Total Worker Health Intervention Increases Activity of Sedentary Workers

Lucas J. Carr, PhD,[1] Christoph Leonhard, PhD,[2] Sharon Tucker, RN, PhD,[3] Nathan Fethke, PhD,[4] Roberto Benzo, BS,[1] Fred Gerr, MD[4]

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Introduction: Office employees are exposed to hazardous levels of sedentary work. Interventions that integrate health promotion and health protection elements are needed to advance the health of sedentary workers. This study tested an integrated intervention on occupational sedentary/physical activity behaviors, cardiometabolic disease biomarkers, musculoskeletal discomfort, and work productivity.

Design: Two-group, RCT. Data were collected between January and August 2014.

Setting/participants: Overweight/obese adults working in sedentary desk jobs were randomized to: (1) a health protection–only group (HPO, $n=27$); or (2) an integrated health protection/health promotion group (HP/HP, $n=27$).

Intervention: HPO participants received an ergonomic workstation optimization intervention and three e-mails/week promoting rest breaks and posture variation. HP/HP participants received the HPO intervention plus access to a seated activity permissive workstation.

Main outcome measures: Occupational sedentary and physical activity behaviors (primary outcomes), cardiometabolic health outcomes, musculoskeletal discomfort, and work productivity (secondary outcomes) were measured at baseline and post-intervention (16 weeks).

Results: The HP/HP group increased occupational light intensity physical activity over the HPO group and used the activity permissive workstations 50 minutes/work day. Significant associations were observed between activity permissive workstation adherence and improvements in several cardiometabolic biomarkers (weight, total fat mass, resting heart rate, body fat percentage) and work productivity outcomes (concentration at work, days missed because of health problems).

Conclusions: The HP/HP group increased occupational physical activity and greater activity permissive workstation adherence was associated with improved health and work productivity outcomes. These findings are important for employers interested in advancing the well-being of sedentary office workers.

Trial registration: This study is registered at www.clinicaltrials.gov NCT02071420.
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Introduction

The health of today's working population is influenced by the work environment, which has become increasingly sedentary with the rise of the desktop computer. Sedentary jobs have risen 83% since 1950 and currently account for 43% of all U.S. jobs.[1] This is an important public health issue, as the WHO estimates that 3.2 million people die annually because of physical inactivity, making it the fourth leading cause of mortality.[2] Excessive sedentary work (e.g., tasks characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture)[3] places employees at increased risk for multiple chronic diseases,[4] obesity,[5] poorer cognitive function,[6,7] and mental distress.[8,9] Sedentary computer work has also been associated with upper body musculoskeletal symptoms and disorders.[10,11] Sedentary work tasks can therefore be

From the [1]Department of Health and Human Physiology, University of Iowa, Iowa City, Iowa; [2]The Chicago School of Professional Psychology at Xavier University of Louisiana, New Orleans, Louisiana; [3]University of Iowa Hospitals and Clinics, Iowa City, Iowa; and [4]Department of Occupational and Environmental Health, University of Iowa, Iowa City, Iowa

Address correspondence to: Lucas J. Carr, PhD, Department of Health and Human Physiology, University of Iowa, 225 S. Grand Avenue, Iowa City IA 52242. E-mail: lucas-carr@uiowa.edu.
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categorized as a hazardous exposure that increases worker's risk to adverse health outcomes and premature mortality.

Conversely, evidence suggests interrupting prolonged periods of sedentary time with even light-intensity bouts of physical activity may result in improved cardiometabolic biomarkers[12,13] and reduced musculoskeletal discomfort.[14] Regular physical activity has also been related to reduced decrements in quality of performed work and overall job performance.[15]

In an effort to advance the health of sedentary workers, employers have implemented narrowly focused health promotion only (e.g., promoting lifestyle behaviors off the job that reduce worker's risk)[16] or health protection only (e.g., reducing worker's exposure to risk factors arising within the work environment) programs.[17] Health promotion programs focused on promoting physical activity have largely relied on behavioral approaches aimed at motivating employees to be more active outside of working hours. Such approaches have suffered from poor attendance and failed to instill long-term behavior changes.[16,18] Conversely, health protection programs targeting sedentary employees have used postural ergonomic interventions and workstation adjustments. These approaches have mixed effects.[19]

In an effort to advance the health and well-being of workers more effectively and efficiently, the National Institute of Occupational Safety and Health announced the Total Worker Health Initiative (TWH), which has called for comprehensive programs that integrate both health promotion and health protection elements.[20] However, it is currently unclear whether integrated interventions are more effective than non-integrated interventions.[21,22] Further, few TWH interventions have focused exclusively on the needs of sedentary workers.[21] Of the studies conducted to date, most have introduced "activity permissive workstations," including treadmill desks and sit–stand desks, to reduce work sitting time.[23]

The authors have conducted three studies testing seated activity permissive workstations that allow the user to engage in light-intensity physical activity while remaining in a normal working position. This work suggests that even slow pedaling (40 rpm) on a seated elliptical workstation results in light-intensity physical activity (1.7 METs).[24] These devices are highly accepted among sedentary employees,[24,25] do not impair the employee's ability to complete computer work tasks such as typing,[24] and reduce occupational sedentary time.[25,26] However, this health promotion approach has yet to be combined with a health protection approach. Therefore, the objective of this study was to test the effect of an integrated health promotion/health protection worksite intervention (HP/HP) against a health protection–only intervention (HPO) on occupational physical activity, cardiometabolic biomarkers, musculoskeletal discomfort, and work productivity among a sample of adults working in full-time sedentary occupations. The study's hypothesis was that the HP/HP intervention would result in increased occupational physical activity and improved cardiometabolic biomarkers when compared with the HPO group.

