Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

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Complete List of Authors:	Carr, Lucas; University of Iowa, Health and Human Physiology Karvinen, Kristina; Nipissing University, School of Physical and Health Education Peavler, Mallory; East Carolina University, Kinesiology Smith, Rebecca; East Carolina University, Kinesiology Cangelosi, Kayla; East Carolina University, Kinesiology
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Corresponding Author:

Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu

Co-Authors:

Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay, Ontario, Canada

Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA

Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

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ABSTRACT

Background. Sedentary behavior has been estimated to be responsible for 9% of premature deaths worldwide. The purpose of this study was to test the efficacy of a multipronged technology intervention for reducing daily sedentary time and improving cardiometabolic disease risk amongst sedentary university employees using a randomized controlled trial design. **Methods**. Forty adults working in sedentary jobs were randomized to either: 1) an intervention group (N=23; 47.6±9.9 yrs; 94.1% female; 33.2±4.5 kg/m^2); 2) or wait list control group (N=17; 42.6±8.9 yrs; 86.9% female; 31.7±4.9 kg/m^2). The intervention group received a theory-based, internet-delivered program, a portable pedal machine at work and a pedometer for 12 weeks. Primary (sedentary and physical activity behavior) and secondary (heart rate, blood pressure, height, weight, waist circumference, percent body fat, cardiorespiratory fitness, fasting lipids) outcomes were measured at baseline and post-intervention. Exploratory outcomes including intervention compliance and process evaluation measures were also assessed post-intervention. **Results**. The intervention group reduced percent of daily time spent sedentary (P=0.03) and increased percent time in moderate intensity physical activity compared to the control group. A significant interaction effect was observed for waist circumference (P=0.03) with no changes in any other cardiometabolic risk factors observed. Intervention participants logged onto the website 71.3% of all intervention days, used the pedal machine 37.7% of all working intervention days, and pedaled an average of 31.1 minutes/day. **Discussion**. These findings suggest the intervention was engaging and resulted in reductions in daily sedentary time amongst full-time sedentary employees. These findings hold public health significance due to the growing number of sedentary jobs and the potential of these technologies in large-scale worksite programs. ClinicalTrials.gov #NCT01371084

Article focus

- The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control.

- We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks.
- As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

Key messages

- This multicomponent intervention resulted in significant reductions in time spent sedentary and waist circumference when comparing the intervention group to the wait list control group.
- The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group.
- The findings of this study are important given the paucity of research in this area and growing evidence demonstrating the importance of limiting daily sedentary time for reducing risk of chronic diseases.

Strengths

- Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3) conducted a 12 week trial which extends previous sedentary interventions that have typically been of brief durations; 4) measured Cardiometabolic risk factors; and 5) conducted a process evaluation to identify features of the intervention that worked particularly well.

Limitations

- Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of middle-aged females working at a single institution which limits generalizability; and 2) differential drop out, although follow-up analyses indicate no differences between those that

dropped and those that completed amongst the control group for age (P=0.40), BMI (P=0.52), or daily sedentary time (P=0.22).

INTRODUCTION

Prolonged sedentary behavior is an independent risk factor for multiple chronic health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic syndrome[5] and obesity.[6] Conversely, evidence suggests breaking up prolonged periods of sedentary behavior may result in cardiometabolic health benefits, independent of more intense physical activity, including reductions in waist circumference,[7 8] body mass index (BMI), fasting glucose and triglyceride levels.[8] However, to date, few interventions have been conducted to reduce sedentary behaviors of adults.[9]

Adults working in full-time sedentary jobs are at particular risk for being sedentary as they often spend more than 75% of work time sitting[10 11].Currently, more than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional behaviorally focused worksite interventions have focused primarily on increasing physical activity and have resulted in modest effect sizes (Cohen's *d* = 0.21-0.22).[14 15] In a shift away from behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of modifying the work environment to reduce occupational sedentary time. However, to date, only a handful of worksite interventions have been conducted to reduce sedentary time, most of which have not demonstrated effectiveness.[17] Of the sedentary worksite interventions that have been conducted, most have been limited by self-report methods of sedentary time[17] and/or short intervention durations[18 19]. Overall, there is a need for interventions aimed specifically at reducing sedentary time amongst adults. The worksite is an ideal setting for delivering such interventions.

In a study testing the feasibility of modifying the work environment as a means of reducing occupational sedentary time, our team provided portable pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10]. Participants rated the pedal machines as feasible for use while completing their work. Further, despite a lack of any accompanying behavioral intervention, participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per day. Although these results are promising, it is possible the addition of a motivational behavioral intervention could result in increased pedaling compliance and reduced sedentary time.

The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control. We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks. As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

METHODS

Subjects and Design

We utilized a 12 week randomized controlled trial design comparing a treatment group to a no treatment waitlist control group. We recruited apparently healthy but sedentary (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass index (BMI) $\geq$ 25.0 kg/m^2) adults working in full-time (minimum of 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting). Participants of all races and ethnic backgrounds working at a large southern university were passively recruited through email advertisements placed on an electronic mailing list serve. Research staff members screened participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer. Participants were not compensated for participation in the study. Experimental protocols were approved by the University and Medical Center Institutional Review Board and voluntary informed consent was obtained from each participant.

A total of 192 people responded to our advertisements of which 143 were excluded from participation due to: not meeting eligibility criteria (N=120); declined to participate (N=19); or other reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using the an online random sequence generator.[20] Participants were assigned to one of two groups by a research staff member not involved in data collection based on the order in which they enrolled into the study. A total of 49 participants deemed interested and eligible for participation were randomized to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40 participants completed all baseline and post-intervention assessments. Nine participants were lost to follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention participants and 17 control participants (see Table 1). More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

[Figure 1 here]

Group Descriptions

Wait List Control Group

Participants randomized to the wait list control group were asked to maintain their current behaviors for 12 weeks at which time they were given the option to receive the intervention treatment materials.

Intervention Group

The intervention comprised of three primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite (Figure 2); 2) access to an internet-delivered motivational intervention (Walker Tracker, Portland, OR); and 3) a pedometer (Omron HJ-150). The pedal machine is a portable (18” height, 20” length) device that has been demonstrated as acceptable for use during sedentary office work [10] (Figure 2). The pedal machine is accompanied by a PC interface and software package that allows for objective monitoring of individual pedal activity. This software also provides the user with real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the pedal machine to each participant’s worksite, downloaded the pedal tracking software to the participant’s work computer, and worked with the participant to identify the most feasible set up. Intervention participants were asked to keep the pedal machine connected to their PC during all working hours.

Intervention participants were also provided access to a motivational website that was individually customized to the local culture of the worksite of which participants were recruited (Figure 4). Examples of customization included posting local images and messages specific to the local institution. The content of the intervention targeted constructs of the Social Cognitive Theory[21] including self-monitoring, social support, self-efficacy, and perceived environment. For example, participants were prompted via daily email messages to self-monitor their daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on the website was used to fuel a virtual competition (aimed at building social support) in which small groups of intervention participants (4-5 per group) collectively traveled across America (Figure 2). Participants were also emailed three theory-based motivational messages each week targeting goal setting, self-efficacy, and perceived environment. Specific goals were not set for intervention participants, rather participants received advice on how to set goals and suggestions for daily pedaling time (e.g. “Try fitting in 10 minutes of pedaling during your lunch today.”) Finally, using a forum similar to Facebook, participants were able to post profile photos and status updates on a newsfeed and send messages to members of their small groups further fostering social support.

[Figure 2 here]

Measures

All measures were collected at baseline and post-intervention (12 weeks) in a controlled laboratory setting by two staff members blinded to participant’s group assignment. The primary outcome was daily sedentary time as measured objectively by the StepWatch (Orthocare Innovations, Mountlake Terrace, Wash, USA). The StepWatch is an ankle monitor that has been demonstrated as a reliable[22] and accurate measure of light intensity walking[23] and pedaling.[24] Participants were asked to wear the monitor during all wakeful hours for seven consecutive days. Days in which participants wore the monitors for less than 10 hours were excluded from final analysis. Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%) days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for 13.8 hours/day.

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[25] Fasting blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively), HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%

respectively).[26] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill walking test which had been previously demonstrated as a valid estimate of total aerobic fitness amongst middle-aged adults.[27]

Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was assessed objectively via the activity tracking software. Pedal compliance data was downloaded directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g., number of website logins, number of steps logged on the website) was assessed objectively at the end of 12 weeks via a backend tracking database made available by the website administrators. In order to assess which components of the intervention participants 'perceived' as helpful for reducing their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention completers. Participants rated each intervention component using a five point Likert scale.

Design/Statistical Analysis

Baseline descriptive and independent variables were analyzed by one-way analysis of variance (ANOVA) (see Table 1). The sample size was calculated to detect, with 80% power, at $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was identified as a reasonable estimate based on our previous study in which participants used the pedal machines an average of 23 minutes/day without a motivational intervention.[10] All outcome measures were evaluated before and after the 12-week experimental period within and between groups by two-way (group × time) repeated measures ANOVA. When indicated by a significant F value, post hoc procedures were performed (Tukey). Cohen's *d* effect size[28] was computed to assess the magnitude of change for primary outcomes. Statistical significance was set *a priori* at $P<0.05$.

RESULTS

Baseline characteristics of both groups are presented in Table 1. There were no significant differences found between the Control and Intervention groups for age (P=0.10), gender (P=0.46), percentage Non-Hispanic White (P=0.40), college education (%) (P=0.24), Income > $40,000 (%) (P=0.94) or BMI (P=0.40) (Table 1). Likewise, there were no significant differences found for daily monitor wear time (P=0.35), percent time spent sedentary (P=0.42) or in any physical activity behaviors between groups at baseline (Table 2).

Table 1. Baseline characteristics between groups Mean ± S.D. (N=40)

	Control Group N=17	Intervention Group N=23	P-value
Age (years)	47.6 ± 9.9	42.6 ± 8.9	0.10
Female %	94.1%	86.9%	0.46
Height (in)	65.2 ± 3.2	65.4 ± 3.4	0.89
Weight (lbs)	201.3 ± 30.2	194.1 ± 34.9	0.50
Body Mass Index (BMI)	33.2 ± 4.5	31.7 ± 4.9	0.36
Non-Hispanic White (%)	76.5%	63.6%	0.40
College Graduate (%)	71.0%	86.0%	0.24
Income >$40,000 (%)	62.5%	63.6%	0.94

Significant group x time interaction effects were observed for absolute number of daily sedentary minutes (F(2,38)=8.25; P<0.01), percentage of daily time spent sedentary ((F(2,38)=4.71; P=0.04) (Table 2) and percentage of daily time spent in moderate intensity physical activity (F(2,38)=4.37; P=0.04) with the intervention group improving in each variable. No significant main effects or interaction effects were observed for absolute minutes of moderate intensity activity or for absolute or relative time spent in light and/or vigorous intensity physical activity (Table 2).

Table 2. Absolute and relative time spent in sedentary and physical activity behaviors at baseline and post-intervention (N=40).

	Control (N=17)		Intervention (N=23)			
	Baseline	**12 Weeks**	**Baseline**	**12 Weeks**	**P**	**d**
Minutes Sedentary	544.2±76.9	599.7±106.6	584.9±136.1	526.1+77.3*†	<0.01	0.37
% Time Sedentary	65.7±7.5	67.5±8.0	67.6±7.2	63.9+7.9†	0.03	0.22
Minutes Light	265.7±84.0	262.2±70.8	263.9±69.5	270.3+69.5	0.67	0.05
% Time Light	31.9±8.1	30.3±8.4	30.6±8.2	32.7+7.6	0.14	0.15
Minutes Moderate	18.6±25.2	17.4±23.7	14.5±18.5	23.3+28.0	0.11	0.11
% Time Moderate	2.3±3.2	2.0±2.9	1.5±1.5	2.8+3.4†	0.04	0.13
Minutes Vigorous	1.2±2.6	1.5±2.7	2.7±6.4	4.9+10.9	0.51	0.21
% Time Vigorous	0.1±0.3	0.2±0.3	0.3±0.6	0.6+1.3	0.38	0.22

Mean ± S.D.

*Significant difference between groups at same time point (p<0.05)

†Significant difference within groups compared to baseline (p<0.05)

There were no significant differences between groups at baseline for any cardiometabolic risk factors (Table 3). A significant group x time interaction was observed for waist circumference (F(2,38)=5.02; P=0.03) (Table 3). No significant main effects or interaction effects were observed for any other cardiometabolic risk factors.

Table 3. Cardiometabolic risk factors at baseline and post-intervention (N=40).

	Control (N=17)		**Intervention (N=23)**		**P Value**
	Baseline	12 Weeks	Baseline	12 Weeks	
Weight	201.4+30.2	202.4+30.5	194.2+34.9	194.4+34.5	0.63
BMI	33.2+4.5	33.4+4.6	31.8+5.0	31.9+5.0	0.76
Systolic BP	117.1+13.0	117.5+12.8	120.0+13.8	115.7+10.8	0.19
Diastolic BP	72.8+10.3	73.2+10.6	78.2+10.3	75.4+7.4	0.34
Waist Circumference (cm)	92.9+11.1	93.9+10.8	92.6+11.2	91.6+11.3	0.03
Estimated V02	29.6+2.5	30.0+2.6	30.8+5.1	31.1+4.6	0.86
Total Cholesterol	184.4+25.9	185.0+18.9	191.4+26.3	189.7+27.0	0.68
Triglycerides	130.6+65.4	131.0+59.9	98.4+45.2	118.4+57.3	0.38
HDL	47.6+18.4	46.7+18.9	45.7+17.6	43.7+16.4	0.76
LDL	111.2+32.1	120.2+25.3	119.4+23.2	116.7+29.4	0.28
TC/HDL Ratio	3.8+1.7	4.5+1.9	4.7+2.1	4.7+2.1	0.57

Mean ± S.D.

*Significant difference between groups at the same time point ($p<0.05$)

† Significant difference within groups compared to baseline ($p<0.05$)

A total of 23 participants completed the intervention and provided compliance data (see Table 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they had access to the website (including weekends) (Table 4). Intervention participants also logged an average of 7945 ± 4634 steps per day on the website over the 12 weeks. Participants pedaled an average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding weekends). Participants pedaled an average of 31.1±31.6 minutes per day on the days they used the pedal machines and for an average of 16.1±17.2 minutes per pedaling bout

Table 4. Intervention compliance measures amongst Intervention completers (N=23).

	Mean/%	**S.D.**
Web Compliance % (Days Logged in/Days with Access)	71.3	
Average Steps Logged Per Day	7945	4634
Average Days Pedaled Over 12 Weeks	22.6	17.6
Pedal Compliance % (Days Pedaled/Days with Access)	37.7	
Average Pedal Bouts/Day	1.9	0.9
Average Minutes Pedaled/Day Used	31.1	31.6
Average Minutes Pedaled/Pedal Bout	16.1	17.2

When asked to rate the helpfulness of each intervention feature for reducing their sedentary time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity on the website as “extremely helpful” (median Likert score = 5.0; Table 5). Participants rated the email reminders to log daily activity and access to the pedal machine as “quite helpful” ((median Likert score = 5.0; Table 5).

Table 5 : Quartile and median Likert scale responses (1=Not at all helpful; 2=A little helpful; 3=moderately helpful; 4=Quite helpful; 5=Extremely helpful) on helpfulness of individual intervention components for reducing sedentary time (N=23).

