expenditure by 197 kcal/day with approximately 90 min/day of treadmill desk use. Using the American College of Sports Medicine metabolic equation for walking,[29] and the reported MET value for traditional seated office work,[30] the expected increase in energy expenditure associated with observed levels of treadmill desk use in this study (45 min/day, 1.8 miles/hour) would result in an approximate 100 kcal/day increase in energy expenditure (assuming a negligible energy contribution due to working while walking and a body mass equal to the sample mean). Given a constant energy intake, a 100 kcal/day increase in daily energy expenditure would likely be helpful for weight gain prevention but insufficient to elicit substantive weight loss.[31]

Public health guidelines specifically encourage accumulation of moderate-to-vigorous physical activity. The average speed that workers in this study preferred to walk at while working was 1.8 miles/hour, which equates to an approximate intensity of 2.4 METs,[29] a value less than what is considered at least moderate intensity (i.e., 3 METs or ≈ 3 miles/hour), [29,32,33] and therefore must be only considered light intensity physical activity. Therefore, it is clear that use of treadmill desks in the workplace does not fulfill public health recommendations to engage in physical activity that is of at least moderate intensity.[32]

Although there has been a randomized cross-over trial of physician's use of treadmill desks,[12] other interventions have been quasi-experimental in design.[8-10] Thus, this study represents the first randomized controlled trial of shared-treadmill desk use among office workers with predominantly seated working assignments. A primary strength of this study is that we tracked each participant's daily use of the treadmill desk in great detail via an electronic reporting system with follow-up inquiries when reports were not submitted. As such, we are confident in our reporting of treadmill desk adherence, daily/session durations, and walking speed. Further, although all of these previous intervention studies have reported objectively monitored changes in physical activity and/or sedentary behavior, none have presented the results in as much detail as we have herein, clearly explicating patterns and magnitudes of a full spectrum of movement/non-movement detected during working hours, but also during the remainder of the day outside of working hours. Further, this study represents a unique evaluation of behavior changes with a shared-treadmill desk paradigm which is more likely appropriate as a distribution choice in real world workplaces, in contrast to the dedicated-use paradigm implemented in all previous intervention studies.

Considering participants in this study's intervention group completed an average of 45 min/day of treadmill walking while at work, one would expect an approximate increase of 3,500 steps/day during scheduled working hours (based on an estimate of ≈ 80 steps/min[24] at this study's documented mean walking speed during week 12 [1.8 miles/hour]). However, we only observed an increase of a little more than 1,000 steps/day among the intervention group at the follow-up assessment. This discrepancy could be due to a compensation effect, whereby individuals become less active, accumulating fewer steps during periods when not using the treadmill desk. Also, this discrepancy could be due to a limitation of the ActiGraph GT3X+ accelerometer, which may have failed to adequately identify steps accumulated at the lower-end of the intensity spectrum (e.g., steps taken at slow treadmill walking speeds while using the treadmill desk).[16] In consideration of this possibility, the observed intervention-related increases in ambulatory behavior (i.e., steps/day, steps/min) associated with treadmill desk usage in this study may be underestimates of the true intervention effect and therefore should be interpreted with caution.

This was a randomized controlled trial with strategic behavioral support initiatives; however, adherence to the intervention was still less than optimal in this real world working environment. We acknowledge that the administration of such behavioral support methods may not be feasible in many work environments due to various cost and time considerations. Although it is unknown how adherence to the treadmill desk intervention may have been different without the aforementioned behavioral support, it seems unlikely that participants would have achieved adherence levels at or above those observed herein without such strategies. As such, employers implementing shared-treadmill desk paradigms in the workplace without behavioral support strategies may experience lower levels of treadmill desk usage than we observed in this study.

We had company management support for the study, indeed they initiated it.[14] However, the day-to-day work priorities still necessarily superseded workers' intent to engage fully in using the treadmill desk workstations as planned. Due to space and cost considerations, the company only purchased a limited number of treadmill desks. Since there have already been studies of individuals with access to dedicated treadmill desks in their own office or workspace,[9,12] and shared access is likely a more realistic distribution scheme in real world workplaces, we also specifically chose to implement shared access to treadmill desks. It is worth noting that less expensive treadmill desks have recently been introduced to the commercial market (e.g., Exerpeutic 2000 WorkFit ≈ $700.00, LifeSpan TR1200-DT5 ≈ $1,500). These less expensive treadmill desks may make dedicated-use distribution a more viable option for many employers in the future.