Methods

Subjects and Design

Healthy, but physically inactive, overweight/obese adults working in full-time sedentary jobs (self-reported sitting ≥75% of work day) were recruited. This group represents a highly prevalent proportion of today's workforce, which is also at increased risk for chronic diseases. Participants of all races and ethnic backgrounds working at a large private company (1,200 employees) in the Midwest were recruited via an electronic advertisement placed on the company's wellness website. The advertisement included a link to an online eligibility survey. Research staff contacted interested and eligible employees via telephone to schedule a baseline testing session. Exclusionary criteria were:

1. limitations with or contraindications to physical activity as indicated by the Physical Activity Readiness Questionnaire[27];
2. self-reported acute illness or injury;
3. any self-reported cognitive impairments, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety);
4. self-reported diagnosis of a chronic condition such as heart failure or cancer;
5. medications contraindicated with physical activity;
6. having a height-adjustable workstation;
7. BMI <25.0 kg/m^2; or
8. reporting sitting <75% of a typical work day. Participants were compensated $40 for completing both baseline and post-intervention testing sessions.

Experimental protocols were approved by the Human Subjects Office IRB and voluntary written informed consent was obtained from each participant.

A total of 145 people responded to the advertisements, of which 83 were excluded for not meeting eligibility criteria: having a height-adjustable workstation (n=33), excluded medication use (n=32), low BMI (n=17), or having a non-sedentary occupation (n=13) (Figure 1). Three eligible participants declined to participate. Participants were consented immediately upon arrival for their baseline evaluation session and were then randomized to one of two groups:

1. an HP/HP group (ergonomic workstation optimization intervention; three activity-promoting e-mails/week and access to a seated active workstation); or
2. an HPO group (ergonomic intervention and e-mails only).

A block randomization procedure with random-sized (2–5) blocks was used to assign participants to treatment arms. A 1:1 randomization scheme was generated by the principal investigator using an online random sequence generator.[28] On the basis of the randomization schedule, participants were provided a sealed envelope indicating their treatment assignment by a research assistant who was previously unaware of the randomization schedule. Following randomization, group responsibilities were explained. Participants returned 16 weeks later to recomplete all baseline assessments. Participants were enrolled and completed all testing sessions between January 2014 and August 2014.

Health Protection–Only Group

The HPO group received a 30-minute face-to-face consultation aimed at optimizing each employee's computer workstation ergonomics, based on the authors' prior work.[10,11,17] All consultations were conducted by a single staff member trained by a certified ergonomist. Participants' working posture was analyzed while completing normal work tasks. Next, participants were provided tips for optimizing their workstation, and workstation adjustments were implemented if needed. Participants were encouraged to shift their posture regularly and take breaks from sitting every 30–45 minutes. Participants received three weekly e-mails promoting improved posture (30%), regular breaks from sitting (40%), self-efficacy for physical activity (15%), small changes to the work environment (10%), and tips for reducing occupational stress (5%). Messages were theory-based, targeting Social Cognitive Theory[29] constructs including self-monitoring, social support, self-efficacy, and perceived environment. Participants were asked to respond to 16 of 48 e-mails (33%) with a word or short phrase in an effort to promote participant engagement. HPO participants were asked to continue to use their workstations for the next 16 weeks.

Integrated Health Protection/Health Promotion Group

In addition to the intervention components received by the HPO group, the HP/HP group also received access to a portable seated elliptical machine (activeLife Trainer™, DuoDesk, LLC, New Orleans, LA; Appendix Figure 1, available online) placed underneath their desk for 16 weeks. The activeLife Trainer™ weighs 36 pounds and measures 30" in length, 21.5" in width, and 14.5" in height. The activeLife Trainer™ uses a forward–backward pedaling motion and securely attaches to standard five-wheeled office chairs allowing for comfortable pedaling at standard height desks. The research team worked with each participant to identify the most comfortable position for using the device (Appendix Figure 1, available online).