Please rate how helpful each of the following intervention components was in reducing your daily sedentary time.	Likert Scale		
	Q1	Median	Q3
Pedal machine biofeedback display (minutes pedaled, calories burned, etc.)	4.0	5.0	5.0
Wearing the pedometer	4.0	5.0	5.0
Self-monitoring daily steps and pedal time on the website	4.0	5.0	5.0
Email reminders to log physical activity on website	4.0	4.0	5.0
Access to pedal exercise machine at work	4.0	4.0	5.0
'Walk Across America' Group Challenge on website	3.0	3.0	5.0
Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8

DISCUSSION

The primary findings of this study suggest that this multicomponent intervention resulted in significant reductions in both absolute and relative time spent sedentary in a small sample of sedentary, overweight employees. The decreased sedentary time observed among the intervention group appears to be have been at least partially replaced by an increase in light and moderate intensity activity. Our findings are important as they expand upon the paucity of research aimed specifically at reducing sedentary time. Few worksite studies have been conducted that have specifically targeted reducing sedentary time.[17] Of the interventions that have been conducted in the worksite, most have relied upon self-report measures of sedentary time[17] and have been conducted over a relatively short duration[18 19]. Our study utilized an objective measure of sedentary behavior and was conducted over 12 weeks. The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group. This is important, as it has been suggested that decreasing sedentary time can result in improved health benefits independent of physical activity.[2 29-31]

Sedentary time amongst the intervention group was reduced by an average of 59 minutes/day or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention that included educational materials on sedentary health risks and tips to reduce sedentary time.[19] However, this study did not include a control group. In a study that did include a control group, Evans et al. found no between group differences in objectively measured sitting time after five days of point-of-choice software reminders to stand up every 30 minutes while at work.[18]

We also observed a group x time interaction effect for waist circumference. This finding is important as waist circumference has been shown to predict mortality amongst adults with coronary artery disease.[32] Confidence in this finding is strengthened by past studies that have reported higher levels of sedentary behavior to be associated with a higher waist circumference[33] and interruptions from sedentary time to be associated with reduced waist circumference levels.[8] Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical activity program which demonstrated modest improvements in daily steps and waist circumference.[34] The lack of changes in other cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are needed to determine whether reducing sedentary time results in cardiometabolic risk reduction.

Participant compliance to the website overall was high with participants logging into the website an average of 71% of all intervention days. This is important as past internet-delivered intervention studies have identified engagement to be a challenge [35 36] and a predictor of intervention success.[37] By comparison, Lewis et al. reported participants logged on to a physical activity website a median number of 50 times (13.7%) over 12 months.[38] Reasons for such high website compliance in the present study may be due to the tailoring of the website to include locally relevant images and messages.

Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day) was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These findings suggest the added motivational intervention, which included suggestions for setting goals and finding time to pedal each day, resulted in improved daily compliance that was sustained over a longer duration. Despite the logistical limitation of the portable pedal machine when paired with standard height desks (i.e., many participants reported their knees hit the underside of their desk while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize compliance with such portable pedal machines in future studies, it is recommended these devices be paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

Intervention participants reported features that provided feedback including the pedal machine tracking software, pedometers and self-monitoring daily activity on the website (which was immediately followed by a graph illustrating the individual's daily progress) as the most helpful features for reducing their daily sedentary time. This information is important and could be used to inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past studies which have found biofeedback as a useful tool to improve health behaviors.[39 40]

The main limitation of the study was the limited generalizability due to a small sample size that comprised primarily of middle-aged females working at a single institution. We also experienced differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed amongst the control group for age (P=0.40), BMI (P=0.52), or daily sedentary time (P=0.22).

The present study is among the first interventions aimed specifically at reducing daily sedentary time to demonstrate between group differences in objectively measured sedentary time. Compliance with the motivational website was high while compliance with the pedal machine was moderate. While a group x time interaction was found for waist circumference, no between group differences were observed for any other cardiometabolic risk factors. More sedentary focused interventions are needed to examine whether reducing sedentary time can be sustained long-term and whether long-term changes result in significant reductions in risk for chronic diseases.

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Competing Interests: All authors have completed the ICMJE uniform disclosure form at **www.icmje.org/coi_disclosure.pdf** and declare: no financial support from the funder Oak Ridge Associated Universities for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, and no other relationships or activities that could appear to have influenced the submitted work**.”**

Contributorship Statement:

- Dr. Lucas Carr was responsible for the design of the study and lead the manuscript preparation.
- Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript preparation.
- Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for leading the intervention which included duties of interacting with participants on a daily basis.
- Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation and were responsible for collecting data at the baseline and post-intervention time points.

Data Sharing

- Extra data is available by emailing Dr. Lucas Carr at **lucas-carr@uiowa.edu**.

Figure Legend

Figure 1. Sequence of events and recruitment/enrollment schematic. Study was coordinated at East Carolina University, Greenville, NC, from June 2011-June 2012.

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the Walk Across American group challenge.

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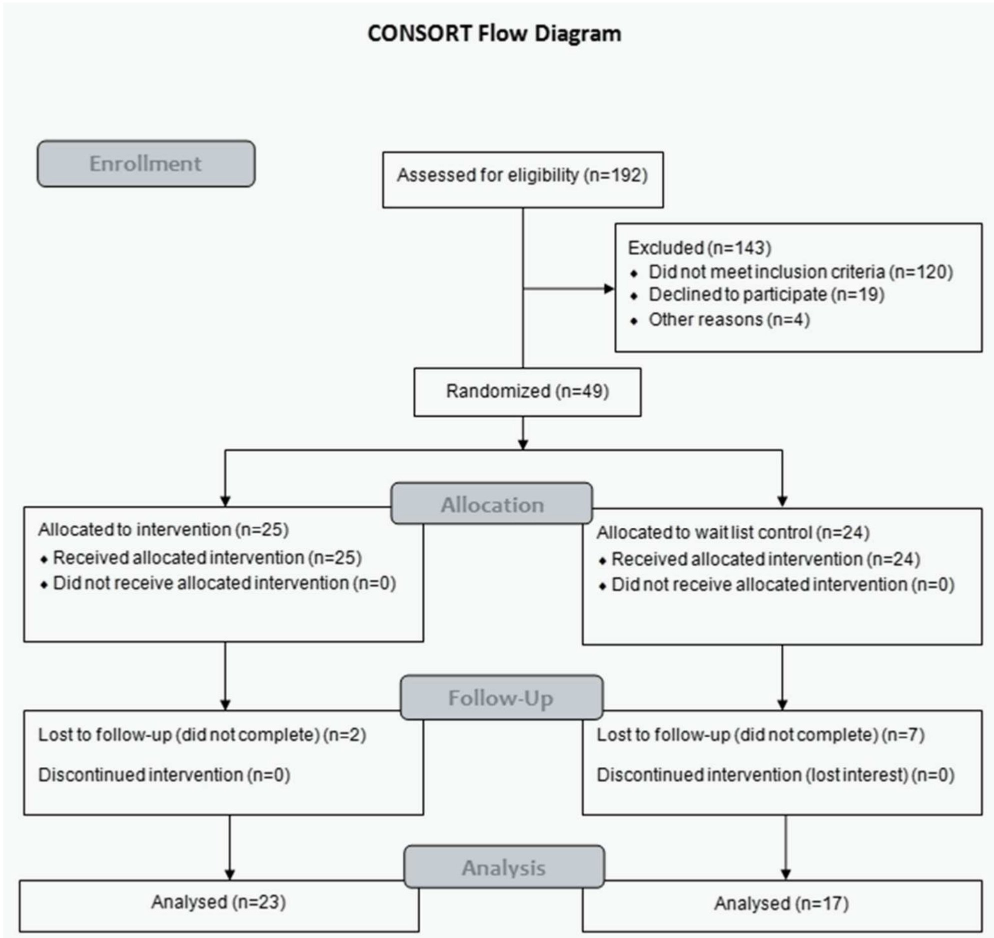

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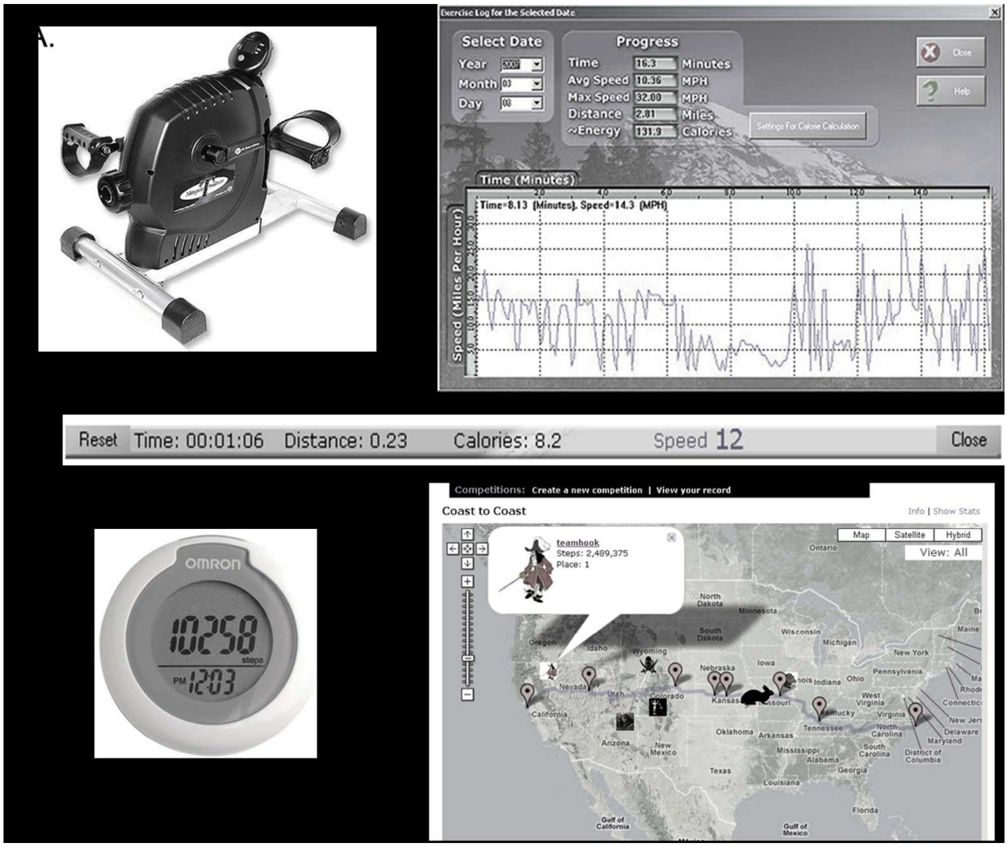

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3-4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	NA
Participants	4a	Eligibility criteria for participants	4-5
	4b	Settings and locations where the data were collected	7
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	7
	6b	Any changes to trial outcomes after the trial commenced, with reasons	NA
Sample size	7a	How sample size was determined	8
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	5
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	5
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	5
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5

Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	5&7
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	NA
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	5
	13b	For each group, losses and exclusions after randomisation, together with reasons	5
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	5
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1 (p.9)
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	5
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	8-13
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	8-13
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	15
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	15
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	13-16
Other information			
Registration	23	Registration number and name of trial registry	ClinicalTrials.gov (NCT01371084)
Protocol	24	Where the full trial protocol can be accessed, if available	Oak Ridge Associated Universities

			Grant (#212112)
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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PRESS RELEASE

Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace

Lucas J Carr,[1,2] Kristen A Walaska,[1] Bess H Marcus[1,3]

[1]Centers for Behavioral and Preventive Medicine, The Miriam Hospital, Providence, Rhode Island, USA
[2]Department of Exercise and Sport Science, East Carolina University, Greenville, North Carolina, USA
[3]Program in Public Health, Brown University, Providence, Rhode Island, USA

Correspondence to
Dr Lucas J Carr, Department of Exercise and Sport Science, East Carolina University, 172 Minges Coliseum, Greenville, NC 27858, USA; carrl@ecu.edu

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ABSTRACT

Background Sedentary time is independently associated with an increased risk of metabolic disease. Worksite interventions designed to decrease sedentary time may serve to improve employee health.

Objective The purpose of this study is to test the feasibility and use of a pedal exercise machine for reducing workplace sedentary time.

Methods Eighteen full-time employees (mean age+SD 40.2+10.7 years; 88% female) working in sedentary occupations were recruited for participation. Demographic and anthropometric data were collected at baseline and 4 weeks. Participants were provided access to a pedal exercise machine for 4 weeks at work. Use of the device was measured objectively by exercise tracking software, which monitors pedal activity and provides the user real-time feedback (eg, speed, time, distance, calories). At 4 weeks, participants completed a feasibility questionnaire.

Results Participants reported sitting 83% of their working days. Participants used the pedal machines an average of 12.2+6.6 out of a possible 20 working days and pedalled an average of 23.4+20.4 min each day used. Feasibility data indicate that participants found the machines feasible for use at work. Participants also reported sedentary time at work decreased due to the machine.

Discussion Findings from this study suggest that this pedal machine may be a feasible tool for reducing sedentary time while at work. These findings hold public health significance due to the growing number of sedentary jobs in the USA and the potential of the device for use in large-scale worksite health programmes.

The health-related benefits of regular moderate and vigorous intensity physical activity have been well established.[1–3] Conversely, physical inactivity is a leading preventable cause of death and all-cause mortality,[4] and has been referred to as one of the most important public health problems of the 21st century.[5] Within the realm of physical inactivity, researchers of the past decade have explored more specifically the health implications and associated health mechanisms of 'sedentary behaviour'.[6] Recent reviews have defined sedentary behaviour as 'activities that do not increase energy expenditure substantially above resting levels' and include activities such as lying down, sitting and using screen-based technologies such as televisions and computers.[7 8] Interestingly, even short bouts of reduced energy expenditure have been associated with substantial detriments to metabolic health in animals models.[9–12] Emerging studies with humans seem to corroborate such findings, as time spent being sedentary has been demonstrated to be independently associated with an increased risk of metabolic diseases.[13] Furthermore, sedentary time in the form of sitting has been associated with an increased likelihood of being overweight/obese.[14] Conversely, evidence supports breaking up prolonged bouts of sedentary time as a means of improving metabolic risk factors such as body mass index (BMI), waist circumference, fasting glucose levels and triglyceride levels.[15]

The workplace has been identified as an ideal setting for reducing sedentary time as full-time employees working a 40 h work week spend over a third of their weekly wakeful hours at work. In addition, working days are associated with less standing time and more time sitting time compared with non-work days,[16] and evidence suggests occupational activity as a whole is on the decline with high physical activity occupations decreasing while low activity occupations have risen steadily over the past half century.[17 18]

Previous worksite programmes aimed at increasing employees' physical activity have demonstrated efficacy for increasing physical activity, with some demonstrating improvements in worksite-specific outcomes such as attendance and job stress.[19 20] Past worksite physical activity interventions have taken many approaches for promoting physical activity, including promoting stair use through point of decision prompts, promoting active transport and providing access to worksite fitness facilities.[21 22] It could be argued, however, that many of these approaches are somewhat limited with regard to their reach and impact in that they do not target the large portion of time in which the typical desk/computer-dependent employee is working and therefore sedentary. With the rise in screen-based technologies in the worksite, computer use, an identified barrier to physical activity,[23] has become a staple of the typical work day. Still, few worksite intervention approaches have focused specifically on reducing the sitting time of sedentary employees for improving health.[24] Furthermore, no worksite interventions to date have attempted to reduce sedentary time while adapting to the typical computer work environment in which sitting is necessary.

Thompson *et al*[25] recently tested the feasibility of a walking workstation designed to allow employees to continue their work while being active. Hospital employees in four different occupations were recruited for participation. While using the walking workstations, participants increased daily walking by an average of 2000 steps or an equivalent of 100 kcal/day.[26] Participants also reported that they could perform normal work tasks (ie, computer work, professional phone calls) while using the device and declines in productivity were not reported to be an issue. However, such devices do have limitations that might prohibit widespread use such as high cost, size requirements that may not be met in small offices, lack of portability and lack of use for special needs populations such as those with orthopaedic limitations or joint pain.

McAlpine *et al*[27] conducted a study testing the energy expenditure of an office stepping device that seemingly addressed several of the feasibility limitations of the walking workstation. The device used in their study was portable, cost feasible, nearly silent and when attached to a personal computer (PC) connected accelerometer allowed for self-monitoring. While the stepping device did result in significant increases in energy expenditure above sitting in a controlled laboratory setting, the study did not explore the feasibility of the device in a real-life setting.