In summary, findings from this study suggest that a shared-treadmill desk paradigm, implemented in a real world office workplace and coupled with structured behavioral support strategies, can be effective in promoting positive changes in physical activity behaviors among overweight/obese office workers. The changes cannot be used to justify using treadmill desks as a replacement for exercise (i.e., moderate-to-vigorous physical activity) as promoted in public health recommendations, however. Less than desirable adherence to the treadmill desk intervention described herein reaffirms the need for further research in this area. Investigations comparing shared-use vs. dedicated-use workstation alternatives (including treadmill desks) are a logical next step to advance knowledge in the field.

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Figure 1. Participant flow diagram.

Figure 2. Treadmill desk intervention characteristics. Data are presented in panels: A) mean adherence, B) daily treadmill desk usage, C) treadmill desk session duration, and D) walking speed while using the treadmill desk. Error bars = *SE*.

Figure 3. Changes in ambulatory behavior during the full-day (12:00 a.m. – 11:59 p.m.). Data are presented in panels: A) baseline and follow-up values for steps/day, B) baseline-adjusted changes in steps/day, C) baseline and follow-up values for steps/min, and D) baseline-adjusted changes in steps/min. All values presented as M (*SE*). Intervention group = treadmill desk intervention group; control group = usual working condition control group; Δ = change (follow-up – baseline); error bars = *SE*.

*Significant differential change between groups ($p < 0.05$).

Figure 4. Changes in ambulatory behavior during working hours (8:00 a.m. – 4:30 p.m.). Data are presented in panels: A) baseline and follow-up values for steps/day, B) baseline-adjusted changes in steps/day, C) baseline and follow-up values for steps/min, and D) baseline-adjusted changes in steps/min. All values presented as M (*SE*). Intervention group = treadmill desk intervention group; control group = usual working condition control group; Δ = change (follow-up – baseline); error bars = *SE*.

*Significant differential change between groups ($p < 0.05$).

Figure

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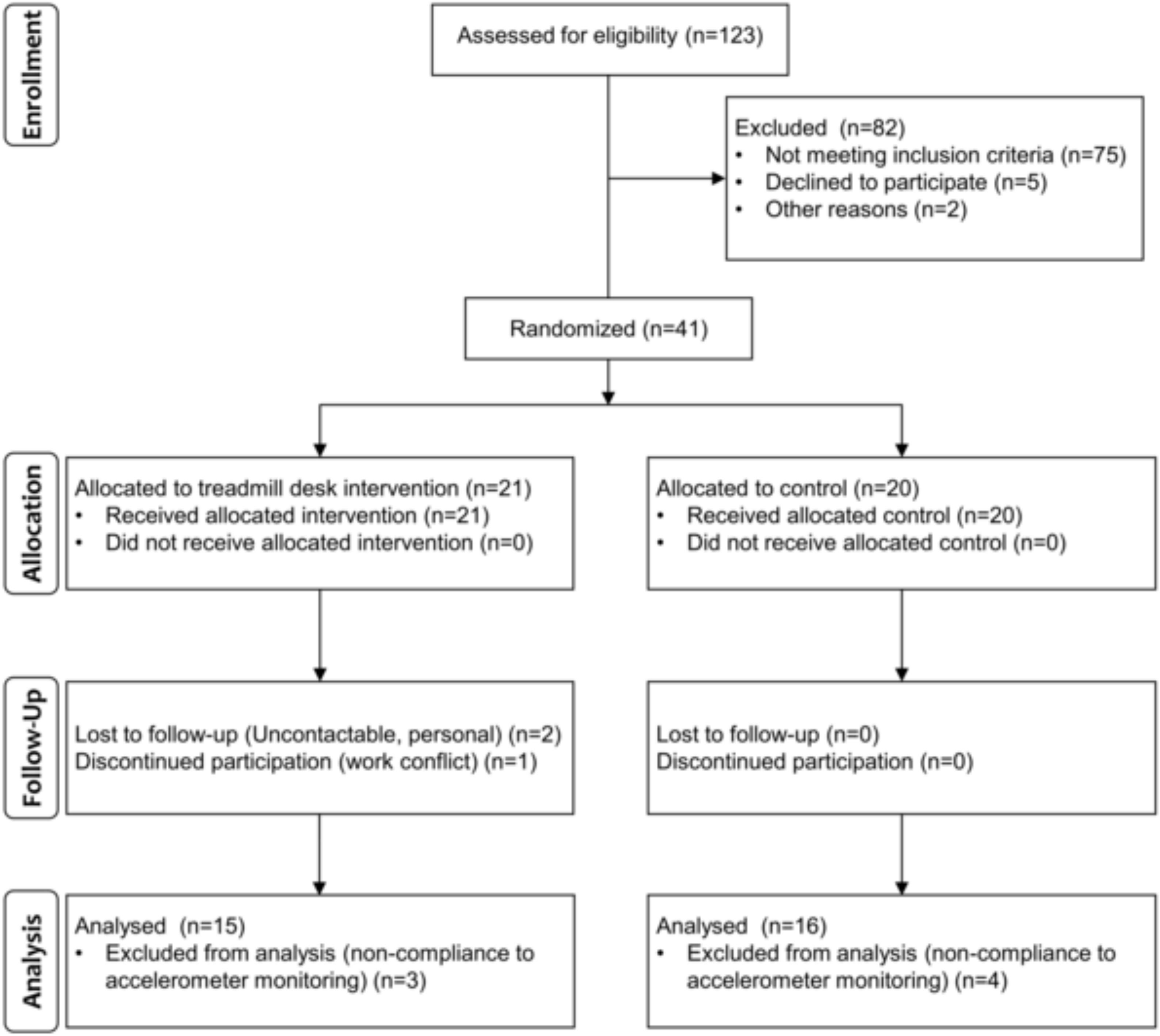