The HP/HP group was also provided a Bluetooth-enabled fifth generation iPod Touch (Apple, Cupertino, CA) with an application developed by a third party iOS developer to track participant's daily pedaling behaviors objectively and automatically and to provide users with real-time feedback on daily pedal time, distance, speed, and estimated caloric expenditure (Appendix Figure 1, available online). Participants were instructed to keep the iPod and activeLife Trainer™ at their desk at all times, keep the iPod charged, and use the application to view their daily pedaling progress. Participants were provided a pedaling goal sheet, which progressed from 30 minutes/day at Week 1 to 80 minutes/day at Week 16. All participants were

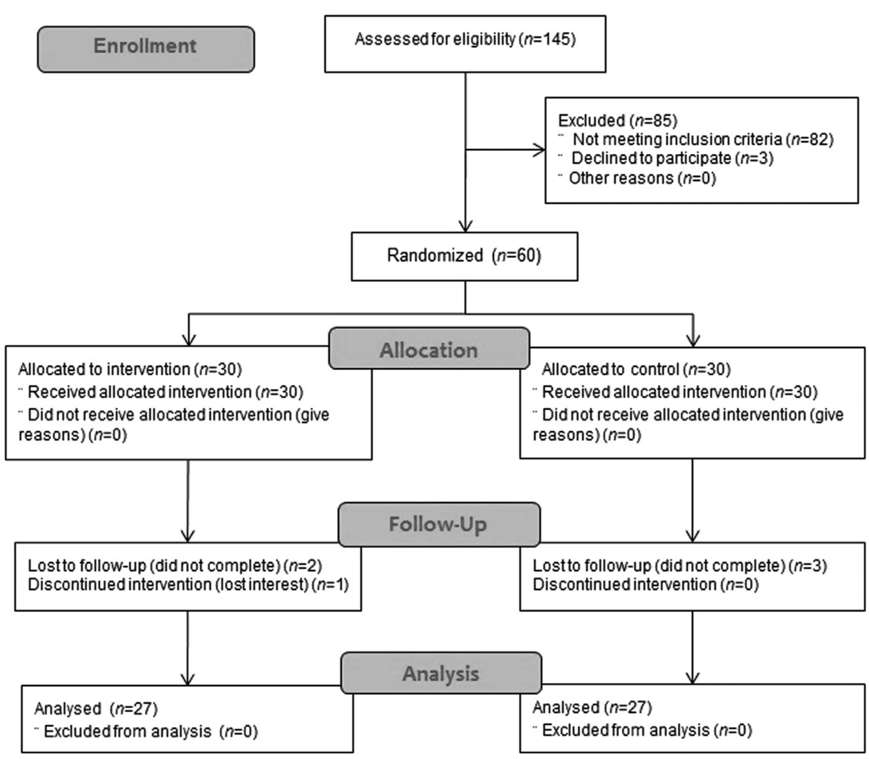

Figure 1. CONSORT Flow Diagram depicting recruitment/enrollment schematic.

encouraged to use the goal sheet as a guide but also to pedal at a pace/resistance they felt most comfortable completing while working.

Measures

All measures were collected at baseline and 16 weeks post-intervention in a controlled laboratory by a single staff member blinded to participant's group assignment. The primary outcome was percentage of occupational time spent sedentary and physically active as measured objectively via an ankle-worn accelerometer (GENEActiv Original, Activinsights Ltd, Kimbolton, United Kingdom). The GENEActiv was chosen for this study as it has demonstrated excellent reliability (coefficient of variation $[CV]_{intra}$=1.4%, CV_{inter}=2.1%) and validity (r =0.98, $p<0.001$)[30] for differentiating between sedentary behavior and physical activity intensity. The GENEActiv can also be worn on the ankle, making it ideally suited to measure lower leg ambulation.[31] Participants wore the monitor on the outside of the right ankle during all non-bathing hours for 5 continuous working days. Participants were asked to track monitor wear time and time spent at work using an activity log. Total activity counts during work time were measured, which is consistent with previous studies.[31] Previously established cut points for differentiating between sedentary behavior, light-intensity physical activity, and moderate-intensity physical activity were applied.[30] Days participants wore the monitors for <12 hours were excluded from final analysis.

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was measured via tactile arterial palpation at the radial artery. Height was measured to the nearest 0.5 cm using a professional-grade height rod (Seca 769, Hanover, MD). Weight, fat mass, lean mass, and body composition were measured using a multifrequency bioelectrical impedance analyzer (InBody 720, BioSpace Inc., Cerritos, CA), which has demonstrated excellent reliability (CV=1.8%)[32] and strong criterion validity when compared to dual-energy x-ray absorptiometry among obese adults (intraclass correlation coefficient [ICC]=0.83 for fat mass; ICC=0.90 for fat-free mass)[33] and healthy adults (r =0.80 to 0.91 for body composition).[32] Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[34] Estimated cardiorespiratory fitness was assessed via the Astrand–Rhyming submaximal cycle ergometer test, which has been demonstrated as an accurate estimate of cardiorespiratory fitness among adults.[35]

Work productivity was measured with the 13-item WHO Health and Work Performance Questionnaire,[36] which estimates workplace costs of health problems in terms of reduced job performance, sickness absence, and work-related accidents/injuries. Self-reported musculoskeletal symptoms were measured via the Standardized Nordic Musculoskeletal Symptom Questionnaire,[37] a commonly used and validated instrument for assessment of low back, shoulder, and distal upper extremity musculoskeletal symptoms.