Several portable pedal exercise machines that also address many of the limitations of the walking workstation have recently become commercially available. One machine in particular, the MagneTrainer mini exercise bike (3D Innovations, LLC, Greeley, CO) is a cost feasible, stable yet portable device that can be set up in front of most standard office chairs for use while sitting and also allows for objective self-monitoring (eg, time used, distance pedalled, average speed, caloric expenditure) through a PC connection. To our knowledge, no studies have explored the feasibility or use of a portable pedal machine for reducing time spent sedentary in an occupational setting. Therefore, the primary aims of this study are to test the feasibility, acceptability and use of a portable, pedal exercise machine for reducing sedentary time in a free-living, occupationally sedentary adult population. We hypothesise that participants will find the machines feasible and acceptable for use in the sedentary work environment, and that participants will decrease their sedentary time at work as a result of using the pedal machine.

METHODS

Subjects

A total of 18 healthy, adult, (age 40.2+10.7 years; BMI 26.7+5.0 kg/m^2; 88% female) full-time employees (self-report working a minimum of 35 h/week) working in sedentary (minimum of 75% of working day spent sitting), desk/computer-dependent occupations was recruited from the greater Providence, Rhode Island, region for participation by local internet advertisements. Assessments occurred between October 2009 and March 2010. Participants were devoid of ambulatory/exercise limitations, and free from overt cardiovascular, metabolic, respiratory or neurological diseases as assessed by medical history screening. Participants were compensated US$15 each time they attended two separate assessment sessions (total of US$30 possible). Experimental protocols were approved by the Lifespan Office of Research Administration in Providence, Rhode Island, and voluntary informed consent was obtained from each participant.

Experimental design

All testing assessments were conducted at a research laboratory located at the Miriam Hospital in Providence, Rhode Island, USA. Participants were asked to attend two testing sessions, one at baseline and a follow-up assessment 4 weeks later. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a calibrated medical balance beam scale (Detecto, Webb City, Missouri, USA). BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared. Participants completed a modified version of the 7-day physical activity recall questionnaire,[28] which included supplementary questions targeting the total number of hours and minutes spent ‘sitting’, ‘standing but not walking’ and ‘walking’ while at work over the previous 4 weeks. Participants then completed a 6-min pedal test following the Astrand-Rhyming protocol[29] to become familiarised with the pedal machine.

Participants were then provided access to a MagneTrainer pedal exercise machine (3D Innovations) for use while at work for four continuous weeks (figure 1). The MagneTrainer pedal exercise machine was chosen due to its relatively low cost (US$150 for pedal machine and software), portability and compact size (18 in height, 20 in length) and its ability to monitor and record participant’s daily and accumulated pedalling activity objectively through a PC connection (FitXF Exercise Tracking Software; 3D Innovations). The FitXF software also provides users with real-time feedback on pedal speed, time used, distance and calories, which is displayed on their computer monitor. The FitXF software also begins recording pedal activity the moment the user begins pedalling and stores daily and accumulated summary data for total time spent pedalling

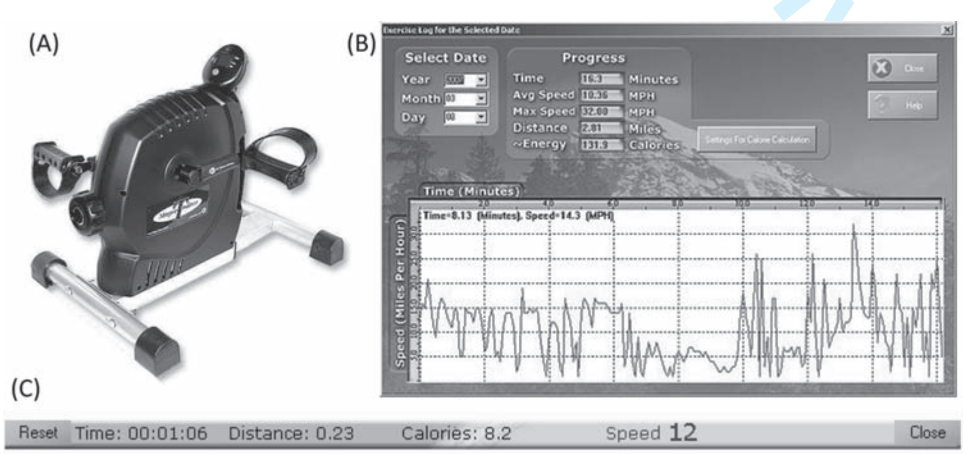

Figure 1 (A) The portable pedal exercise machine. (B) A screenshot of the exercise log, which provides feedback on pedal use activity per day. (C) A screenshot of the real-time monitor, which provides real-time feedback to the user.

(min/day), average speed (mph/day), distance pedalled (miles/day) and estimated caloric expenditure (kcal/day). A member of the research team delivered the pedal machine to the participant's worksite, downloaded the FitXF software to the participant's work computer and worked with the participant to identify the most feasible physical set up for using the machine (eg, under the desk, next to the desk). All participants were required to gain clearance from their immediate supervisor before enrolling in the study.

Following 4 weeks, pedalling activity data were downloaded from each participant's personal work computer with the authorisation of the participant's supervisor. Participants then returned to the testing facility to repeat all baseline tests and to complete a 23-item, five-point Likert scale (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) feasibility/acceptability questionnaire designed to enquire about the user's opinions and experiences with the machine (see appendix 1) as well as the intensity at which they typically pedalled using the Borg 0–10 rating of perceived exertion (RPE) scale.[30] Participants were also asked to report any barriers to using the machine and/or suggested improvements for the machine while at work. Consistent with the purpose of testing the feasibility and acceptability of the pedal machine, participants were only provided access to the machine and were not provided any behavioural intervention materials for the purpose of reducing sedentary time (eg, goals, motivational resources, self-monitoring prompts) during the course of the study.

Statistical analyses

Minutes of pedallling activity and days of pedalling activity were recorded and downloaded from the pedal machine through the FitXF exercise tracking software. Means and SD of pedal use activity were calculated and are presented in table 1. Medians and quartiles of the feasibility/acceptability data were calculated and are presented in table 2. Means and SD of average pedal time per day used for each participant were calculated and are presented in figure 2. Average pedal time among all users on days 1–20 and compliance using the pedal machine (percentage participants that pedalled each day during days 1–20) was summarised and is presented in figure 3 Paired t tests were conducted to test whether participants' time spent sitting, standing and/or walking changed over time from the baseline to the 4-week assessment. Statistical significance was set a priori at $p<0.05$.

RESULTS

On average, participants were middle aged (mean 40.2±10.7 years), overweight (mean BMI 26.8±5.0 kg/m^2) and primarily female (88%). Participants self-reported working an average of 40.9±4.7 h/week. Participants reported sitting an average of 6.80±1.5 h (83%) of their total working day. Participants pedalled an average of 12.2±6.6 (range 2–20 days) out of a possible 20 working days in which they had access to the pedal machine (61% compliance) and pedalled an average of 23.4+20.4 min on days they used the machine (see table 1 and figure 2). The estimated averages provided by the FitXF software for distance pedalled per day and caloric expenditure per day per participant equalled 4.8±3.6 miles/day and 186.5±142.2 kcal/day, respectively. Participants self-reported pedalling at an average intensity of 4.4±1.6 or 'somewhat hard' on the Borg 0–10 RPE scale. Average pedal time was maintained over the duration of the study, whereas the number of participants who used the machines each day (compliance) declined progressively over the course of 4 weeks (figure 3). As presented in table 2, when asked to respond to several statements pertaining to their experience with the pedal machine using a 1–5 Likert scale (1, strongly disagree; 5, strongly agree), participants reported the pedal machine to be 'easy to use', and 'as an alternative activity during bad weather'. Participants overwhelmingly reported they would 'use the pedal machine regularly at work if offered one by their employer' and reported neither their 'work productivity' nor their 'quality of work' declined as a result of using the machine at work. Participants reported 'their sedentary time at work decreased as a result of using the machine'. However, no significant differences in self-reported time spent sitting ($p=0.11$), standing ($p=0.65$) and/or walking ($p=0.77$) were observed from baseline to 4 weeks.

DISCUSSION

Findings from this study suggest this portable pedal exercise machine is a feasible tool for reducing time spent sedentary while at work. Overall, participants reported positive experiences with the pedal machine and reported that they would use the machine at work if offered one by their employer. When provided access to the device, on average participants used the machines more than half of all working days although compliance did decrease over the course of the 4 weeks (see figure 3). This is not a surprising finding given the lack of any behavioural intervention provided to these previously sedentary participants during the course of the study. However, the average minutes pedalled per day was maintained throughout the 4 weeks and participants pedalled for an amount of time (23 min per day used) that could result in health benefits if performed on a regular basis and at an average intensity reported by participants (eg, 'somewhat hard' on the Borg 0–10 scale).[3] A logical next step would be to test the efficacy of combining the pedal machine with a behavioural intervention for reduc-

Table 1 Accumulated and daily means±SD and ranges of pedal time, pedal speed, distance pedalled and caloric expenditure

	Mean+SD	Range
Average total pedal time (min)	358.0±401.7	4.0–1489.0
Average number days pedalled	12.2±6.6	2.0–20.0
Average pedal time/day used (min)	23.4±20.4	1.2–73.1
Average pedal speed (mph)	12.5±4.4	5.3–18.4
Average distance pedalled (miles)	69.0±62.6	0.5–214.0
Average distance pedalled/day used (miles)	4.8±3.6	0.3–13.4
Average total kcal expended (kcal)	2758.8±2699.7	18.0–8334.8
Average total kcal expended/day used (kcal)	186.5±142.2	9.0–501.9

Data were downloaded using the FitXF exercise tracking software.

Table 2 Quartile and median Likert scale responses (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) to feasibility/acceptability questions following 4 weeks of access to the pedal machine

Do you agree or disagree with the following statement?	Q1	Median	Q3
If offered to me by my employer, I would use the machine while at work	4.3	5.0	5.0
My physical activity increased while at work as a result of the machine	3.0	4.0	5.0
My physical activity increased outside of work as a result of the machine	2.3	3.0	4.0
The pedal machine is easy to use	4.0	4.0	5.0
I would use the machine as an alternative activity in bad weather	4.0	5.0	5.0
I am comfortable using the machine in the presence of others	3.0	4.0	5.0
The time I spent sedentary at work decreased as a result of the machine	3.0	4.0	4.0
I would use the machine while at home	4.0	5.0	5.0
The machine is too noisy	1.0	1.0	2.0
My work-related productivity decreased while using the machine	1.0	1.0	2.8
The quality of my work decreased while using the machine	1.0	1.0	2.0
The machine interfered with my daily work-related tasks	1.0	1.0	2.0
I was more tired on days I used the machine	1.0	2.0	2.0
I had more back pain on days I used the machine	1.0	1.5	2.0
I had more joint pain on days I used the machine	1.0	1.0	2.0
I had more muscle aches on days I used the machine	1.0	1.5	2.0
I could conduct a professional telephone call while using the machine	2.0	3.0	5.0
I could conduct normal computer tasks while using the machine	2.0	3.0	4.0
I could read comfortably while using the machine	4.0	4.0	5.0
The real-time monitor increased my use of the machine	3.3	4.0	5.0

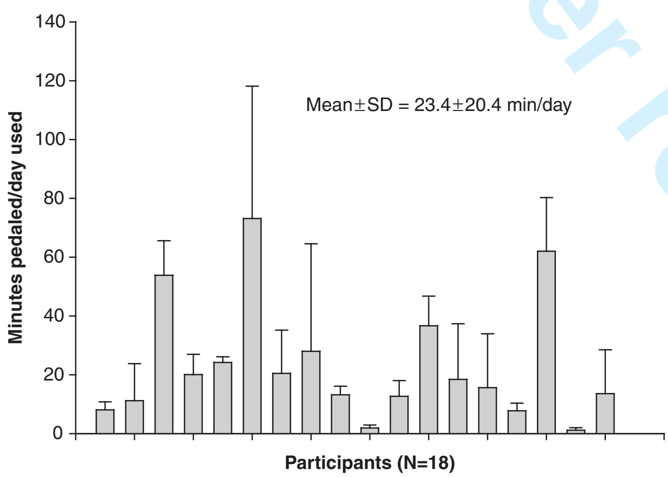

Figure 2 Average pedal time for days pedal machine was used per participant (N=18).

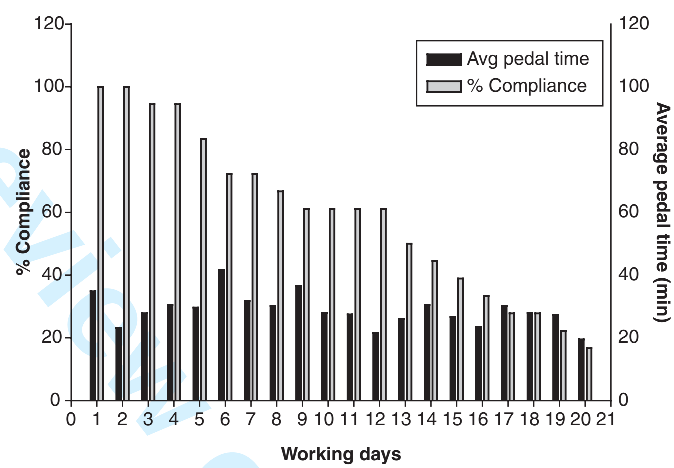

Figure 3 Average pedal time (minutes) and percentage of participants who pedaled each working day.

ing sedentary time at work and reducing the risk of chronic diseases.

When examining the pedal machine used from a human factors perspective, the MagneTrainer offers several features that make it a particularly attractive tool for future health promotion studies. Importantly, the device offers functions that are directly in line with three out of four features previously identified as necessary for technologies designed to promote physical activity and reduce sedentary time.[31] It is suggested that such technologies should: (1) give users proper credit for activities completed; (2) provide users personal awareness of his or her activity levels; (3) consider the practical constraints of users; and (4) support social influence.[31]

First, through the PC connection, the MagneTrainer pedal machine automatically and objectively monitors participants' pedalling activity (eg, credits user for activity completed). This function would be especially important from an assessment perspective in future research studies, and could potentially serve as a means to monitor employee participation in worksite wellness programmes that offer financial incentives for participation.

Second, the software enabled real-time feedback monitor and progress monitor, which summarises past activity by day and provides the user with a personal awareness of his or her current and past activity levels. The pedal machine provides users with real-time feedback of time spent pedalling (minutes), average speed (mph), maximum speed (mph), distance pedalled (miles) and estimated calories burned (kcal), which is displayed on a thin monitor that can be moved anywhere on the user's desktop. When asked to report how often they self-monitored their pedalling activity using the real-time feedback monitor (eg, time, distance, calories, speed) using a 1–4 Likert scale (1, never; 2, rarely; 3, occasionally; 4, frequently), participants reported frequently using the monitor (3.7+0.9). In addition, participants agreed the monitor increased their use of the machine (4.0+0.9 on 5-point Likert scale) suggesting that the monitor is a motivational tool.

What is already known on this topic

Evidence of the negative impact prolonged sedentary time has on metabolic health is growing. Many new devices with the potential to reduce prolonged sedentary time have recently become available on the commercial market. However, few studies have tested the feasibility and use of such devices among free-living populations in the work environment.

What this study adds

This study demonstrates a portable pedal exercise machine (MagneTrainer) to be feasible for use in the sedentary work environment. This study also found participants used the machines regularly without being provided a behavioural intervention. This study supports future interventions that test the efficacy of combining such devices with evidence-based behavioural approaches to reduce sedentary time at work.