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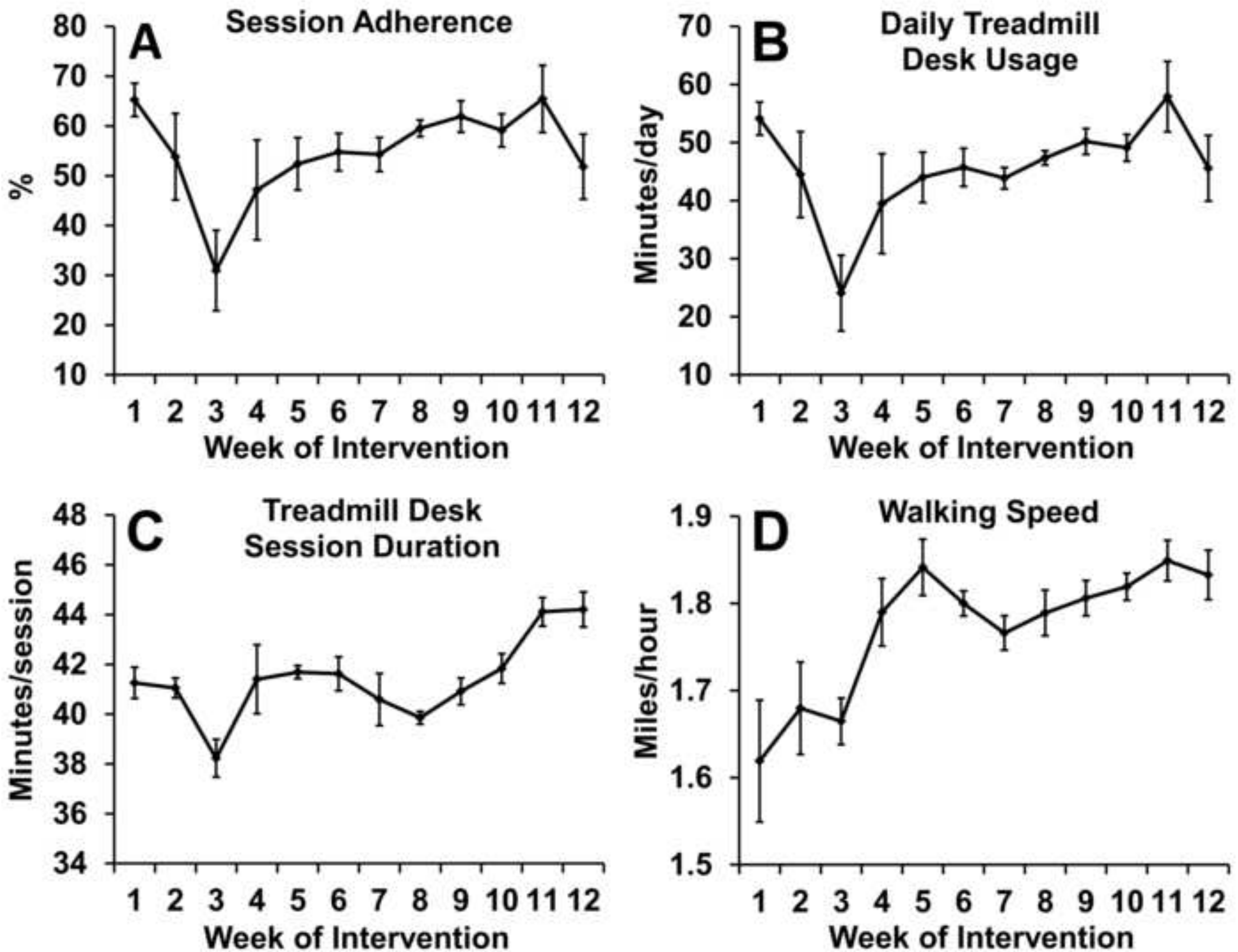