Adherence to the active workstation (i.e., minutes pedaled/day, total days pedaled, number of 5-second pedaling bouts pedaled/day, pedaling speed) was assessed objectively via the iPod activity tracking application for the HP/HP group only. Adherence data were downloaded directly from each individual's iPod at the end of 16 weeks. E-mail response rates were manually tracked for the 16 e-mails sent requesting a response. To assess the helpfulness of individual intervention components, HP/HP completers were administered a process evaluation survey at 16 weeks. Participants rated the helpfulness of each intervention component using a 4-point Likert scale (1, *Not at all*; 2, *Very little*; 3, *Somewhat*; 4, *To a great extent*).

Statistical Analysis

A sample size of 51 was estimated (recruiting 60, assuming 15% attrition) as necessary to detect, with 80% power, at $\alpha \leq 0.05$, a 4.0% decrease in percentage of daily work time spent sedentary. The 4.0% reduction was identified as a reasonable estimate based on the authors' previous study in which participants reduced their percentage sedentary time by 3.7% over 12 weeks.[26] Means (SDs) were used to describe data where appropriate. This study was not powered to detect differences in cardiometabolic biomarkers, musculoskeletal discomfort, or work productivity outcomes. These measures were collected as secondary outcomes and to inform future trials. The paired samples *t*-test was used to estimate any within-group differences from baseline to post-intervention. ANCOVA was used to test for differences between groups at post-intervention. Baseline values of interest (e.g., age, gender, physical activity) were included as covariates in the model for all continuous variables consistent with recommended statistical procedures.[38] The underlying assumption of no between-group differences at baseline was confirmed for all measures by a two-sample *t*-test or Mann–Whitney rank sum test when appropriate. The strength of the linear relationships between daily pedaling time and changes in secondary outcomes was assessed via Pearson (or non-parametric, as appropriate) correlations. Finally, effect sizes for between-group differences of the primary outcomes of interest at 16 weeks (post-intervention) were calculated using Cohen's *d*.[39]

Results

A total of 60 participants interested and eligible for participation were randomized to one of two groups: HP/HP (n=30) or HPO (n=30). Of the 60 who enrolled, 54 participants completed all baseline and post-intervention assessments. Five participants (8.3%) were lost to follow-up and one participant discontinued from the intervention. Final analyses were completed on 54 participants, with 27 HP/HP and 27 HPO completers. Baseline group characteristics are presented in Table 1. Overall, participants were middle-aged and mostly classified as obese. Most participants were college-educated, reported an annual income >$50,000, and reported being non-Hispanic/white. Differential dropout was not observed and attrition overall was low at 7.0% (n=4).

Table 2 illustrates changes in occupational time spent in sedentary and physically active behaviors. Participants wore the activity monitor on 92% (495 of 540) of all possible days. No between-group differences were observed for monitor wear time at baseline or post-intervention. No between-group differences were

Table 1. Baseline Characteristics Between Groups (M ± SD)

	Active control (N=27)	Integrated intervention (N=27)	*p*-value
Age (years)	45.0±10.7	45.2±10.9	0.95
Female (%)	70.0	70.0	1.00
Height (cm)	168.6±7.9	169.0±11.1	0.84
Weight (lbs)	206.4±29.6	215.9±42.7	0.18
BMI	33.0±5.6	34.5±6.8	0.23
Non-Hispanic (%)	100.0	100.0	1.00
White (%)	85.2	96.0	0.70
College graduate (%)	81.0	67.0	0.36
Income >$50,000 (%)	67.0	44.4	0.50
Years worked at current job	11.3±10.3	11.1±9.5	0.92
Average hours worked/week	38.1±6.7	40.8±5.4	0.13

observed for any sedentary or physical activity measures at baseline. A significant within-group (baseline to post-intervention) change was observed in the HP/HP group for total occupational physical activity counts (p=0.03). A significant intervention effect favoring the HP/HP group was also observed for percentage of occupational time spent in light-intensity physical activity (p=0.04, Cohen's d=0.38). An intervention effect for percentage of occupational time spent sedentary was not observed but trended toward significance (p=0.08, Cohen's d=0.26). No intervention effects were observed for any of the measured cardiometabolic biomarkers, including weight (p=0.80), fat mass (p=0.66), lean mass (p=0.85), waist circumference (p=0.99), estimated $V0_2$ (p=0.76), resting systolic blood pressure (p=0.90), resting diastolic blood pressure (p=0.48), or resting heart rate (p=0.32) (data not presented). No intervention effects were observed for any of the measured musculoskeletal discomfort outcomes, including self-reported low back pain (p=0.94), neck pain (p=0.68), or shoulder pain (p=0.84) over the past 7 days. No significant intervention effects were observed for any work productivity items measured on the Health and Work Performance Questionnaire (data not presented). However, self-reported time spent concentrating on work improved in the HP/HP group (p=0.03) but not the HPO group (p=0.84) from baseline to post-intervention.

Participants who completed the HP/HP (n=27) used the active workstations an average of 70% (SD 56 days) of all work days and pedaled an average of 50.2 (SD 40.5) minutes/day (Appendix Figure 2, available online). Participants engaged in an average of 18.6 (SD 34.8) separate pedaling bouts/day, which lasted an average of 4.4 (SD 4.3) minutes/bout. Finally, participants pedaled at an average speed of 59.3 (SD 9.5) rpm. Participants responded to an average of 44% (SD 17%) of the 16 e-mails that requested a response. Following completion of the study, the HP/HP group rated the activity permissive workstation (mean Likert score, 3.2 of 4.0) and the ergonomic assessment (median Likert score, 2.9 of 4.0) most positively, followed by the regular e-mails (mean Likert score, 2.5 of 4.0).