Third, the portability, stability and near silent operation of the pedal machine allows this machine to be used in most typical office settings without interfering with daily operations. Importantly, portable pedal machines may serve as a tool to reduce sedentary time in the work environment without necessarily influencing the sitting time necessary for performing computer-related tasks. Participants reported the machine to be quiet, easy to use and usable in a typical office. Participants also reported that the pedal machine did not interfere with their quality of work or work productivity and did not result in any added pain to their joints or back. Participants agreed that they could read while using the pedal machine but not all users agreed they could complete computer tasks. Such practical considerations are important to consider for future worksite programmes that use the pedal machine.

Finally, while the pedal machine does not necessarily support social influence, previous worksite physical activity promotion studies using pedometers have utilised a social support component with great success.[32] Therefore, it stands to reason that the pedal machine could stimulate social support in the same light. In addition, our staff received 166 emails from interested participants in less than 72 h following an advertisement posted on the Lifespan hospital intranet website. The overwhelming response to this study is indicative of sedentary employees' desire to become more active while at work.

The results of this study should be interpreted with caution as this study is limited by a sample of primarily educated, Caucasian (94%) women (89%). It is possible that the pedal machine may not be viewed as favourably by men, racial and ethnic minority populations and/or individuals working in non-desk-dependent occupations. For example, individuals working in jobs that do not require a specific office space would probably not benefit from this machine. In addition, simply providing access to devices like the pedal machine is not enough to stimulate long-term use. The novelty of this device appeared to wear off over time, and may benefit from a combination of evidence-based behavioural techniques such as regular email prompts for sustained use. Future interventions testing the efficacy of combining behavioural content with the pedal machine are warranted. Finally, the pedal machine used in this study has certain limitations that deserve mention. For instance, the accuracy of the caloric expenditure output has yet to be confirmed.

Collectively, these findings hold public health significance due to the growing number of sedentary jobs in the USA, our growing understanding of the costs sedentary behaviour has on our health, and the potential of portable pedal machines (eg, portable, low cost, objective monitoring) for use in large-scale worksite health programmes. Future physical activity promotion interventions utilising portable and practical devices such as the pedal machine are warranted.

Contributors The contributing authors have made substantial contributions to the conception, design, analysis and interpretation of data, drafting of the article and have all given final approval of the current version and agree to its submission.

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Appendix 1 Feasibility questionnaire

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. The pedal machine is easy to use					
2. The pedal machine could be used in the typical office-style work environment					
3. The pedal machine is too noisy					
4. I would use the pedal machine as an alternative to be active on days that the weather is bad					
5. I felt comfortable using the pedal machine in the presence of others at my work					
6. My work-related productivity decreased while using the pedal machine					
7. The quality of my work decreased while using the pedal machine					
8. The pedal machine interfered with my daily work-related tasks					
9. I could conduct a normal, professional telephone conversation while using the pedal machine					
10. I could conduct normal computer-related tasks while using the pedal machine					
11. I could read comfortably while using the pedal machine					
12. I was more tired on days I used the pedal machine					
13. I had more back pain on days I used the pedal machine					
14. I had more joint pain on days I used the pedal machine					
15. I had more muscle aches on days I used the pedal machine					
16. My physical activity increased while at work as a result of the pedal machine					
17. The time I spent being sedentary decreased while at work as a result of the pedal machine					
18. My physical activity increased outside of work as a result of the pedal machine					
19. If I were offered a pedal machine by my employer, I would use it while at work					
20. I would use the pedal machine while at home					
21. The real-time monitor increased my use of the pedal machine					

Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace

Lucas J Carr, Kristen A Walaska and Bess H Marcus

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Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

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Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

Corresponding Author:

Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu

Co-Authors:

Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay, Ontario, Canada

Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA

Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

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ABSTRACT

Background. Excessive sedentary behavior has been estimated to be responsible for 9% of premature deaths worldwide. The purpose of this study was to test the efficacy of a multicomponent technology intervention for reducing daily sedentary time and improving cardiometabolic disease risk amongst sedentary, overweight university employees using a randomized controlled trial design.

Methods. Forty adults working in sedentary jobs were randomized to either: 1) an intervention group (N=23; 47.6±9.9 yrs; 94.1% female; 33.2±4.5 kg/m^2); 2) or wait list control group (N=17; 42.6±8.9 yrs; 86.9% female; 31.7±4.9 kg/m^2). The intervention group received a theory-based, internet-delivered program, a portable pedal machine at work and a pedometer for 12 weeks. Primary (sedentary and physical activity behavior measured objectively via StepWatch) and secondary (heart rate, blood pressure, height, weight, waist circumference, percent body fat, cardiorespiratory fitness, fasting lipids) outcomes were measured at baseline and post-intervention. Exploratory outcomes including intervention compliance and process evaluation measures were also assessed post-intervention.

Results. The intervention group reduced time spent sedentary (-57.8 minutes/day; p<0.01) and waist circumference (-1.0 cm; p=0.03) compared to the control group after adjusting for baseline values. Intervention participants logged onto the website 71.3% of all intervention days, used the pedal machine 37.7% of all working intervention days, and pedaled an average of 31.1 minutes/day.

Discussion. These findings suggest the intervention was engaging and resulted in reductions in daily sedentary time amongst full-time sedentary employees. These findings hold public health significance due to the growing number of sedentary jobs and the potential of these technologies in large-scale worksite programs. ClinicalTrials.gov #NCT01371084

Article focus

- The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control.

- We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks.
- As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

Key messages

- This multicomponent intervention resulted in significant reductions in time spent sedentary and waist circumference when comparing the intervention group to the wait list control group.
- The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group.
- The findings of this study are important given the paucity of research in this area and growing evidence demonstrating the importance of limiting daily sedentary time for reducing risk of chronic diseases.

Strengths

- Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3) conducted a 12 week trial which extends previous sedentary interventions that have typically been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process evaluation to identify features of the intervention that worked particularly well.

Limitations

- Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of middle-aged females working at a single institution which limits generalizability; and 2) differential drop out, although follow-up analyses indicate no differences between those that

dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

INTRODUCTION

Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day may be effective for improving various cardiometabolic disease risk factors .[7 8]The modern workplace has been identified as a setting in which individuals engage in prolonged bouts of sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional behaviorally focused worksite interventions have focused primarily on increasing physical activity and have resulted in modest effect sizes (Cohen's *d* = 0.21-0.22).[14 15] In a shift away from behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of modifying the work environment to reduce occupational sedentary time.

To date, only a handful of sedentary interventions have been conducted in the worksite. While many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies conducted in the worksite have been limited by the use of self-report measures of sedentary time and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and the possible desire/need of many employers and employees to remain seated while completing their work, there is a need for interventions that promote ‘active sitting’ as opposed to ‘reduced sitting’ as a means for reducing sedentary time.

In a previous study testing the feasibility of modifying the work environment as a means of reducing occupational sedentary time through promoting active sitting, our team provided portable pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10]. Importantly, participants rated the pedal machines as feasible and acceptable for use while completing their work. Further, despite a lack of any accompanying behavioral intervention, participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per day. Although these results are promising, it is possible the addition of a motivational behavioral intervention could result in increased pedaling compliance and reduced sedentary time.

The primary aim of the present study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks. As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

METHODS

Subjects and Design

Many sedentary interventions to date have been limited by short durations. Therefore, we conducted a 12 week randomized controlled trial design comparing a treatment group to a no treatment wait-list control group. We recruited apparently healthy but sedentary (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass index (BMI) $\geq$ 25.0 kg/m^2) adults working in full-time (reporting minimum of 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting).

Participants were required to gain permission from their supervisor prior to enrollment. Research staff members screened participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer. Participants were not compensated for participation in the study. Experimental protocols were approved by the University and Medical Center Institutional Review Board and voluntary written informed consent was obtained from each participant.

Participants of all races and ethnic backgrounds working at a large southern university were passively recruited through email advertisements placed on an electronic mailing list serve that served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were excluded from participation due to: not meeting eligibility criteria which primarily consisted of not meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using an online random sequence generator.[21] Participants were assigned to one of two groups by a research staff member not involved in data collection based on the order in which they enrolled into the study. A total of 49 participants deemed interested and eligible for participation were randomized to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40 participants completed all baseline and post-intervention assessments. Nine participants were lost to follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention participants and 17 control participants (see Table 1). More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

[Figure 1 here]

Group Descriptions

Wait List Control Group

Participants randomized to the wait-list control group were asked to maintain their current behaviors for 12 weeks at which time they were given the option to receive the intervention treatment materials.

Intervention Group

The primary intent of the intervention was to encourage participants to reduce their time spent sedentary. The name used to promote the study on advertisements and study materials was "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height, 20" length) device that has been demonstrated as acceptable for use during sedentary office work [10]. Because participants were sedentary employees working in professional environments, the rationale for providing them pedal machines at work was to allow them to engage in light intensity activity (i.e. active sitting) that they could perform for long periods throughout the day without causing them to perspire. The pedal machine is accompanied by a PC interface and software package that allows for objective monitoring of individual pedal activity. This software also provides the user with real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the pedal machine to each participant's worksite, downloaded the pedal tracking software to the participant's work computer, and worked with the participant to identify the most feasible set up. Intervention participants were asked to keep the pedal machine connected to their PC during all working hours. Intervention participants were required to gain clearance to use the pedal machines and software at their work prior to participation. No additional interaction between the research staff and participant's supervisors occurred during the course of the study. Participants were located in 18 different buildings across campus. No participants worked within visible proximity of each other.

Intervention participants were also provided access to a motivational website that was individually customized to the local culture of the worksite of which participants were recruited (Figure 2). Examples of customization included posting local images and messages specific to the local institution. The content of the intervention focused primarily on reducing time spent sedentary (both increasing active sitting via pedaling and taking breaks from sitting). Example messages included "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at work although some messages broadly targeted sedentary time in general and could have impacted sedentary time outside of work. Messages were theory based targeting constructs of the Social Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived environment. For example, participants were prompted via daily email messages to self-monitor their daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on the website was used to fuel a virtual competition (aimed at building social support) in which small groups of intervention participants (4-5 per group) collectively traveled across America. Participants were also emailed three theory-based motivational messages each week targeting goal setting, self-efficacy, and perceived environment. Specific goals were not set for intervention participants, rather participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook, participants were able to post profile photos and status updates on a newsfeed and send messages to members of their small groups further fostering social support.

[Figure 2 here]

Measures

All measures were collected at baseline and post-intervention (12 weeks) in a controlled laboratory setting by two staff members blinded to participant's group assignment. The two staff members were provided specific measurement duties to ensure each measure was collected by the same staff member at both baseline and post-intervention. The primary outcome was daily sedentary time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations, Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the monitor during all wakeful hours for seven consecutive days and keep track of wear time using an activity log. Days in which participants wore the monitors for less than 10 hours were excluded from final analysis. Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%) days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for 13.8 hours/day. The threshold for sedentary (0 steps/min) was based on the recommendation provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute depending on height and stride length[26].

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively), HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65% respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill walking test which had been previously demonstrated as a valid estimate of total aerobic fitness amongst middle-aged adults.[29]

Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was assessed objectively via the activity tracking software. Pedal compliance data was downloaded directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g., number of website logins, number of steps logged on the website) was assessed objectively at the end of 12 weeks via a backend tracking database made available by the website administrators. In order to assess which components of the intervention participants 'perceived' as helpful for reducing their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention completers. Participants rated each intervention component using a five point Likert scale.

Design/Statistical Analysis

A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80% power, at α=0.05, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was identified as a reasonable estimate based on our previous study in which participants used the same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means (SD) were used to describe data where appropriate.

The paired samples t-test was used to determine any within group differences at baseline and post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups at post-intervention. Baseline values of interest were included as covariates in the model for all continuous variables consistent with recommended statistical procedures [30]. The underlying assumption no between group differences at baseline was confirmed for all measures by one way

ANOVA. Finally, the 95% confidence interval (CI) for the mean differences of all primary and secondary outcomes of interest are presented.

RESULTS

Baseline characteristics of both groups are presented in Table 1. Overall, participants were middle-aged and mostly classified as obese. More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Differential drop out was observed over the course of the study, although sensitivity analyses indicate no differences between those that dropped and those that completed the study for measures of age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

Table 1. Baseline characteristics by group Mean ± S.D. (N=40)

	Control Group N=17	**Intervention Group N=23**	**All (N=40)**
Age (years)	47.6(9.9)	42.6(8.9)	44.7(9.6)
Female %	94.1%	86.9%	90%
Height (in)	65.2(3.2)	65.4(3.4)	65.4(3.4)
Weight (lbs)	201.3(30.2)	194.1(34.9)	197.2(32.8)
Body Mass Index (BMI)	33.2(4.5)	31.7(4.9)	32.4(4.8)
Non-Hispanic White (%)	76.5%	63.6%	70.0%
College Graduate (%)	71.0%	86.0%	78.5%
Income >$40,000 (%)	62.5%	63.6%	63.0%

Table 2 illustrates changes in the primary outcomes of sedentary and physical activity behaviors for both groups. No differences were observed for any of these measures at baseline. A significant intervention effect favoring the intervention group (95% CI, -0.99, 118.4 minutes/day) was observed for absolute number of daily sedentary minutes after adjusting for baseline values.

Intervention effects reached near significance for both percent daily time spent sedentary (95% CI, -6.8%, -0.6%) and percent time spent in moderate intensity physical activity (95% CI, 0.0, 2.6%) (see Table 2).

Table 2. Absolute and relative time spent in sedentary and physical activity behaviors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Minutes Sedentary					<0.01**
Control	544.2(76.9)	599.7(106.6)	+55.5 (2.8, 108.1)	0.04*	
Intervention	584.9(136.1)	526.1(77.3)	-58.7 (-118.4, 0.99)	0.04*	
% Time Sedentary					0.06
Control	65.7(7.5)	67.5(8.0)	-1.8% (-2.7%, 6.3%)	0.41	
Intervention	67.6(7.2)	63.9(7.9)	-3.7% (-6.8%, -0.6%)	0.02*	
Minutes Light					0.64
Control	265.7(84.0)	262.2(70.8)	- 3.5 (-45.6, 38.6)	0.86	
Intervention	263.9(69.5)	270.3(69.5)	+6.4 (-18.7, 31.5)	0.6	
% Time Light					0.16
Control	31.9(8.1)	30.3(8.4)	-1.6% (-6.0%, 2.8%)	0.46	
Intervention	30.6(8.2)	32.7(7.6)	2.1% (-0.8%, 4.9%)	0.15	
Minutes Moderate					0.13
Control	18.6(25.2)	17.4(23.7)	-1.2 (-4.9, 2.4)	0.5	
Intervention	14.5(18.5)	23.3(28.0)	+8.8 (-1.6, 19.2)	0.09	
% Time Moderate					0.06
Control	2.3(3.2)	2.0(2.9)	-0.3% (-0.7%, 0.2%)	0.21	
Intervention	1.5(1.5)	2.8(3.4)	+1.3% (0.0%, 2.6%)	0.04*	
Minutes Vigorous					0.33
Control	1.2(2.6)	1.5(2.7)	+0.4 (-0.2, 0.9)	0.19	
Intervention	2.7(6.4)	4.9(10.9)	+2.2 (-2.7, 7.0)	0.37	
% Time Vigorous					0.25
Control	0.1(0.3)	0.2(0.3)	0.0% (0.0%, 0.1%)	0.32	
Intervention	0.3(0.6)	0.6(1.3)	+0.3% (-0.3, 0.9%)	0.26	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] p < 0.05 for within group change from baseline (paired t-test)

** p<0.05 for between group differences at post-intervention (ANCOVA)

294 Table 3 illustrates changes in the secondary outcomes of cardiometabolic risk factors for both groups. A significant intervention effect was observed for waist circumference p=0.03 after adjusting for baseline values (Table 3). No significant intervention effects were observed for any other cardiometabolic risk factors.