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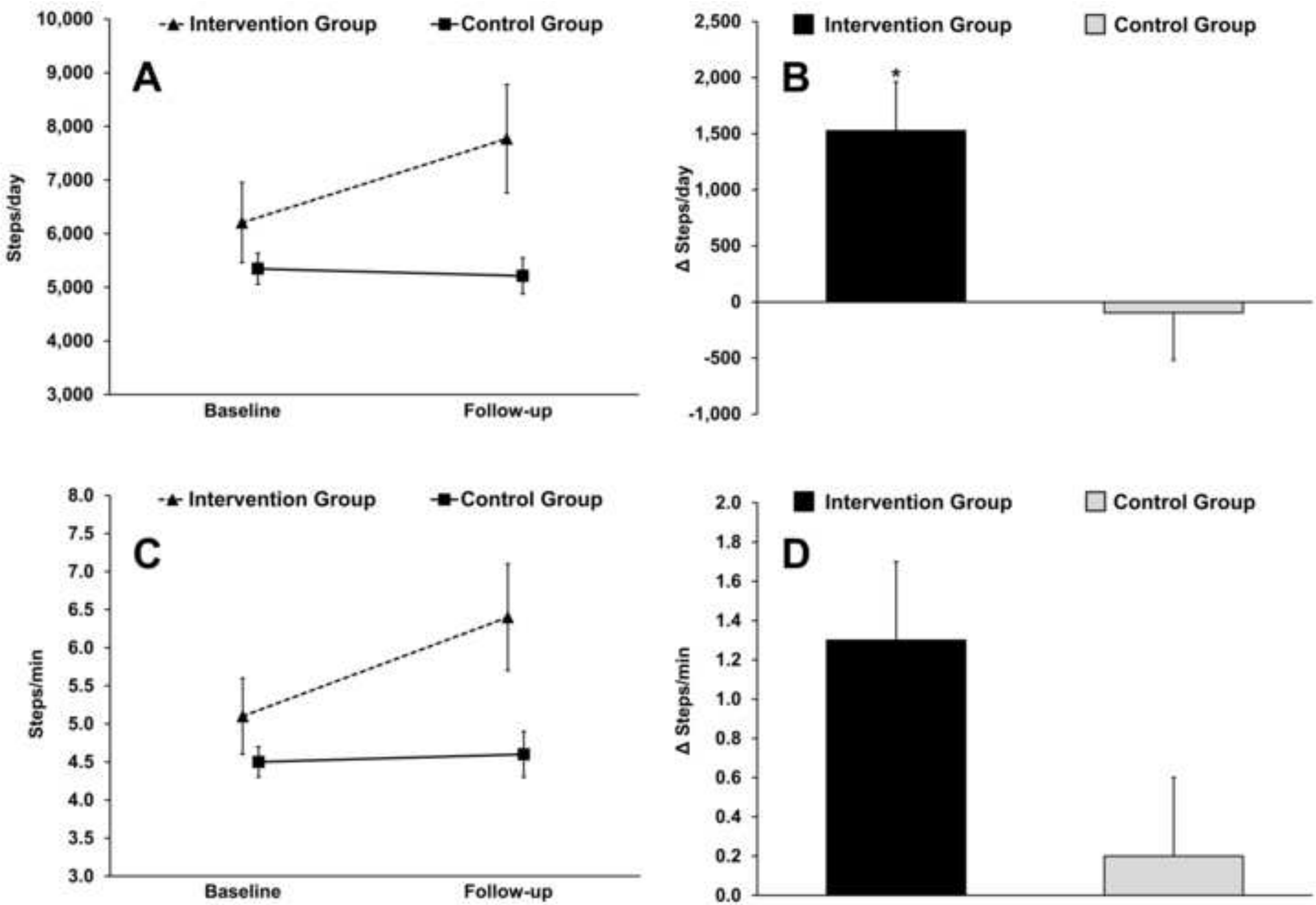