Significant inverse relations were observed between average minutes pedaled/day and changes in weight, total fat mass, body fat percentage, and resting heart rate among HP/HP completers (Table 3). Significant inverse relations were also observed between the number of pedaling bouts/day and changes in body fat percentage and resting heart rate. A significant inverse association was observed between average pedaling speed and change in waist circumference. Finally, significant associations were observed between average minutes pedaled/day and improvements in work performance outcomes, including self-reported concentration at work and days missed because of physical/mental health problems over the past 4 weeks.

Discussion

The primary findings of this study indicate that an integrated HP/HP intervention significantly increased occupational light-intensity physical activity when compared with a non-integrated HPO group. This is an important addition to the literature on TWH interventions, as only one study[22] has examined whether integrated interventions are more beneficial than non-integrated interventions. Further, the present study represents one of the few TWH interventions targeted specifically to sedentary office workers.

The HP/HP group significantly increased total occupational physical activity from baseline to post-intervention by 11.5%, consistent with the percentage of work time spent using the activity permissive workstations (50.2 minutes/day = 10.2% of work day). This finding suggests

Table 2. Occupational Time Spent Sedentary and Physically Active at Baseline and Post-Intervention

	Baseline	Post-intervention	Mean difference[a] (95% CI)	Within group *p*-value	Group x time effect *p*-value
Total occupational physical activity (average counts/work day)					0.14
Control	91,266 (25,098)	91,124 (25,088)	−142 (−10,623, 10,339)	0.98	—
Intervention	84,665 (20,999)	94,417 (26,556)	9,752 (1,067, 18,436)	**0.03**	—
Percent work time sedentary (% workday)					0.08
Control	86.0 (4.4)	86.4 (4.6)	0.4 (−1.0, 1.8)	0.57	—
Intervention	86.8 (4.3)	84.8 (5.9)	−2.0 (−4.4, 0.3)	0.09	—
Percent work time in light intensity physical activity (% work day)					**0.04**
Control	4.7 (2.8)	4.3 (2.9)	−0.4 (−1.1, 0.2)	0.29	—
Intervention	4.2 (1.5)	4.9 (2.2)	0.7 (−0.2, 1.7)	0.08	—
Percent work time in moderate intensity physical activity (% work day)					0.38
Control	7.8 (2.0)	7.9 (2.2)	0.07 (−0.7, 0.8)	0.85	—
Intervention	8.0 (3.4)	9.1 (5.2)	1.1 (−1.1, 3.2)	0.32	—
Percent work time in vigorous intensity physical activity (% work day)					0.44
Control	1.5 (1.0)	1.5 (0.9)	0.0 (−0.3, 0.3)	0.84	—
Intervention	1.0 (0.7)	1.3 (0.7)	0.3 (0.0, 0.5)	0.10	—

Note: Boldface indicates statistical significance ($p < 0.05$). Data presented as Mean (SD).
[a]Mean change from baseline (95% CI), adjusted for baseline value (ANCOVA).

most pedaling time was of light intensity, which is consistent with previous findings.[24] Those estimates suggest 50 minutes of pedaling on a seated elliptical workstation at the recorded pace (59 rpm) would result in roughly 107 additional kilocalories burned/day and a reduction of 1.1 pounds if sustained for a sufficient amount of time. This finding is important considering the findings of Church et al.,[1] which estimate daily occupational energy expenditure has decreased by an average of 100 kilocalories/day since 1960 and that this reduction accounts for a large portion of the increase in mean U.S. body weight.

HP/HP participants used the active workstation an average of 70% of all work days for an average of 50 minutes/day over 16 weeks. This adherence data is far superior to what the authors found in two previous studies, which included a cycle-style pedal machine (MagneTrainer, 3D Innovations, Greeley, CO).[25,26] Participants used the cycle devices 38% of all work days for an average of 31 minutes/day over 12 weeks.[26] Significant declines in daily pedaling time were also observed over 12 weeks. Conversely, although a slight decline was observed over the first 3 weeks in the present study, daily pedaling time reached a near steady state over the remainder of the intervention, suggesting participants might maintain this level of activity over the long term (Appendix Figure 2, available online). Design differences between the cycle and elliptical workstations likely contributed to the improved adherence in the present study. Cycle-style devices use an up/down pedaling motion, which causes users' knees to hit their desks whereas elliptical-style devices employ a forward/backward pedaling motion that minimizes this issue. Though a long-term follow-up assessment is needed to confirm long-term adherence rates, this finding is important given how few physical activity interventions result in long-term behavior maintenance.[40]

These findings take on added meaning in light of a recent meta-analysis that concluded worksite interventions that include environmental supports like activity permissive workstations are more effective than those that do not.[41] These findings are consistent with the hierarchy of hazard control systems, which suggests the most effective way to mitigate hazardous work exposure is to eliminate or substitute the source of the exposure with a better option. If sedentary workstations are considered a source of hazardous sedentary work time, replacing or modifying them with activity permissive options may be an effective way to sustainably minimize workers' exposure to hazardous sedentary work. In the present study, 19 of 27 (70%) HP/HP participants chose