Table 3. Cardiometabolic risk factors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Weight (lbs)					0.58
Control	201.4(30.2)	202.4(30.5)	+1.0 (-1.0, 3.0)	0.31	
Intervention	194.2(34.9)	194.4(34.5)	+0.2 (-2.3, 2.7)	0.86	
BMI (kg/m2)					0.76
Control	33.2(4.5)	33.4(4.6)	+0.2 (-0.1, 0.5)	0.21	
Intervention	31.8(5.0)	31.9(5.0)	-0.1 (-0.3, 0.5)	0.57	
Systolic BP (mmHg)					0.70
Control	117.1(13.0)	117.5(12.8)	-0.8 (-5.0, 3.6)	0.71	
Intervention	120.0(13.8)	115.7(10.8)	-4.3 (-8.0, -0.7)	0.02*	
Diastolic BP (mmHg)					0.51
Control	72.8(10.3)	73.2(10.6)	-0.1 (-5.0, 4.8)	0.96	
Intervention	78.2(10.3)	75.4(7.4)	-2.8 (-6.2, 0.7)	0.11	
Waist Circumference (cm)					0.03**
Control	92.9(11.1)	93.9(10.8)	+1.0 (-0.7, 2.7)	0.22	
Intervention	92.6(11.2)	91.6(11.3)	-1.0 (-2.1, 0.3)	0.06	
Estimated V02 (ml/kg/min)					0.10
Control	29.6(2.5)	30.0(2.6)	+0.3 (-0.1, 0.8)	0.14	
Intervention	30.8(5.1)	31.1(4.6)	+0.3 (-0.6, 1.1)	0.53	
Total Cholesterol (mg/dL)					0.83
Control	184.4(25.9)	185.0(18.9)	-0.8 (-15.1, 13.4)	0.91	
Intervention	191.4(26.3)	189.7(27.0)	+0.7 (-5.9, 7.2)	0.83	
HDL (mg/dL)					0.65
Control	47.6(18.4)	46.7(18.9)	-0.9 (-6.8, 5.1)	0.76	
Intervention	45.7(17.6)	43.7(16.4)	-2.1 (-8.1, 3.4)	0.46	
LDL (mg/dL)					0.96
Control	111.2(32.1)	120.2(25.3)	+5.4 (-11.3, 22.1)	0.50	
Intervention	119.4(23.2)	116.7(29.4)	-3.7 (-12.8, 5.4)	0.41	
Triglycerides					0.91
Control	130.6(65.4)	131.0(59.9)	+4.7 (-24.0, 33.3)	0.73	
Intervention	98.4(45.2)	118.4(57.3)	+18.3 (-0.1, 36.7)	0.05	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] $p < 0.05$ for within group change from baseline (paired t-test)

** $p<0.05$ for between group differences at post-intervention (ANCOVA)

A total of 23 participants completed the intervention and provided compliance data (see Table 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they had access to the website (including weekends) (Table 4). Intervention participants also logged an average of 7945 ± 4634 steps per day on the website over the 12 weeks. Participants pedaled an average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding weekends). Participants pedaled an average of 31.1±31.6 minutes per day on the days they used the pedal machines and for an average of 16.1±17.2 minutes per pedaling bout

Table 4. Intervention compliance measures amongst Intervention completers (N=23).

	Mean/%	**S.D.**
Web Compliance % (Days Logged in/Days with Access)	71.3	35.7
Average Steps Logged Per Day	7945	4634
Average Days Pedaled Over 12 Weeks	22.6	17.6
Pedal Compliance % (Days Pedaled/Days with Access)	37.7	29.3
Average Pedal Bouts/Day	1.9	0.9
Average Minutes Pedaled/Day Used	31.1	31.6
Average Minutes Pedaled/Pedal Bout	16.1	17.2

When asked to rate the helpfulness of each intervention feature for reducing their sedentary time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity on the website as “extremely helpful” (median Likert score = 5.0; Table 5). Participants rated the email reminders to log daily activity and access to the pedal machine as “quite helpful” (median Likert score = 4.0; Table 5).

Table 5 : Quartile and median Likert scale responses (1=Not at all helpful; 2=A little helpful; 3=moderately helpful; 4=Quite helpful; 5=Extremely helpful) on helpfulness of individual intervention components for reducing sedentary time (N=23).

Please rate how helpful each of the following intervention components was in reducing your daily sedentary time.	Likert Scale		
	Q1	Median	Q3
Pedal machine biofeedback display (minutes pedaled, calories burned, etc.)	4.0	5.0	5.0
Wearing the pedometer	4.0	5.0	5.0
Self-monitoring daily steps and pedal time on the website	4.0	5.0	5.0
Email reminders to log physical activity on website	4.0	4.0	5.0
Access to pedal exercise machine at work	4.0	4.0	5.0
'Walk Across America' Group Challenge on website	3.0	3.0	5.0
Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8

DISCUSSION

The primary findings of this study suggest that this multicomponent intervention resulted in significant time spent sedentary in a small sample of inactive, overweight employees. The decreased sedentary time observed among the intervention group appears to be have been at least partially replaced by an increase in moderate intensity activity. Our findings are important as the present study was among the first worksite interventions to promote ‘active sitting’ as a means of reducing sedentary time. Further, the present study was conducted over a longer duration (12 weeks) compared to similar trials [19 31] and utilized an objective measure of sedentary/physical activity behavior whereas many previous interventions have relied upon self-report measures of sedentary time[17]. The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group. This is important, as it has been suggested that decreasing sedentary time can result in improved health benefits independent of physical activity.[2 32-34]

Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention that included educational materials on sedentary health risks and tips to reduce sedentary time.[31] However, this study did not include a control group. In a study that did include a control group, Evans et al. found no between group differences in objectively measured sitting time after five days of point-of-choice software reminders to stand up every 30 minutes while at work.[19]

We also observed a significant intervention effect for waist circumference. This finding is important as waist circumference has been shown to predict mortality amongst adults with coronary artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist circumference to be sensitive to change in the absence of changes in other measures of adiposity[36] as well as studies reporting interruptions from sedentary time to be associated with waist circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical activity program which demonstrated modest improvements in daily steps and waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk reduction.

Participant compliance to the website overall was high with participants logging into the website an average of 71% of all intervention days. This is important as past internet-delivered intervention studies have identified engagement to be a challenge [38 39] and a predictor of intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high website compliance in the present study may be due to the tailoring of the website to include locally relevant images and messages and/or the regular email messages.

Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day) was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These findings suggest the added motivational intervention, which included suggestions for setting goals and finding time to pedal each day, resulted in improved daily compliance that was sustained over a longer duration. Despite the logistical limitation of the portable pedal machine when paired with standard height desks (i.e., many participants reported their knees hit the underside of their desk while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize compliance with such portable pedal machines in future studies, it is recommended these devices be paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

Intervention participants reported features that provided feedback including the pedal machine tracking software, pedometers and self-monitoring daily activity on the website (which was immediately followed by a graph illustrating the individual's daily progress) as the most helpful features for reducing their daily sedentary time. This information is important and could be used to inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

The main limitation of the study was the limited generalizability due to a small sample size that comprised primarily of middle-aged females working at a single institution. We also experienced differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age, BMI, or daily sedentary time.

The present study is among the first interventions conducted within the worksite aimed specifically at reducing daily sedentary time to demonstrate between group differences in objectively measured sedentary time. Compliance with the motivational website was high while compliance with the pedal machine was moderate. These findings are promising considering the relatively low cost of the intervention which cost a total of $180 (pedal machine and software, pedometer, access to website) per participant. While an intervention effect was observed for waist circumference, no between group differences were observed for any other cardiometabolic risk factors. More sedentary focused interventions are needed to examine whether reducing sedentary time can be sustained long-term and whether long-term changes result in significant reductions in risk for chronic diseases.

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Contributorship Statement:

- Dr. Lucas Carr was responsible for the design of the study and lead the manuscript preparation.
- Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript preparation.
- Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for leading the intervention which included duties of interacting with participants on a daily basis.
- Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation and were responsible for collecting data at the baseline and post-intervention time points.

Data Sharing

- Extra data is available by emailing Dr. Lucas Carr at **lucas-carr@uiowa.edu**.

Figure Legend

Figure 1. Sequence of events and recruitment/enrollment schematic. Study was coordinated at East Carolina University, Greenville, NC, from June 2011-June 2012.

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.

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Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

Corresponding Author:

Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu

Co-Authors:

Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay, Ontario, Canada

Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA

Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

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ABSTRACT

Background. Excessive sedentary behavior has been estimated to be responsible for 9% of premature deaths worldwide. The purpose of this study was to test the efficacy of a multicomponent technology intervention for reducing daily sedentary time and improving cardiometabolic disease risk amongst sedentary, overweight university employees using a randomized controlled trial design.

Methods. Forty adults working in sedentary jobs were randomized to either: 1) an intervention group (N=23; 47.6±9.9 yrs; 94.1% female; 33.2±4.5 kg/m^2); 2) or wait list control group (N=17; 42.6±8.9 yrs; 86.9% female; 31.7±4.9 kg/m^2). The intervention group received a theory-based, internet-delivered program, a portable pedal machine at work and a pedometer for 12 weeks. Primary (sedentary and physical activity behavior measured objectively via StepWatch) and secondary (heart rate, blood pressure, height, weight, waist circumference, percent body fat, cardiorespiratory fitness, fasting lipids) outcomes were measured at baseline and post-intervention. Exploratory outcomes including intervention compliance and process evaluation measures were also assessed post-intervention.

Results. The intervention group reduced time spent sedentary (-57.8 minutes/day; $p<0.01$) and waist circumference (-1.0 cm; $p=0.03$) compared to the control group after adjusting for baseline values. Intervention participants logged onto the website 71.3% of all intervention days, used the pedal machine 37.7% of all working intervention days, and pedaled an average of 31.1 minutes/day.

Discussion. These findings suggest the intervention was engaging and resulted in reductions in daily sedentary time amongst full-time sedentary employees. These findings hold public health significance due to the growing number of sedentary jobs and the potential of these technologies in large-scale worksite programs. ClinicalTrials.gov #NCT01371084

Article focus

- The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control.

- We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks.
- As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

Key messages

- This multicomponent intervention resulted in significant reductions in time spent sedentary and waist circumference when comparing the intervention group to the wait list control group.
- The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group.
- The findings of this study are important given the paucity of research in this area and growing evidence demonstrating the importance of limiting daily sedentary time for reducing risk of chronic diseases.

Strengths

- Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3) conducted a 12 week trial which extends previous sedentary interventions that have typically been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process evaluation to identify features of the intervention that worked particularly well.

Limitations

- Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of middle-aged females working at a single institution which limits generalizability; and 2) differential drop out, although follow-up analyses indicate no differences between those that

dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

INTRODUCTION

Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day may be effective for improving various cardiometabolic disease risk factors .[7 8]

The modern workplace has been identified as a setting in which individuals engage in prolonged bouts of sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional behaviorally focused worksite interventions have focused primarily on increasing physical activity and have resulted in modest effect sizes (Cohen's d = 0.21-0.22).[14 15] In a shift away from behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of modifying the work environment to reduce occupational sedentary time.

To date, only a handful of sedentary interventions have been conducted in the worksite. While many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies conducted in the worksite have been limited by the use of self-report measures of sedentary time and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and the possible desire/need of many employers and employees to remain seated while completing their work, there is a need for interventions that promote ‘active sitting’ as opposed to ‘reduced sitting’ as a means for reducing sedentary time.

In a previous study testing the feasibility of modifying the work environment as a means of reducing occupational sedentary time through promoting active sitting, our team provided portable pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10]. Importantly, participants rated the pedal machines as feasible and acceptable for use while completing their work. Further, despite a lack of any accompanying behavioral intervention, participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per day. Although these results are promising, it is possible the addition of a motivational behavioral intervention could result in increased pedaling compliance and reduced sedentary time.

The primary aim of the present study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We hypothesized that the intervention group would significantly reduce daily sedentary time and select cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks. As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

METHODS

Subjects and Design

Many sedentary interventions to date have been limited by short durations. Therefore, we conducted a 12 week randomized controlled trial design comparing a treatment group to a no treatment wait-list control group. We recruited apparently healthy but sedentary (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass index (BMI) $\geq$ 25.0 kg/m^2) adults working in full-time (reporting minimum of 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting). Participants were required to gain permission from their supervisor prior to enrollment. Research staff members screened participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer. Participants were not compensated for participation in the study. Experimental protocols were approved by the University and Medical Center Institutional Review Board and voluntary written informed consent was obtained from each participant.

Participants of all races and ethnic backgrounds working at a large southern university were passively recruited through email advertisements placed on an electronic mailing list serve that served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were excluded from participation due to: not meeting eligibility criteria which primarily consisted of not meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using an online random sequence generator.[21] Participants were assigned to one of two groups by a research staff member not involved in data collection based on the order in which they enrolled into the study. A total of 49 participants deemed interested and eligible for participation were randomized to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40 participants completed all baseline and post-intervention assessments. Nine participants were lost to follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention participants and 17 control participants (see Table 1). More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

[Figure 1 here]

Group Descriptions

Wait List Control Group

Participants randomized to the wait-list control group were asked to maintain their current behaviors for 12 weeks at which time they were given the option to receive the intervention treatment materials.

Intervention Group

The primary intent of the intervention was to encourage participants to reduce their time spent sedentary. The name used to promote the study on advertisements and study materials was "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height, 20" length) device that has been demonstrated as acceptable for use during sedentary office work [10]. Because participants were sedentary employees working in professional environments, the rationale for providing them pedal machines at work was to allow them to engage in light intensity activity (i.e. active sitting) that they could perform for long periods throughout the day without causing them to perspire. The pedal machine is accompanied by a PC interface and software package that allows for objective monitoring of individual pedal activity. This software also provides the user with real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the pedal machine to each participant's worksite, downloaded the pedal tracking software to the participant's work computer, and worked with the participant to identify the most feasible set up. Intervention participants were asked to keep the pedal machine connected to their PC during all working hours. Intervention participants were required to gain clearance to use the pedal machines and software at their work prior to participation. No additional interaction between the research staff and participant's supervisors occurred during the course of the study. Participants were located in 18 different buildings across campus. No participants worked within visible proximity of each other.

Intervention participants were also provided access to a motivational website that was individually customized to the local culture of the worksite of which participants were recruited (Figure 2). Examples of customization included posting local images and messages specific to the local institution. The content of the intervention focused primarily on reducing time spent sedentary (both increasing active sitting via pedaling and taking breaks from sitting). Example messages included "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at work although some messages broadly targeted sedentary time in general and could have impacted sedentary time outside of work. Messages were theory based targeting constructs of the Social Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived environment. For example, participants were prompted via daily email messages to self-monitor their daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on the website was used to fuel a virtual competition (aimed at building social support) in which small groups of intervention participants (4-5 per group) collectively traveled across America. Participants were also emailed three theory-based motivational messages each week targeting goal setting, self-efficacy, and perceived environment. Specific goals were not set for intervention participants, rather participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook, participants were able to post profile photos and status updates on a newsfeed and send messages to members of their small groups further fostering social support.

[Figure 2 here]

Measures

All measures were collected at baseline and post-intervention (12 weeks) in a controlled laboratory setting by two staff members blinded to participant's group assignment. The two staff members were provided specific measurement duties to ensure each measure was collected by the same staff member at both baseline and post-intervention. The primary outcome was daily sedentary time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations, Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the monitor during all wakeful hours for seven consecutive days and keep track of wear time using an activity log. Days in which participants wore the monitors for less than 10 hours were excluded from final analysis. Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%) days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for 13.8 hours/day. The threshold for sedentary (0 steps/min) was based on the recommendation provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute depending on height and stride length[26].

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively), HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65% respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill walking test which had been previously demonstrated as a valid estimate of total aerobic fitness amongst middle-aged adults.[29]

Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was assessed objectively via the activity tracking software. Pedal compliance data was downloaded directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g., number of website logins, number of steps logged on the website) was assessed objectively at the end of 12 weeks via a backend tracking database made available by the website administrators. In order to assess which components of the intervention participants 'perceived' as helpful for reducing their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention completers. Participants rated each intervention component using a five point Likert scale.