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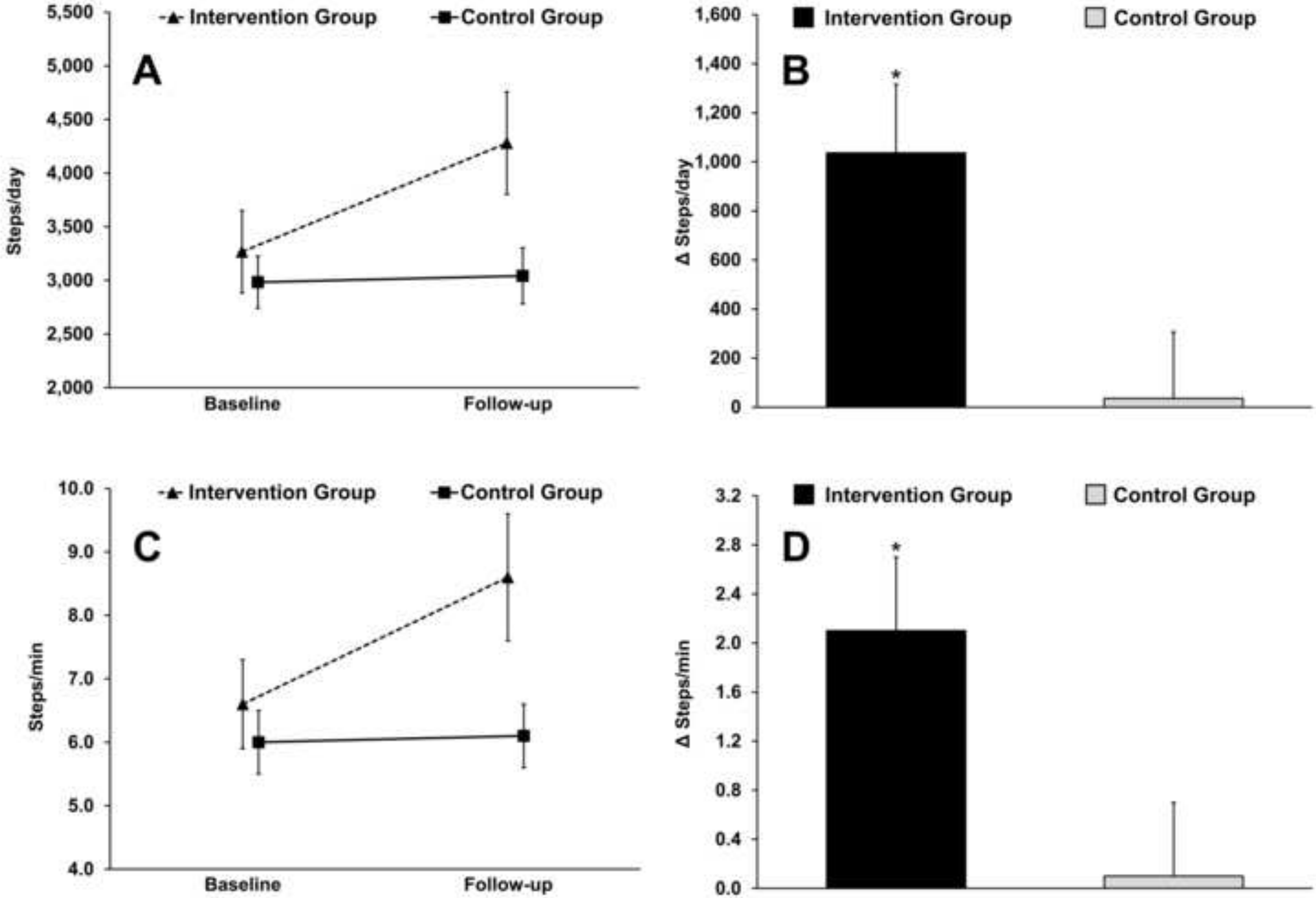

Table 1. Accelerometer-determined Physical Activity and Sedentary Behavior Variable Definitions.