Table 3. Dose-response Relations Between Pedal Time and Changes in Secondary Outcomes Among the Integrated Intervention Group

	Average pedal time/day (min)	Average # of pedal bouts/day	Average pedal speed (rpm)
Delta weight (lbs)	**R= −0.41; *p*=0.04**	–	–
Delta fat mass (lbs)	**R= −0.48; *p*=0.02**	–	–
Delta % body fat	**R= −0.45; *p*=0.02**	**R= −0.41; *p*=0.04**	–
Delta resting heart rate (bpm)	**R= −0.49; *p*=0.01**	**R= −0.45; *p*=0.02**	–
Delta waist circumference (cm)	–	–	**R= −0.48; *p*=0.02**
Concentration while at work	**R= 0.50; *p*=0.01**	–	–
Days missed because of physical/mental health over past 4 weeks	**R= −0.41; *p*=0.03**	–	–

Note: Boldface indicates statistical significance ($p<0.05$).
bpm, beats per minute; cm, centimeter; lbs, pounds; min, minutes.

to keep their active workstation, which suggests most participants were satisfied with the device.

It should be noted the upfront cost of the equipment used in the present study ($600/participant for activeLife Trainer™ plus iPod Nano) might be prohibitive to some organizations. However, these costs are comparable to other activity permissive workstations such as sit–stand and treadmill desks, which have also been shown to be useful for increasing occupational physical activity time.[42] Future studies are needed that compare the cost effectiveness of various activity permissive workstations as these are important considerations for employers making worksite wellness purchasing decisions.

No significant intervention effects were observed for any cardiometabolic disease biomarkers. This finding is inconsistent with many studies that have examined the impact of standing and treadmill desks on cardiometabolic risk factors.[42] However, significant associations were observed between daily use of the activity permissive workstations and improvements in four cardiometabolic biomarkers. Although it is well known that greater physical activity is associated with improvements in a number of cardiometabolic biomarkers,[43] recent research has begun recognizing the importance of light-intensity physical activity that contributes substantially to overall daily energy expenditure.[44] Researchers have even suggested a "re-conceptualization of public health physical activity guidelines to maximize the likelihood of shifting large proportions of sedentary individuals along the physical activity continuum."[44] The present findings suggest light-intensity seated workstation pedaling may reduce risk for cardiometabolic diseases if performed at a sufficient dose and may represent one possible model for shifting sedentary workers along the physical activity continuum.

No intervention effects were observed for any musculoskeletal discomfort outcomes or work productivity outcomes. Though it is known that upper body musculoskeletal symptoms and disorders are common among sedentary office workers,[11] participants of this study did not report reductions in pain of the lower back, neck, or shoulders. This finding is not surprising, as individuals with previous musculoskeletal discomfort were not recruited. Still, this suggests the introduction of the activity permissive workstation did not cause any additional musculoskeletal discomfort. Similarly, though between-group differences in work productivity were not observed, the absence of decrements in work productivity is a potentially positive finding given that the present study tested an approach implemented during the work day. Significant associations were, however, observed between daily minutes spent pedaling and two work productivity outcomes. Specifically, participants who used the active workstations more were more likely to report a reduction in the number of work days missed because of health issues and were more likely to report improved concentration at work. These findings may be of importance to employers because they suggest the HP/HP intervention has potential to yield work productivity improvements.

The relatively small sample, composed primarily of middle-aged, overweight/obese, female volunteers working at a single institution, limits generalizability of the findings. It is possible that this intervention may not be acceptable for men or non-overweight workers. Future studies are encouraged that target more-generalizable samples, as previous research has shown sedentary behavior to be a risk factor independent of sex and weight. Post hoc analyses did not identify relationships between weight and any measures of intervention adherence; therefore, there is no reason to suspect weight would impact intervention success. Postures between the two groups were not compared after installing the portable elliptical machines. Therefore, it is possible the activity permissive workstation altered participants' postures in a way that encouraged users to get up and move more at work. Further research is needed to confirm whether a user's posture remains ergonomically correct while using these devices. This study was one of the first to test an integrated intervention targeted to sedentary office workers. Other strengths include the novel activity permissive workstation, the use of objective measures of occupational activity and intervention adherence, and the measurement of work productivity. More TWH worksite interventions are needed that focus on advancing the health of the growing number of sedentary workers. Specific studies that target the unique challenges small- and medium-sized companies face when implementing worksite wellness programs are also needed.

Conclusions

The findings of this study suggest the integrated HP/HP intervention significantly increased occupational light-intensity physical activity over a non-integrated HPO intervention. The average time participants in the integrated group used the activity permissive workstation (50 minutes/day) would be sufficient to compensate for the decline in daily occupational energy expenditure observed in the U.S. since 1960. Significant associations were observed between activity permissive workstation adherence and both cardiometabolic biomarkers and work productivity outcomes, suggesting greater adherence to the intervention may result in healthier and more-productive employees. These findings are important for employers interested in advancing the health and well-being of sedentary office workers.