Design/Statistical Analysis

A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80% power, at α=0.05, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was identified as a reasonable estimate based on our previous study in which participants used the same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means (SD) were used to describe data where appropriate.

The paired samples t-test was used to determine any within group differences at baseline and post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups at post-intervention. Baseline values of interest were included as covariates in the model for all continuous variables consistent with recommended statistical procedures [30]. The underlying assumption no between group differences at baseline was confirmed for all measures by one way

ANOVA. Finally, the 95% confidence interval (CI) for the mean differences of all primary and secondary outcomes of interest are presented.

RESULTS

Baseline characteristics of both groups are presented in Table 1. Overall, participants were middle-aged and mostly classified as obese. More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Differential drop out was observed over the course of the study, although sensitivity analyses indicate no differences between those that dropped and those that completed the study for measures of age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

Table 1. Baseline characteristics by group Mean ± S.D. (N=40)

	Control Group N=17	**Intervention Group N=23**	**All (N=40)**
Age (years)	47.6(9.9)	42.6(8.9)	44.7(9.6)
Female %	94.1%	86.9%	90%
Height (in)	65.2(3.2)	65.4(3.4)	65.4(3.4)
Weight (lbs)	201.3(30.2)	194.1(34.9)	197.2(32.8)
Body Mass Index (BMI)	33.2(4.5)	31.7(4.9)	32.4(4.8)
Non-Hispanic White (%)	76.5%	63.6%	70.0%
College Graduate (%)	71.0%	86.0%	78.5%
Income >$40,000 (%)	62.5%	63.6%	63.0%

Table 2 illustrates changes in the primary outcomes of sedentary and physical activity behaviors for both groups. No differences were observed for any of these measures at baseline. A significant intervention effect favoring the intervention group (95% CI, -0.99, 118.4 minutes/day) was observed for absolute number of daily sedentary minutes after adjusting for baseline values.

Intervention effects reached near significance for both percent daily time spent sedentary (95% CI, -6.8%, -0.6%) and percent time spent in moderate intensity physical activity (95% CI, 0.0, 2.6%) (see Table 2).

Table 2. Absolute and relative time spent in sedentary and physical activity behaviors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	**Post-Intervention**	**Mean Difference[a] (95% CI)**	**Within Group P value**	**Between Group P value (Post)**
Minutes Sedentary					<0.01**
Control	544.2(76.9)	599.7(106.6)	+55.5 (2.8, 108.1)	0.04*	
Intervention	584.9(136.1)	526.1(77.3)	-58.7 (-118.4, 0.99)	0.04*	
% Time Sedentary					0.06
Control	65.7(7.5)	67.5(8.0)	-1.8% (-2.7%, 6.3%)	0.41	
Intervention	67.6(7.2)	63.9(7.9)	-3.7% (-6.8%, -0.6%)	0.02*	
Minutes Light					0.64
Control	265.7(84.0)	262.2(70.8)	- 3.5 (-45.6, 38.6)	0.86	
Intervention	263.9(69.5)	270.3(69.5)	+6.4 (-18.7, 31.5)	0.6	
% Time Light					0.16
Control	31.9(8.1)	30.3(8.4)	-1.6% (-6.0%, 2.8%)	0.46	
Intervention	30.6(8.2)	32.7(7.6)	2.1% (-0.8%, 4.9%)	0.15	
Minutes Moderate					0.13
Control	18.6(25.2)	17.4(23.7)	-1.2 (-4.9, 2.4)	0.5	
Intervention	14.5(18.5)	23.3(28.0)	+8.8 (-1.6, 19.2)	0.09	
% Time Moderate					0.06
Control	2.3(3.2)	2.0(2.9)	-0.3% (-0.7%, 0.2%)	0.21	
Intervention	1.5(1.5)	2.8(3.4)	+1.3% (0.0%, 2.6%)	0.04*	
Minutes Vigorous					0.33
Control	1.2(2.6)	1.5(2.7)	+0.4 (-0.2, 0.9)	0.19	
Intervention	2.7(6.4)	4.9(10.9)	+2.2 (-2.7, 7.0)	0.37	
% Time Vigorous					0.25
Control	0.1(0.3)	0.2(0.3)	0.0% (0.0%, 0.1%)	0.32	
Intervention	0.3(0.6)	0.6(1.3)	+0.3% (-0.3, 0.9%)	0.26	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] p < 0.05 for within group change from baseline (paired t-test)

** p<0.05 for between group differences at post-intervention (ANCOVA)

Table 3 illustrates changes in the secondary outcomes of cardiometabolic risk factors for both groups. A significant intervention effect was observed for waist circumference p=0.03 after adjusting for baseline values (Table 3). No significant intervention effects were observed for any other cardiometabolic risk factors.

Table 3. Cardiometabolic risk factors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Weight (lbs)					0.58
Control	201.4(30.2)	202.4(30.5)	+1.0 (-1.0, 3.0)	0.31	
Intervention	194.2(34.9)	194.4(34.5)	+0.2 (-2.3, 2.7)	0.86	
BMI (kg/m2)					0.76
Control	33.2(4.5)	33.4(4.6)	+0.2 (-0.1, 0.5)	0.21	
Intervention	31.8(5.0)	31.9(5.0)	-0.1 (-0.3, 0.5)	0.57	
Systolic BP (mmHg)					0.70
Control	117.1(13.0)	117.5(12.8)	-0.8 (-5.0, 3.6)	0.71	
Intervention	120.0(13.8)	115.7(10.8)	-4.3 (-8.0, -0.7)	0.02*	
Diastolic BP (mmHg)					0.51
Control	72.8(10.3)	73.2(10.6)	-0.1 (-5.0, 4.8)	0.96	
Intervention	78.2(10.3)	75.4(7.4)	-2.8 (-6.2, 0.7)	0.11	
Waist Circumference (cm)					0.03**
Control	92.9(11.1)	93.9(10.8)	+1.0 (-0.7, 2.7)	0.22	
Intervention	92.6(11.2)	91.6(11.3)	-1.0 (-2.1, 0.3)	0.06	
Estimated V02 (ml/kg/min)					0.10
Control	29.6(2.5)	30.0(2.6)	+0.3 (-0.1, 0.8)	0.14	
Intervention	30.8(5.1)	31.1(4.6)	+0.3 (-0.6, 1.1)	0.53	
Total Cholesterol (mg/dL)					0.83
Control	184.4(25.9)	185.0(18.9)	-0.8 (-15.1, 13.4)	0.91	
Intervention	191.4(26.3)	189.7(27.0)	+0.7 (-5.9, 7.2)	0.83	
HDL (mg/dL)					0.65
Control	47.6(18.4)	46.7(18.9)	-0.9 (-6.8, 5.1)	0.76	
Intervention	45.7(17.6)	43.7(16.4)	-2.1 (-8.1, 3.4)	0.46	
LDL (mg/dL)					0.96
Control	111.2(32.1)	120.2(25.3)	+5.4 (-11.3, 22.1)	0.50	
Intervention	119.4(23.2)	116.7(29.4)	-3.7 (-12.8, 5.4)	0.41	
Triglycerides					0.91
Control	130.6(65.4)	131.0(59.9)	+4.7 (-24.0, 33.3)	0.73	
Intervention	98.4(45.2)	118.4(57.3)	+18.3 (-0.1, 36.7)	0.05	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] $p < 0.05$ for within group change from baseline (paired t-test)

** $p<0.05$ for between group differences at post-intervention (ANCOVA)

A total of 23 participants completed the intervention and provided compliance data (see Table 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they had access to the website (including weekends) (Table 4). Intervention participants also logged an average of 7945 ± 4634 steps per day on the website over the 12 weeks. Participants pedaled an average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding weekends). Participants pedaled an average of 31.1±31.6 minutes per day on the days they used the pedal machines and for an average of 16.1±17.2 minutes per pedaling bout

Table 4. Intervention compliance measures amongst Intervention completers (N=23).

	Mean/%	S.D.
Web Compliance % (Days Logged in/Days with Access)	71.3	35.7
Average Steps Logged Per Day	7945	4634
Average Days Pedaled Over 12 Weeks	22.6	17.6
Pedal Compliance % (Days Pedaled/Days with Access)	37.7	29.3
Average Pedal Bouts/Day	1.9	0.9
Average Minutes Pedaled/Day Used	31.1	31.6
Average Minutes Pedaled/Pedal Bout	16.1	17.2

When asked to rate the helpfulness of each intervention feature for reducing their sedentary time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity on the website as “extremely helpful” (median Likert score = 5.0; Table 5). Participants rated the email

318 reminders to log daily activity and access to the pedal machine as "quite helpful" ((median Likert score
319 = 4.0; Table 5).
320

Table 5 : Quartile and median Likert scale responses (1=Not at all helpful; 2=A little helpful; 3=moderately helpful; 4=Quite helpful; 5=Extremely helpful) on helpfulness of individual intervention components for reducing sedentary time (N=23).

Please rate how helpful each of the following intervention components was in reducing your daily sedentary time.	Likert Scale		
	Q1	Median	Q3
Pedal machine biofeedback display (minutes pedaled, calories burned, etc.)	4.0	5.0	5.0
Wearing the pedometer	4.0	5.0	5.0
Self-monitoring daily steps and pedal time on the website	4.0	5.0	5.0
Email reminders to log physical activity on website	4.0	4.0	5.0
Access to pedal exercise machine at work	4.0	4.0	5.0
'Walk Across America' Group Challenge on website	3.0	3.0	5.0
Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8

321
322
323 **DISCUSSION**

324 The primary findings of this study suggest that this multicomponent intervention resulted in
325 significant time spent sedentary in a small sample of inactive, overweight employees. The decreased
326 sedentary time observed among the intervention group appears to be have been at least partially
327 replaced by an increase in moderate intensity activity. Our findings are important as the present study
328 was among the first worksite interventions to promote 'active sitting' as a means of reducing
329 sedentary time. Further, the present study was conducted over a longer duration (12 weeks)
330 compared to similar trials [19 31] and utilized an objective measure of sedentary/physical activity

behavior whereas many previous interventions have relied upon self-report measures of sedentary time[17]. The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group. This is important, as it has been suggested that decreasing sedentary time can result in improved health benefits independent of physical activity.[2 32-34]

Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention that included educational materials on sedentary health risks and tips to reduce sedentary time.[31] However, this study did not include a control group. In a study that did include a control group, Evans et al. found no between group differences in objectively measured sitting time after five days of point-of-choice software reminders to stand up every 30 minutes while at work.[19]

We also observed ~~a group x time interaction~~a significant intervention effect for waist circumference. This finding is important as waist circumference has been shown to predict mortality amongst adults with coronary artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist circumference to be sensitive to change in the absence of changes in other measures of adiposity[36] as well as studies reporting interruptions from sedentary time to be associated with waist circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical activity program which demonstrated modest improvements in daily steps and waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk reduction.

Participant compliance to the website overall was high with participants logging into the website an average of 71% of all intervention days. This is important as past internet-delivered intervention studies have identified engagement to be a challenge [38 39] and a predictor of intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high website compliance in the present study may be due to the tailoring of the website to include locally relevant images and messages and/or the regular email messages.

Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day) was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These findings suggest the added motivational intervention, which included suggestions for setting goals and finding time to pedal each day, resulted in improved daily compliance that was sustained over a longer duration. Despite the logistical limitation of the portable pedal machine when paired with standard height desks (i.e., many participants reported their knees hit the underside of their desk while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize compliance with such portable pedal machines in future studies, it is recommended these devices be paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

Intervention participants reported features that provided feedback including the pedal machine tracking software, pedometers and self-monitoring daily activity on the website (which was immediately followed by a graph illustrating the individual's daily progress) as the most helpful features for reducing their daily sedentary time. This information is important and could be used to inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

The main limitation of the study was the limited generalizability due to a small sample size that comprised primarily of middle-aged females working at a single institution. We also experienced differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age, BMI, or daily sedentary time.

The present study is among the first interventions conducted within the worksite aimed specifically at reducing daily sedentary time to demonstrate between group differences in objectively measured sedentary time. Compliance with the motivational website was high while compliance with the pedal machine was moderate. These findings are promising considering the relatively low cost of the intervention which cost a total of $180 (pedal machine and software, pedometer, access to website) per participant. While an intervention effect was observed for waist circumference, no between group differences were observed for any other cardiometabolic risk factors. More sedentary focused interventions are needed to examine whether reducing sedentary time can be sustained long-term and whether long-term changes result in significant reductions in risk for chronic diseases.

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Contributorship Statement:

- Dr. Lucas Carr was responsible for the design of the study and lead the manuscript preparation.
- Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript preparation.
- Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for leading the intervention which included duties of interacting with participants on a daily basis.
- Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation and were responsible for collecting data at the baseline and post-intervention time points.

Data Sharing

- Extra data is available by emailing Dr. Lucas Carr at **lucas-carr@uiowa.edu**.

Figure Legend

Figure 1. Sequence of events and recruitment/enrollment schematic. Study was coordinated at East Carolina University, Greenville, NC, from June 2011-June 2012.

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.

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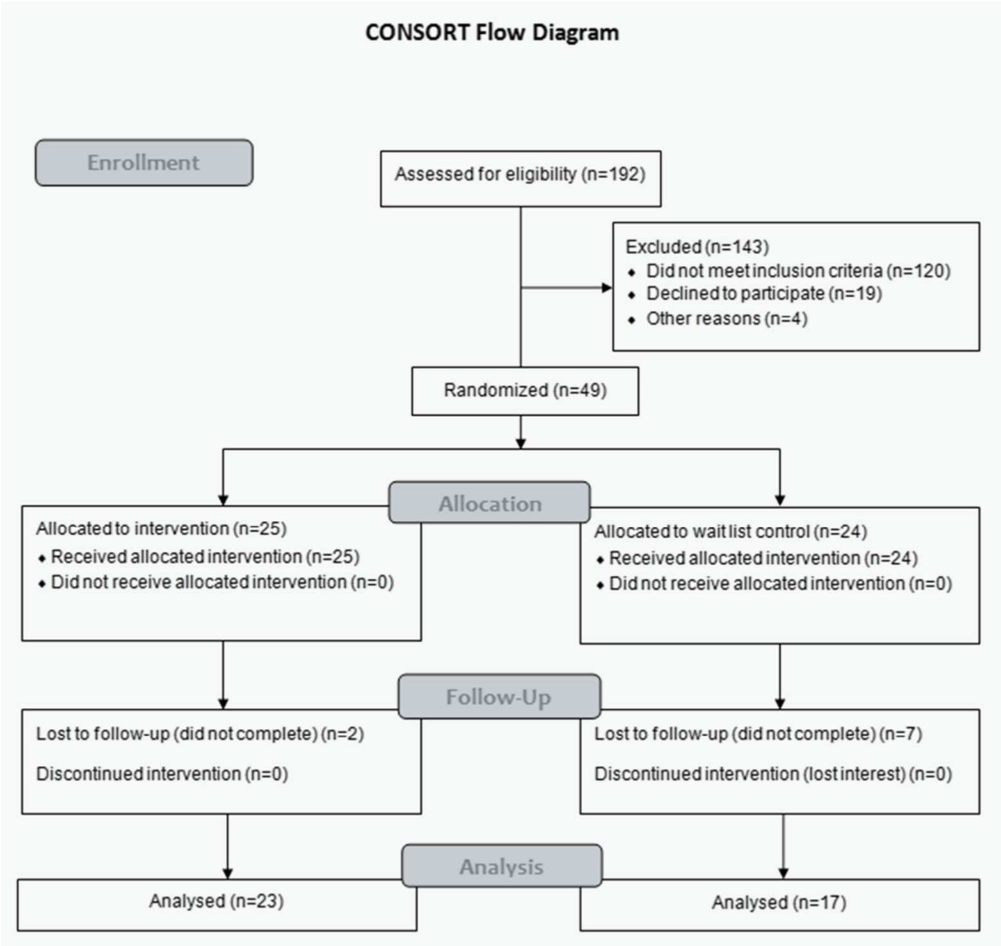