Variable	Definitions*
Step Count Metrics	
Steps/day	Total accumulated steps.[35]
Steps/minute	Total accumulated steps divided by accelerometer wear time.[36]
Non-movement (min/hr)†	Total minutes at 0 steps/minute.[37]
Incidental movement (min/hr)†	Total minutes at 1-19 steps/minute.[37]
Sporadic movement (min/hr)†	Total minutes at 20-39 steps/minute.[37]
Purposeful steps (min/hr)†	Total minutes at 40-59 steps/minute.[37]
Slow walking (min/hr)†	Total minutes at 60-79 steps/minute.[37]
Medium walking (min/hr)†	Total minutes at 80-99 steps/minute.[37]
Brisk walking (min/hr)†	Total minutes at 100-119 steps/minute.[37]
Faster locomotion (min/hr)†	Total minutes ≥ 120 steps/minute.[37]
Activity Count Metrics	
Low-intensity physical activity (min/hr)†	Total minutes at 100-499 activity counts/minute.[36]
Light physical activity (min/hr)†	Total minutes at 500-1,951 activity counts/minute.[38]
Moderate-to-vigorous physical activity (min/hr)†	Total minutes ≥ 1,952 activity counts/minute.[18]
Sedentary time (min/hr)†	Total minutes at < 100 activity counts/minute.[17]
Sedentary bout length (min)	Average length of continuous bouts at < 100 activity counts/minute during valid wear time.[29]
Breaks in sedentary time (transitions/hr)†	Number of occurrences where activity counts rose from < 100 activity counts in one minute to ≥ 100 activity counts in the subsequent minute.[28]

*Values for each variable derived from valid wear time and averaged over valid days (≥ 10 hours/day of wear time).
†Values for each variable divided by accelerometer wear time and multiplied by 60 to derive units in min/hr.

Table 2. Baseline Demographic and Anthropometric Characteristics

Variable	**Treadmill Desk Intervention Group (n=21)**	**Usual Working Condition Control Group (n=20)**	**All (N= 41)**
Age (years)	40.0 (9.5)	40.3 (10.9)	40.1 (10.1)
Height (cm)	164.4 (6.6)	164.2 (5.8)	164.3 (6.1)
Body mass (kg)	97.8 (26.0)	96.1 (22.8)	96.9 (24.2)
Body fat percentage (%)	45.9 (5.6)	44.1 (5.5)	45.0 (5.6)
BMI (kg/m^2)	36.1 (8.7)	35.6 (8.2)	35.8 (8.3)
BMI status (n)			
Overweight	7	4	11
Obese	14	16	30
Race/Ethnicity (n)			
African-American	18	13	31
White	3	5	8
Other	-	2	2
Biological sex (n)			
Male	-	1	1
Female	21	19	40

Note. Values are presented as M (*SD*) except for BMI status, race/ethnicity, and biological sex.

Table 3. Changes in Physical Activity and Sedentary Behavior During the Full-Day Among the Treadmill Desk Intervention Group (n = 15) and the Usual Working Condition Control Group (n = 16).