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References

1. Church TS, Thomas DM, Tudor-Locke C, et al. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One*. 2011;6(5):e19657. http://dx.doi.org/10.1371/journal.pone.0019657.
2. WHO. Global health risks. Mortality and burden of disease attributable to selected major risks. 2009; www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf?ua=1. Accessed July 7, 2015.
3. Tremblay MS. Standardized use of the terms "sedentary" and "sedentary behaviours" [letter]. *Appl Physiol Nutr Metab*. 2012;37:540–542. http://dx.doi.org/10.1139/h2012-124.
4. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162(2):123–132. http://dx.doi.org/10.7326/M14-1651.
5. Hu FB. Sedentary lifestyle and risk of obesity and type 2 diabetes. *Lipids*. 2003;38(2):103–108. http://dx.doi.org/10.1007/s11745-003-1038-4.
6. Voss MW, Carr LJ, Clark R, Weng T. Revenge of the "sit" II: Does lifestyle impact neuronal and cognitive health through distinct mechanisms associated with sedentary behavior and physical activity? *Mental Health Phys Act*. 2014: 7(1):9–24. http://dx.doi.org/1.016/j.mhpa.201?.01.001.
7. Hamer M, Stamatakis E. Prospective study of sedentary behavior, risk of depression, and cognitive impairment. *Med Sci Sports Exerc*. 2014;46(4):718–723. http://dx.doi.org/10.1249/MSS.0000000000000156.
8. Mouchacca J, Abbott GR, Ball K. Associations between psychological stress, eating, physical activity, sedentary behaviours and body weight among women: a longitudinal study. *BMC Public Health*. 2013;13:828. http://dx.doi.org/10.1186/1471-2458-13-828.
9. Hamer M, Coombs N, Stamatakis E. Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from the Health Survey for England. *BMJ Open*. 2014;4(3):e004580. http://dx.doi.org/10.1136/bmjopen-2013-004580.
10. Gerr F, Fethke N. Ascertaining computer use in studies of musculoskeletal outcomes among computer workers: differences between self-report and computer registration software. *Occup Environ Med*. 2011;68(7):465–466. http://dx.doi.org/10.1136/oemed-2011-100116.
11. Gerr F, Marcus M, Ensor C, et al. A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. *Am J Ind Med*. 2002;41(4):221–235. http://dx.doi.org/10.1002/ajim.10066.
12. Lubans DR, Morgan PJ, Tudor-Locke C. A systematic review of studies using pedometers to promote physical activity among youth. *Prev Med*. 2009;48(4):307–315. http://dx.doi.org/10.1016/j.ypmed.2009.02.014.
13. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661–666. http://dx.doi.org/10.2337/dc07-2046.
14. Pronk NP, Katz AS, Lowry M, Payfer JR. Reducing occupational sitting time and improving worker health: the Take-a-Stand Project, 2011. *Prev Chronic Dis*. 2012;9:E154. http://dx.doi.org/10.5888/pcd9.110323.
15. Pronk NP, Martinson B, Kessler RC, Beck AL, Simon GE, Wang P. The association between work performance and physical activity, cardiorespiratory fitness, and obesity. *J Occup Environ Med*. 2004;46(1):19–25. http://dx.doi.org/10.1097/01.jom.0000105910.69449.b7.