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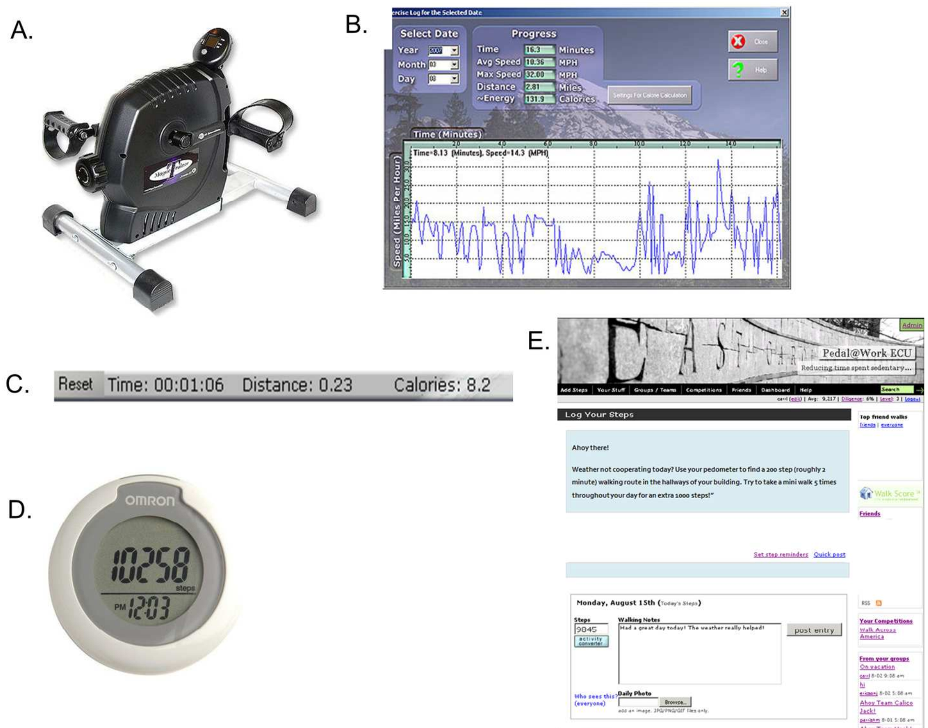

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.
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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3-4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	NA
Participants	4a	Eligibility criteria for participants	4-5
	4b	Settings and locations where the data were collected	7
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	7
	6b	Any changes to trial outcomes after the trial commenced, with reasons	NA
Sample size	7a	How sample size was determined	8
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	5
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	5
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	5
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5

Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	5&7
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	NA
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	5
	13b	For each group, losses and exclusions after randomisation, together with reasons	5
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	5
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1 (p.9)
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	5
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	8-13
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	8-13
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	15
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	15
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	13-16
Other information			
Registration	23	Registration number and name of trial registry	ClinicalTrials. gov (NCT01371084)
Protocol	24	Where the full trial protocol can be accessed, if available	Oak Ridge Associated Universities

Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	Grant (#212112)

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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PRESS RELEASE

Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace

Lucas J Carr,[1,2] Kristen A Walaska,[1] Bess H Marcus[1,3]

[1]Centers for Behavioral and Preventive Medicine, The Miriam Hospital, Providence, Rhode Island, USA
[2]Department of Exercise and Sport Science, East Carolina University, Greenville, North Carolina, USA
[3]Program in Public Health, Brown University, Providence, Rhode Island, USA

Correspondence to
Dr Lucas J Carr, Department of Exercise and Sport Science, East Carolina University, 172 Minges Coliseum, Greenville, NC 27858, USA; carrl@ecu.edu

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ABSTRACT

Background Sedentary time is independently associated with an increased risk of metabolic disease. Worksite interventions designed to decrease sedentary time may serve to improve employee health.

Objective The purpose of this study is to test the feasibility and use of a pedal exercise machine for reducing workplace sedentary time.

Methods Eighteen full-time employees (mean age+SD 40.2+10.7 years; 88% female) working in sedentary occupations were recruited for participation. Demographic and anthropometric data were collected at baseline and 4 weeks. Participants were provided access to a pedal exercise machine for 4 weeks at work. Use of the device was measured objectively by exercise tracking software, which monitors pedal activity and provides the user real-time feedback (eg, speed, time, distance, calories). At 4 weeks, participants completed a feasibility questionnaire.

Results Participants reported sitting 83% of their working days. Participants used the pedal machines an average of 12.2+6.6 out of a possible 20 working days and pedalled an average of 23.4+20.4 min each day used. Feasibility data indicate that participants found the machines feasible for use at work. Participants also reported sedentary time at work decreased due to the machine.

Discussion Findings from this study suggest that this pedal machine may be a feasible tool for reducing sedentary time while at work. These findings hold public health significance due to the growing number of sedentary jobs in the USA and the potential of the device for use in large-scale worksite health programmes.

The health-related benefits of regular moderate and vigorous intensity physical activity have been well established.[1–3] Conversely, physical inactivity is a leading preventable cause of death and all-cause mortality,[4] and has been referred to as one of the most important public health problems of the 21st century.[5] Within the realm of physical inactivity, researchers of the past decade have explored more specifically the health implications and associated health mechanisms of 'sedentary behaviour'.[6] Recent reviews have defined sedentary behaviour as 'activities that do not increase energy expenditure substantially above resting levels' and include activities such as lying down, sitting and using screen-based technologies such as televisions and computers.[7 8] Interestingly, even short bouts of reduced energy expenditure have been associated with substantial detriments to metabolic health in animals models.[9–12] Emerging studies with humans seem to corroborate such findings, as time spent being sedentary has been demonstrated to be independently associated with an increased risk of metabolic diseases.[13] Furthermore, sedentary time in the form of sitting has been associated with an increased likelihood of being overweight/obese.[14] Conversely, evidence supports breaking up prolonged bouts of sedentary time as a means of improving metabolic risk factors such as body mass index (BMI), waist circumference, fasting glucose levels and triglyceride levels.[15]

The workplace has been identified as an ideal setting for reducing sedentary time as full-time employees working a 40 h work week spend over a third of their weekly wakeful hours at work. In addition, working days are associated with less standing time and more time sitting time compared with non-work days,[16] and evidence suggests occupational activity as a whole is on the decline with high physical activity occupations decreasing while low activity occupations have risen steadily over the past half century.[17 18]

Previous worksite programmes aimed at increasing employees' physical activity have demonstrated efficacy for increasing physical activity, with some demonstrating improvements in worksite-specific outcomes such as attendance and job stress.[19 20] Past worksite physical activity interventions have taken many approaches for promoting physical activity, including promoting stair use through point of decision prompts, promoting active transport and providing access to worksite fitness facilities.[21 22] It could be argued, however, that many of these approaches are somewhat limited with regard to their reach and impact in that they do not target the large portion of time in which the typical desk/computer-dependent employee is working and therefore sedentary. With the rise in screen-based technologies in the worksite, computer use, an identified barrier to physical activity,[23] has become a staple of the typical work day. Still, few worksite intervention approaches have focused specifically on reducing the sitting time of sedentary employees for improving health.[24] Furthermore, no worksite interventions to date have attempted to reduce sedentary time while adapting to the typical computer work environment in which sitting is necessary.

Thompson *et al*[25] recently tested the feasibility of a walking workstation designed to allow employees to continue their work while being active. Hospital employees in four different occupations were recruited for participation. While using the walking workstations, participants increased daily walking by an average of 2000 steps or an equivalent of 100 kcal/day.[26] Participants also reported that they could perform normal work tasks (ie, computer work, professional phone calls) while using the device and declines in productivity were not reported to be an issue. However, such devices do have limitations that might prohibit widespread use such as high cost, size requirements that may not be met in small offices, lack of portability and lack of use for special needs populations such as those with orthopaedic limitations or joint pain.

McAlpine *et al*[27] conducted a study testing the energy expenditure of an office stepping device that seemingly addressed several of the feasibility limitations of the walking workstation. The device used in their study was portable, cost feasible, nearly silent and when attached to a personal computer (PC) connected accelerometer allowed for self-monitoring. While the stepping device did result in significant increases in energy expenditure above sitting in a controlled laboratory setting, the study did not explore the feasibility of the device in a real-life setting.

Several portable pedal exercise machines that also address many of the limitations of the walking workstation have recently become commercially available. One machine in particular, the MagneTrainer mini exercise bike (3D Innovations, LLC, Greeley, CO) is a cost feasible, stable yet portable device that can be set up in front of most standard office chairs for use while sitting and also allows for objective self-monitoring (eg, time used, distance pedalled, average speed, caloric expenditure) through a PC connection. To our knowledge, no studies have explored the feasibility or use of a portable pedal machine for reducing time spent sedentary in an occupational setting. Therefore, the primary aims of this study are to test the feasibility, acceptability and use of a portable, pedal exercise machine for reducing sedentary time in a free-living, occupationally sedentary adult population. We hypothesise that participants will find the machines feasible and acceptable for use in the sedentary work environment, and that participants will decrease their sedentary time at work as a result of using the pedal machine.

METHODS

Subjects

A total of 18 healthy, adult, (age 40.2+10.7 years; BMI 26.7+ 5.0 kg/m^2; 88% female) full-time employees (self-report working a minimum of 35 h/week) working in sedentary (minimum of 75% of working day spent sitting), desk/computer-dependent occupations was recruited from the greater Providence, Rhode Island, region for participation by local internet advertisements. Assessments occurred between October 2009 and March 2010. Participants were devoid of ambulatory/exercise limitations, and free from overt cardiovascular, metabolic, respiratory or neurological diseases as assessed by medical history screening. Participants were compensated US$15 each time they attended two separate assessment sessions (total of US$30 possible). Experimental protocols were approved by the Lifespan Office of Research Administration in Providence, Rhode Island, and voluntary informed consent was obtained from each participant.

Experimental design

All testing assessments were conducted at a research laboratory located at the Miriam Hospital in Providence, Rhode Island, USA. Participants were asked to attend two testing sessions, one at baseline and a follow-up assessment 4 weeks later. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a calibrated medical balance beam scale (Detecto, Webb City, Missouri, USA). BMI (kg/m^2) was calculated as weight (kg) divided by height (m) squared. Participants completed a modified version of the 7-day physical activity recall questionnaire,[28] which included supplementary questions targeting the total number of hours and minutes spent 'sitting', 'standing but not walking' and 'walking' while at work over the previous 4 weeks. Participants then completed a 6-min pedal test following the Astrand-Rhyming protocol[29] to become familiarised with the pedal machine.

Participants were then provided access to a MagneTrainer pedal exercise machine (3D Innovations) for use while at work for four continuous weeks (figure 1). The MagneTrainer pedal exercise machine was chosen due to its relatively low cost (US$150 for pedal machine and software), portability and compact size (18 in height, 20 in length) and its ability to monitor and record participant's daily and accumulated pedalling activity objectively through a PC connection (FitXF Exercise Tracking Software; 3D Innovations). The FitXF software also provides users with real-time feedback on pedal speed, time used, distance and calories, which is displayed on their computer monitor. The FitXF software also begins recording pedal activity the moment the user begins pedalling and stores daily and accumulated summary data for total time spent pedalling

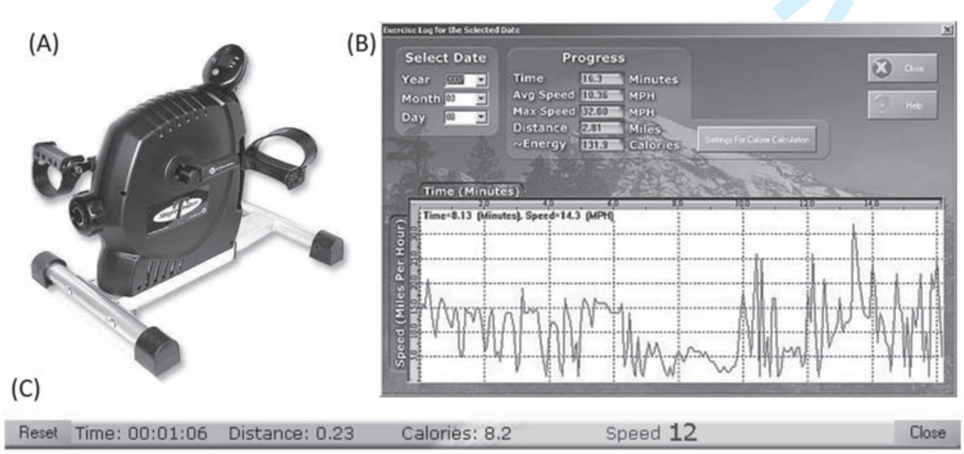

Figure 1 (A) The portable pedal exercise machine. (B) A screenshot of the exercise log, which provides feedback on pedal use activity per day. (C) A screenshot of the real-time monitor, which provides real-time feedback to the user.

Carr LJ, Walaska KA, Marcus BH. *Br J Sports Med* (2011). doi:10.1136/bjsm.2010.079574

(min/day), average speed (mph/day), distance pedalled (miles/day) and estimated caloric expenditure (kcal/day). A member of the research team delivered the pedal machine to the participant's worksite, downloaded the FitXF software to the participant's work computer and worked with the participant to identify the most feasible physical set up for using the machine (eg, under the desk, next to the desk). All participants were required to gain clearance from their immediate supervisor before enrolling in the study.

Following 4 weeks, pedalling activity data were downloaded from each participant's personal work computer with the authorisation of the participant's supervisor. Participants then returned to the testing facility to repeat all baseline tests and to complete a 23-item, five-point Likert scale (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) feasibility/acceptability questionnaire designed to enquire about the user's opinions and experiences with the machine (see appendix 1) as well as the intensity at which they typically pedalled using the Borg 0–10 rating of perceived exertion (RPE) scale.[30] Participants were also asked to report any barriers to using the machine and/or suggested improvements for the machine while at work. Consistent with the purpose of testing the feasibility and acceptability of the pedal machine, participants were only provided access to the machine and were not provided any behavioural intervention materials for the purpose of reducing sedentary time (eg, goals, motivational resources, self-monitoring prompts) during the course of the study.

Statistical analyses

Minutes of pedallling activity and days of pedalling activity were recorded and downloaded from the pedal machine through the FitXF exercise tracking software. Means and SD of pedal use activity were calculated and are presented in table 1. Medians and quartiles of the feasibility/acceptability data were calculated and are presented in table 2. Means and SD of average pedal time per day used for each participant were calculated and are presented in figure 2. Average pedal time among all users on days 1–20 and compliance using the pedal machine (percentage participants that pedalled each day during days 1–20) was summarised and is presented in figure 3 Paired t tests were conducted to test whether participants' time spent sitting, standing and/or walking changed over time from the baseline to the 4-week assessment. Statistical significance was set a priori at $p<0.05$.

RESULTS

On average, participants were middle aged (mean 40.2±10.7 years), overweight (mean BMI 26.8±5.0 kg/m^2) and primarily female (88%). Participants self-reported working an average of 40.9±4.7 h/week. Participants reported sitting an average of 6.80±1.5 h (83%) of their total working day. Participants pedalled an average of 12.2±6.6 (range 2–20 days) out of a possible 20 working days in which they had access to the pedal machine (61% compliance) and pedalled an average of 23.4+20.4 min on days they used the machine (see table 1 and figure 2). The estimated averages provided by the FitXF software for distance pedalled per day and caloric expenditure per day per participant equalled 4.8±3.6 miles/day and 186.5±142.2 kcal/day, respectively. Participants self-reported pedalling at an average intensity of 4.4±1.6 or 'somewhat hard' on the Borg 0–10 RPE scale. Average pedal time was maintained over the duration of the study, whereas the number of participants who used the machines each day (compliance) declined progressively over the course of 4 weeks (figure 3). As presented in table 2, when asked to respond to several statements pertaining to their experience with the pedal machine using a 1–5 Likert scale (1, strongly disagree; 5, strongly agree), participants reported the pedal machine to be 'easy to use', and 'as an alternative activity during bad weather'. Participants overwhelmingly reported they would 'use the pedal machine regularly at work if offered one by their employer' and reported neither their 'work productivity' nor their 'quality of work' declined as a result of using the machine at work. Participants reported 'their sedentary time at work decreased as a result of using the machine'. However, no significant differences in self-reported time spent sitting (p=0.11), standing (p=0.65) and/or walking (p=0.77) were observed from baseline to 4 weeks.