	M (*SE*)		M (95% CI)		
Variable	**Baseline**	**Follow-Up**	**Within-Group Changes[a]**	**Intervention Group vs. Control Group Changes[a]**	**Pairwise *P*-Value**
Step Count Metrics					
Non-movement (min/hr)					
Intervention Group	36.2 (1.2)	35.7 (1.0)	-0.8 (-2.5, 1.0)		
Control Group	37.7 (1.2)	38.3 (1.1)	0.9 (-0.8, 2.5)	-1.6 (-4.1, 0.8)	0.176
Incidental movement (min/hr)					
Intervention Group	19.6 (1.1)	18.7 (0.9)	-0.5 (-2.2, 1.1)		
Control Group	18.3 (1.2)	17.7 (1.0)	-0.9 (-2.5, 0.7)	0.4 (-2.0, 2.7)	0.747
Sporadic movement (min/hr)					
Intervention Group	2.2 (0.2)	2.3 (0.2)	0.0 (-0.3, 0.4)		
Control Group	2.3 (0.2)	2.1 (0.2)	-0.1 (-0.4, 0.2)	0.1 (-0.4, 0.6)	0.606
Purposeful steps (min/hr)					
Intervention Group	0.9 (0.1)	1.6 (0.3)	0.7 (0.3, 1.1)		
Control Group	0.9 (0.1)	0.8 (0.1)	0.0 (-0.4, 0.3)	0.7 (0.2, 1.2)	0.008
Slow walking (min/hr)					
Intervention Group	0.4 (0.1)	0.7 (0.1)	0.3 (0.1, 0.5)		
Control Group	0.4 (0.0)	0.4 (0.0)	0.0 (-0.2, 0.2)	0.3 (0.0, 0.5)	0.032
Medium walking (min/hr)					
Intervention Group	0.3 (0.0)	0.6 (0.1)	0.3 (0.1, 0.5)		
Control Group	0.3 (0.0)	0.3 (0.1)	0.0 (-0.2, 0.2)	0.3 (0.0, 0.6)	0.032
Brisk walking (min/hr)					
Intervention Group	0.3 (0.1)	0.3 (0.1)	0.0 (-0.1, 0.1)		
Control Group	0.2 (0.1)	0.3 (0.1)	0.1 (0.0, 0.2)	-0.1 (-0.2, 0.1)	0.455
All faster locomotion (min/hr)					
Intervention Group	0.1 (0.1)	0.1 (0.1)	0.0 (-0.1, 0.0)		
Control Group	0.0 (0.0)	0.1 (0.0)	0.0 (0.0, 0.1)	0.0 (-0.1, 0.0)	0.279
Activity Count Metrics					
Low-intensity PA (min/hr)					
Intervention Group	10.4 (0.7)	9.8 (0.4)	-0.3 (-1.2, 0.6)		
Control Group	9.5 (0.7)	8.8 (0.6)	-1.0 (-1.8, -0.1)	0.7 (-0.6, 1.9)	0.303
Light PA (min/hr)					
Intervention Group	6.3 (0.3)	7.7 (0.5)	1.4 (0.6, 2.2)		
Control Group	5.9 (0.4)	5.7 (0.5)	-0.2 (-1.0, 0.6)	1.6 (0.5, 2.8)	0.008
Moderate-to-vigorous PA (min/hr)					
Intervention Group	1.2 (0.2)	1.2 (0.2)	0.1 (-0.3, 0.4)		
Control Group	1.1 (0.3)	1.3 (0.2)	0.1 (-0.2, 0.5)	-0.1 (-0.5, 0.4)	0.723
Sedentary time (min/hr)					
Intervention Group	42.2 (1.0)	41.3 (0.9)	-1.1 (-2.8, 0.6)		
Control Group	43.5 (1.0)	44.3 (1.1)	1.0 (-0.6, 2.6)	-2.1 (-4.5, 0.2)	0.076
Sedentary bout length (min)					
Intervention Group	7.7 (0.4)	7.8 (0.4)	-0.2 (-1.1, 0.7)		
Control Group	8.6 (0.6)	8.9 (0.5)	0.5 (-0.3, 1.4)	-0.7 (-2.0, 0.6)	0.272
Breaks in sedentary time (transitions/hr)					
Intervention Group	5.1 (0.2)	5.4 (0.2)	-0.1 (-0.4, 0.3)		
Control Group	5.2 (0.3)	5.7 (0.2)	-0.2 (-0.6, 0.1)	0.1 (-0.3, 0.6)	0.545

[a]Values are presented as least squares means adjusted for baseline value. PA = Physical activity.

Table

Table 4. Changes in Physical Activity and Sedentary Behavior During Working Hours Among the Treadmill Desk Intervention Group (n = 15) and the Usual Working Condition Control Group (n = 16).