16. Dishman RK, Oldenburg B, O'Neal H, Shephard RJ. Worksite physical activity interventions. *Am J Prev Med*. 1998;15(4):344–361. http://dx.doi.org/10.1016/S0749-3797(98)00077-4.
17. Gerr F, Marcus M, Monteilh C, Hannan L, Ortiz D, Kleinbaum D. A randomised controlled trial of postural interventions for prevention of musculoskeletal symptoms among computer users. *Occup Environ Med*. 2005;62(7):478–487. http://dx.doi.org/10.1136/oem.2004.015792.
18. Conn VS, Hafdahl AR, Cooper PS, Brown LM, Lusk SL. Meta-analysis of workplace physical activity interventions. *Am J Prev Med*. 2009; 37(4):330–339. http://dx.doi.org/10.1016/j.amepre.2009.06.008.
19. Brewer S, Van Eerd D, Amick BC III, et al. Workplace interventions to prevent musculoskeletal and visual symptoms and disorders among computer users: a systematic review. *J Occup Rehabil*. 2006;16(3): 325–358. http://dx.doi.org/10.1007/s10926-006-9031-6.
20. Schill AL, Chosewood LC. The NIOSH Total Worker Health program: an overview. *J Occup Environ Med*. 2013;55(12 Suppl):S8–11. http://dx.doi.org/10.1097/JOM.0000000000000037.
21. Anger WK, Elliot DL, Bodner T, et al. Effectiveness of Total Worker Health interventions. *J Occup Health Psychol*. 2015;20(2):226–247. http://dx.doi.org/10.1037/a0038340.
22. Sorensen G, Stoddard AM, LaMontagne AD, et al. A comprehensive worksite cancer prevention intervention: behavior change results from a randomized controlled trial (United States). *J Public Health Policy*. 2003;24(1):5–25. http://dx.doi.org/10.2307/3343174.
23. Tudor-Locke C, Schuna JM Jr, Frensham LJ, Proenca M. Changing the way we work: elevating energy expenditure with workstation alternatives. *Int J Obes (Lond)*. 2014;38(6):755–765. http://dx.doi.org/10.1038/ijo.2013.223.
24. Carr LJ, Maeda H, Luther B, Rider B, Tucker SJ, Leonhard C. Acceptability and effects of a seated active workstation during sedentary work: A proof of concept study. *Int J Workplace Health Manage*. 2014; 7(1):2–15. http://dx.doi.org/10.1108/IJWHM-03-2013-0008.
25. Carr LJ, Walaska KA, Marcus BH. Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace. *Br J Sports Med*. 2012;46(6):430–435. http://dx.doi.org/10.1136/bjsm.2010.079574.
26. Carr LJ, Karvinen K, Peavler M, Smith R, Cangelosi K. Multicomponent intervention to reduce daily sedentary time: a randomised controlled trial. *BMJ Open*. 2013;3(10):e003261. http://dx.doi.org/10.1136/bmjopen-2013-003261.
27. Cardinal BJ, Esters J, Cardinal MK. Evaluation of the revised physical activity readiness questionnaire in older adults. *Med Sci Sports Exerc*. 1996;28(4):468–472. http://dx.doi.org/10.1097/00005768-199604000-00011.
28. Random Sequence Generator. Random.org. www.random.org/sequences/. Accessed October 30, 2013.
29. Bandura A, ed. *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice-Hall; 1986.
30. Esliger DW, Rowlands AV, Hurst TL, Catt M, Murray P, Eston RG. Validation of the GENEA accelerometer. *Med Sci Sports Exerc*. 2011; 43(6):1085–1093. http://dx.doi.org/10.1249/MSS.0b013e31820513be.
31. Wijsman CA, Westendorp RG, Verhagen EA, et al. Effects of a web-based intervention on physical activity and metabolism in older adults: randomized controlled trial. *J Med Internet Res*. 2013;15(11):e233. http://dx.doi.org/10.2196/jmir.2843.
32. Jensky-Squires NE, Dieli-Conwright CM, Rossuello A, Erceg DN, McCauley S, Schroeder ET. Validity and reliability of body composition analysers in children and adults. *Br J Nutr*. 2008;100(4):859–865. http://dx.doi.org/10.1017/S0007114508925460.
33. Faria SL, Faria OP, Cardeal MD, Ito MK. Validation study of multi-frequency bioelectrical impedance with dual-energy X-ray absorpti ometry among obese patients. *Obes Surg*. 2014;24(9):1476–1480. http://dx.doi.org/10.1007/s11695-014-1190-5.
34. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*, 7th ed., Philadelphia, PA: Lippincott Williams & Wilkins; 2006.
35. Siconolfi SF, Cullinane EM, Carleton RA, Thompson PD. Assessing VO2max in epidemiologic studies: modification of the Astrand-Rhyming test. *Med Sci Sports Exerc*. 1982;14(5):335–338.
36. Kessler RC, Barber C, Beck A, et al. The World Health Organization Health and Work Performance Questionnaire (HPQ). *J Occup Environ Med*. 2003;45(2):156–174. http://dx.doi.org/10.1097/01.jom.0000052967.43131.51.
37. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon*. 1987; 18(3):233–237. http://dx.doi.org/10.1016/0003-6870(87)90010-X.
38. Van Breukelen GJ. ANCOVA versus change from baseline: more power in randomized studies, more bias in nonrandomized studies [corrected]. *J Clin Epidemiol*. 2006;59(9):920–925. http://dx.doi.org/10.1016/j.jclinepi.2006.02.007.
39. Cohen J, ed. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. Hillsdale, NJ: Erlbaum; 1988.
40. Jepson RG, Harris FM, Platt S, Tannahill C. The effectiveness of interventions to change six health behaviours: a review of reviews. *BMC Public Health*. 2010;10:538. http://dx.doi.org/10.1186/1471-2458-10-538.
41. Neuhaus M, Eakin EG, Straker L, et al. Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations. *Obes Rev*. 2014;15(10):822–838. http://dx.doi.org/10.1111/obr.12201.
42. MacEwen BT, MacDonald DJ, Burr JF. A systematic review of standing and treadmill desks in the workplace. *Prev Med*. 2015;70:50–58. http://dx.doi.org/10.1016/j.ypmed.2014.11.011.
43. Powell KE, Paluch AE, Blair SN. Physical activity for health: What kind? How much? How intense? On top of what? *Annu Rev Public Health*. 2011;32:349–365. http://dx.doi.org/10.1146/annurev-publhealth-031210-101151.
44. Smith L, Ekelund U, Hamer M. The potential yield of non-exercise physical activity energy expenditure in public health. *Sports Med*. 2015;45(4):449–452. http://dx.doi.org/10.1007/s40279-015-0310-2.

Appendix

Supplementary data

Supplementary data associated with this article can be found at http://dx.doi.org/10.1016/j.amepre.2015.06.022.