Variable	M (*SE*)		M (95% CI)		
	Baseline	**Follow-Up**	**Within-Group Changes[a]**	**Intervention Group vs. Control Group Changes[a]**	**Pairwise *P*-Value**
Step Count Metrics					
Non-movement (min/hr)					
Intervention Group	33.7 (1.8)	31.6 (1.9)	-2.2 (-4.9, 0.4)		
Control Group	34.7 (1.5)	36.0 (1.7)	1.5 (-1.1, 4.0)	-3.7 (-7.4, 0.0)	0.049
Incidental movement (min/hr)					
Intervention Group	20.6 (1.8)	20.4 (1.5)	-0.1 (-2.7, 2.6)		
Control Group	19.9 (1.5)	18.6 (1.7)	-1.4 (-4.0, 1.1)	1.4 (-2.3, 5.1)	0.459
Sporadic movement (min/hr)					
Intervention Group	2.4 (0.2)	2.6 (0.3)	0.1 (-0.4, 0.7)		
Control Group	2.4 (0.2)	2.3 (0.2)	-0.2 (-0.7, 0.3)	0.3 (-0.4, 1.0)	0.384
Purposeful steps (min/hr)					
Intervention Group	1.3 (0.1)	2.6 (0.5)	1.3 (0.5, 2.1)		
Control Group	1.3 (0.2)	1.3 (0.1)	0.0 (-0.8, 0.7)	1.4 (0.3, 2.4)	0.016
Slow walking (min/hr)					
Intervention Group	0.7 (0.1)	1.2 (0.3)	0.6 (0.2, 1.0)		
Control Group	0.7 (0.1)	0.6 (0.1)	0.0 (-0.4, 0.3)	0.6 (0.1, 1.1)	0.019
Medium walking (min/hr)					
Intervention Group	0.5 (0.1)	1.1 (0.2)	0.6 (0.2, 1.0)		
Control Group	0.5 (0.1)	0.5 (0.1)	0.0 (-0.4, 0.4)	0.6 (0.1, 1.1)	0.021
Brisk walking (min/hr)					
Intervention Group	0.6 (0.2)	0.4 (0.1)	-0.1 (-0.3, 0.0)		
Control Group	0.5 (0.1)	0.6 (0.1)	0.1 (-0.1, 0.3)	-0.2 (-0.5, 0.0)	0.097
All faster locomotion (min/hr)					
Intervention Group	0.2 (0.1)	0.1 (0.0)	-0.1 (-0.1, 0.0)		
Control Group	0.1 (0.0)	0.1 (0.0)	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.1)	0.426
Activity Count Metrics					
Low-intensity PA (min/hr)					
Intervention Group	11.3 (1.0)	11.2 (0.7)	0.1 (-1.6, 1.8)		
Control Group	10.5 (1.0)	9.6 (1.1)	-1.1 (-2.7, 0.6)	1.2 (-1.2, 3.6)	0.311
Light PA (min/hr)					
Intervention Group	6.5 (0.4)	9.1 (1.0)	2.6 (1.2, 4.1)		
Control Group	6.1 (0.4)	5.8 (0.5)	-0.3 (-1.7, 1.1)	2.9 (0.9, 5.0)	0.007
Moderate-to-vigorous PA (min/hr)					
Intervention Group	1.6 (0.3)	1.3 (0.2)	-0.3 (-0.7, 0.0)		
Control Group	1.7 (0.4)	1.8 (0.3)	0.1 (-0.3, 0.4)	-0.4 (-0.9, 0.1)	0.102
Sedentary time (min/hr)					
Intervention Group	40.6 (1.3)	38.4 (1.5)	-2.4 (-5.0, 0.2)		
Control Group	41.7 (1.4)	42.8 (1.6)	1.2 (-1.3, 3.7)	-3.6 (-7.2, -0.1)	0.047
Sedentary bout length (min)					
Intervention Group	7.3 (0.6)	6.6 (0.7)	-0.7 (-2.0, 0.7)		
Control Group	7.6 (0.6)	8.7 (0.8)	1.2 (-0.1, 2.5)	-1.8 (-3.7, 0.1)	0.057
Breaks in sedentary time (transitions/hr)					
Intervention Group	6.3 (0.4)	6.5 (0.4)	0.2 (-0.4, 0.9)		
Control Group	5.9 (0.3)	5.6 (0.3)	-0.4 (-1.0, 0.2)	0.6 (-0.3, 1.5)	0.153

[a]Values are presented as least squares means adjusted for baseline value. PA = Physical activity.

Table

Table 5. Changes in Anthropometric Characteristics of the Treadmill Desk Intervention Group (n = 15) and the Usual Working Condition Control Group (n = 16).

	Mean (*SE*)		Mean (95% CI)		
Variable	**Baseline**	**Follow-Up**	**Within-Group Changes[a]**	**Intervention Group vs. Control Group Changes[a]**	**Pairwise *P*-Value**
Body mass (kg)					
Intervention Group	99.1 (7.3)	98.6 (7.2)	-0.5 (-2.2, 1.2)		
Control Group	97.4 (6.2)	97.3 (6.3)	-0.2 (-1.8, 1.5)	-0.3 (-3.9, 3.2)	0.769
Body fat percentage (%)					
Intervention Group	46.1 (1.6)	44.9 (1.4)	-1.0 (-3.1, 1.1)		
Control Group	43.9 (1.5)	42.8 (1.7)	-1.3 (-3.3, 0.8)	0.3 (-2.6, 3.2)	0.838
Body mass index (kg/m^2)					
Intervention Group	36.8 (2.4)	36.6 (2.3)	-0.2 (-0.8, 0.4)		
Control Group	36.0 (2.2)	35.9 (2.3)	-0.1 (-0.7, 0.5)	-0.1 (-1.0, 0.7)	0.758

[a]Values are presented as least squares means adjusted for baseline value.

Evaluation of a Treadmill Desk Intervention

Findings from this study suggest that using shared-treadmills desks in an office workplace can elicit favorable changes in light physical activity and sedentary behavior among overweight/obese workers. However, the use of treadmill desks should not be advocated as a replacement for moderate-to-vigorous physical activity promoted in public health guidelines.