DISCUSSION

Findings from this study suggest this portable pedal exercise machine is a feasible tool for reducing time spent sedentary while at work. Overall, participants reported positive experiences with the pedal machine and reported that they would use the machine at work if offered one by their employer. When provided access to the device, on average participants used the machines more than half of all working days although compliance did decrease over the course of the 4 weeks (see figure 3). This is not a surprising finding given the lack of any behavioural intervention provided to these previously sedentary participants during the course of the study. However, the average minutes pedalled per day was maintained throughout the 4 weeks and participants pedalled for an amount of time (23 min per day used) that could result in health benefits if performed on a regular basis and at an average intensity reported by participants (eg, 'somewhat hard' on the Borg 0–10 scale).[3] A logical next step would be to test the efficacy of combining the pedal machine with a behavioural intervention for reduc-

Table 1 Accumulated and daily means±SD and ranges of pedal time, pedal speed, distance pedalled and caloric expenditure

	Mean+SD	Range
Average total pedal time (min)	358.0±401.7	4.0–1489.0
Average number days pedalled	12.2±6.6	2.0–20.0
Average pedal time/day used (min)	23.4±20.4	1.2–73.1
Average pedal speed (mph)	12.5±4.4	5.3–18.4
Average distance pedalled (miles)	69.0±62.6	0.5–214.0
Average distance pedalled/day used (miles)	4.8±3.6	0.3–13.4
Average total kcal expended (kcal)	2758.8±2699.7	18.0–8334.8
Average total kcal expended/day used (kcal)	186.5±142.2	9.0–501.9

Data were downloaded using the FitXF exercise tracking software.

Table 2 Quartile and median Likert scale responses (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) to feasibility/acceptability questions following 4 weeks of access to the pedal machine

Do you agree or disagree with the following statement?	Q1	Median	Q3
If offered to me by my employer, I would use the machine while at work	4.3	5.0	5.0
My physical activity increased while at work as a result of the machine	3.0	4.0	5.0
My physical activity increased outside of work as a result of the machine	2.3	3.0	4.0
The pedal machine is easy to use	4.0	4.0	5.0
I would use the machine as an alternative activity in bad weather	4.0	5.0	5.0
I am comfortable using the machine in the presence of others	3.0	4.0	5.0
The time I spent sedentary at work decreased as a result of the machine	3.0	4.0	4.0
I would use the machine while at home	4.0	5.0	5.0
The machine is too noisy	1.0	1.0	2.0
My work-related productivity decreased while using the machine	1.0	1.0	2.8
The quality of my work decreased while using the machine	1.0	1.0	2.0
The machine interfered with my daily work-related tasks	1.0	1.0	2.0
I was more tired on days I used the machine	1.0	2.0	2.0
I had more back pain on days I used the machine	1.0	1.5	2.0
I had more joint pain on days I used the machine	1.0	1.0	2.0
I had more muscle aches on days I used the machine	1.0	1.5	2.0
I could conduct a professional telephone call while using the machine	2.0	3.0	5.0
I could conduct normal computer tasks while using the machine	2.0	3.0	4.0
I could read comfortably while using the machine	4.0	4.0	5.0
The real-time monitor increased my use of the machine	3.3	4.0	5.0

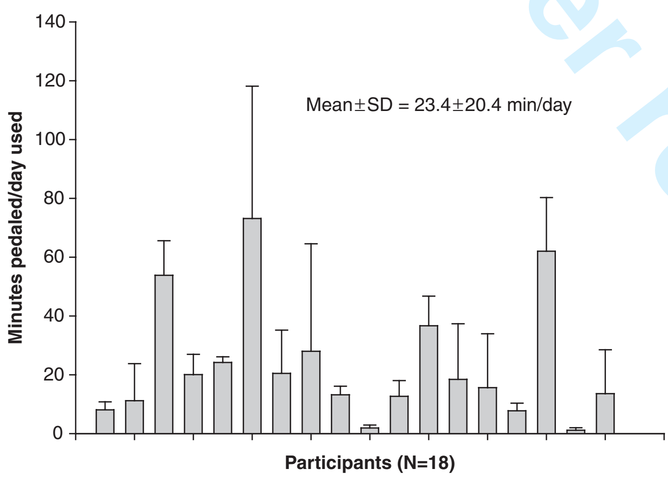

Figure 2 Average pedal time for days pedal machine was used per participant (N=18).

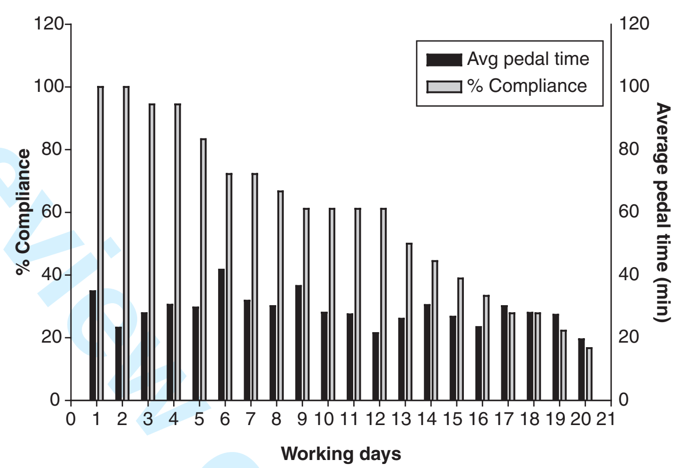

Figure 3 Average pedal time (minutes) and percentage of participants who pedaled each working day.

ing sedentary time at work and reducing the risk of chronic diseases.

When examining the pedal machine used from a human factors perspective, the MagneTrainer offers several features that make it a particularly attractive tool for future health promotion studies. Importantly, the device offers functions that are directly in line with three out of four features previously identified as necessary for technologies designed to promote physical activity and reduce sedentary time.[31] It is suggested that such technologies should: (1) give users proper credit for activities completed; (2) provide users personal awareness of his or her activity levels; (3) consider the practical constraints of users; and (4) support social influence.[31]

First, through the PC connection, the MagneTrainer pedal machine automatically and objectively monitors participants' pedalling activity (eg, credits user for activity completed). This function would be especially important from an assessment perspective in future research studies, and could potentially serve as a means to monitor employee participation in worksite wellness programmes that offer financial incentives for participation.

Second, the software enabled real-time feedback monitor and progress monitor, which summarises past activity by day and provides the user with a personal awareness of his or her current and past activity levels. The pedal machine provides users with real-time feedback of time spent pedalling (minutes), average speed (mph), maximum speed (mph), distance pedalled (miles) and estimated calories burned (kcal), which is displayed on a thin monitor that can be moved anywhere on the user's desktop. When asked to report how often they self-monitored their pedalling activity using the real-time feedback monitor (eg, time, distance, calories, speed) using a 1–4 Likert scale (1, never; 2, rarely; 3, occasionally; 4, frequently), participants reported frequently using the monitor (3.7+0.9). In addition, participants agreed the monitor increased their use of the machine (4.0+0.9 on 5-point Likert scale) suggesting that the monitor is a motivational tool.

What is already known on this topic

Evidence of the negative impact prolonged sedentary time has on metabolic health is growing. Many new devices with the potential to reduce prolonged sedentary time have recently become available on the commercial market. However, few studies have tested the feasibility and use of such devices among free-living populations in the work environment.

What this study adds

This study demonstrates a portable pedal exercise machine (MagneTrainer) to be feasible for use in the sedentary work environment. This study also found participants used the machines regularly without being provided a behavioural intervention. This study supports future interventions that test the efficacy of combining such devices with evidence-based behavioural approaches to reduce sedentary time at work.

Third, the portability, stability and near silent operation of the pedal machine allows this machine to be used in most typical office settings without interfering with daily operations. Importantly, portable pedal machines may serve as a tool to reduce sedentary time in the work environment without necessarily influencing the sitting time necessary for performing computer-related tasks. Participants reported the machine to be quiet, easy to use and usable in a typical office. Participants also reported that the pedal machine did not interfere with their quality of work or work productivity and did not result in any added pain to their joints or back. Participants agreed that they could read while using the pedal machine but not all users agreed they could complete computer tasks. Such practical considerations are important to consider for future worksite programmes that use the pedal machine.

Finally, while the pedal machine does not necessarily support social influence, previous worksite physical activity promotion studies using pedometers have utilised a social support component with great success.[32] Therefore, it stands to reason that the pedal machine could stimulate social support in the same light. In addition, our staff received 166 emails from interested participants in less than 72 h following an advertisement posted on the Lifespan hospital intranet website. The overwhelming response to this study is indicative of sedentary employees' desire to become more active while at work.

The results of this study should be interpreted with caution as this study is limited by a sample of primarily educated, Caucasian (94%) women (89%). It is possible that the pedal machine may not be viewed as favourably by men, racial and ethnic minority populations and/or individuals working in non-desk-dependent occupations. For example, individuals working in jobs that do not require a specific office space would probably not benefit from this machine. In addition, simply providing access to devices like the pedal machine is not enough to stimulate long-term use. The novelty of this device appeared to wear off over time, and may benefit from a combination of evidence-based behavioural techniques such as regular email prompts for sustained use. Future interventions testing the efficacy of combining behavioural content with the pedal machine are warranted. Finally, the pedal machine used in this study has certain limitations that deserve mention. For instance, the accuracy of the caloric expenditure output has yet to be confirmed.

Collectively, these findings hold public health significance due to the growing number of sedentary jobs in the USA, our growing understanding of the costs sedentary behaviour has on our health, and the potential of portable pedal machines (eg, portable, low cost, objective monitoring) for use in large-scale worksite health programmes. Future physical activity promotion interventions utilising portable and practical devices such as the pedal machine are warranted.

Contributors The contributing authors have made substantial contributions to the conception, design, analysis and interpretation of data, drafting of the article and have all given final approval of the current version and agree to its submission.

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Appendix 1 Feasibility questionnaire

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. The pedal machine is easy to use					
2. The pedal machine could be used in the typical office-style work environment					
3. The pedal machine is too noisy					
4. I would use the pedal machine as an alternative to be active on days that the weather is bad					
5. I felt comfortable using the pedal machine in the presence of others at my work					
6. My work-related productivity decreased while using the pedal machine					
7. The quality of my work decreased while using the pedal machine					
8. The pedal machine interfered with my daily work-related tasks					
9. I could conduct a normal, professional telephone conversation while using the pedal machine					
10. I could conduct normal computer-related tasks while using the pedal machine					
11. I could read comfortably while using the pedal machine					
12. I was more tired on days I used the pedal machine					
13. I had more back pain on days I used the pedal machine					
14. I had more joint pain on days I used the pedal machine					
15. I had more muscle aches on days I used the pedal machine					
16. My physical activity increased while at work as a result of the pedal machine					
17. The time I spent being sedentary decreased while at work as a result of the pedal machine					
18. My physical activity increased outside of work as a result of the pedal machine					
19. If I were offered a pedal machine by my employer, I would use it while at work					
20. I would use the pedal machine while at home					
21. The real-time monitor increased my use of the pedal machine					

Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace

Lucas J Carr, Kristen A Walaska and Bess H Marcus

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Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

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Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

Corresponding Author:

Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu

Co-Authors:

Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay, Ontario, Canada

Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA

Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

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ABSTRACT

Objectives: To test the efficacy of a multicomponent technology intervention for reducing daily sedentary time and improving cardiometabolic disease risk amongst sedentary, overweight university employees.

Design: Blinded, randomized controlled trial

Setting: A large south eastern university in the U.S.

Participants: Forty-nine middle-aged, primarily female, sedentary and overweight adults working in sedentary jobs enrolled in the study. A total of 40 participants completed the study.

Interventions: Participants were randomized to either: 1) an intervention group (N=23; 47.6+9.9 yrs; 94.1% female; 33.2+4.5 kg/m2); 2) or wait list control group (N=17; 42.6+8.9 yrs; 86.9% female; 31.7+4.9 kg/m2). The intervention group received a theory-based, internet-delivered program, a portable pedal machine at work and a pedometer for 12 weeks. The wait-list control group maintained their behaviors for 12 weeks.

Outcome measures: Primary (sedentary and physical activity behavior measured objectively via StepWatch) and secondary (heart rate, blood pressure, height, weight, waist circumference, percent body fat, cardiorespiratory fitness, fasting lipids) outcomes were measured at baseline and post-intervention (12 weeks). Exploratory outcomes including intervention compliance and process evaluation measures were also assessed post-intervention.

Results: Compared to controls, the intervention group reduced daily sedentary time (mean change (95%CI): -58.7 min/day (-118.4, 0.99; p<0.01)) after adjusting for baseline values and monitor wear time. Intervention participants logged onto the website 71.3% of all intervention days, used the pedal machine 37.7% of all working intervention days, and pedaled an average of 31.1 minutes/day.

Conclusions: These findings suggest the intervention was engaging and resulted in reductions in daily sedentary time amongst full-time sedentary employees. These findings hold public health significance due to the growing number of sedentary jobs and the potential of these technologies in large-scale worksite programs.

Trial Registration: ClinicalTrials.gov #NCT01371084

Article focus

- The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control.
- We hypothesized that the intervention group would significantly reduce daily sedentary time compared to the wait-list control group after 12 weeks.
- As a secondary aim, we tested the effectiveness of this intervention for improving several cardiometabolic risk factors including adiposity, blood pressure, estimated aerobic fitness and blood lipids.
- As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

Key messages

- This multicomponent intervention resulted in significant reductions in time spent sedentary and waist circumference when comparing the intervention group to the wait list control group.
- The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group.
- The findings of this study are important given the paucity of research in this area and growing evidence demonstrating the importance of limiting daily sedentary time for reducing risk of chronic diseases.

Strengths

- Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3) conducted a 12 week trial which extends previous sedentary interventions that have typically been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process evaluation to identify features of the intervention that worked particularly well.

Limitations

- Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of middle-aged females working at a single institution which limits generalizability; and 2) differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

INTRODUCTION

Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day may be effective for improving various cardiometabolic disease risk factors .[7 8]The modern workplace has been identified as a setting in which individuals engage in prolonged bouts of sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional behaviorally focused worksite interventions have focused primarily on increasing physical activity and have resulted in modest effect sizes (Cohen's d = 0.21-0.22).[14 15] In a shift away from behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of modifying the work environment to reduce occupational sedentary time.

To date, only a handful of sedentary interventions have been conducted in the worksite. While many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies conducted in the worksite have been limited by the use of self-report measures of sedentary time and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and the possible desire/need of many employers and employees to remain seated while completing their work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a means for reducing sedentary time.

In a previous study testing the feasibility of modifying the work environment as a means of reducing occupational sedentary time through promoting active sitting, our team provided portable pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10]. Importantly, participants rated the pedal machines as feasible and acceptable for use while completing their work. Further, despite a lack of any accompanying behavioral intervention, participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per day. Although these results are promising, it is possible the addition of a motivational behavioral intervention could result in increased pedaling compliance and reduced sedentary time.

The primary aim of the present study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time amongst a sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We hypothesized that the intervention group would significantly reduce daily sedentary time compared to the wait-list control group after 12 weeks. As a secondary aim, we tested the effectiveness of intervention on cardiometabolic risk factors including measures of adiposity, blood pressure, estimated aerobic fitness and blood lipids. We hypothesized the intervention group would reduce their overall cardiometabolic disease risk compared to the wait-list control group. Finally, as an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

METHODS

Subjects and Design

Many sedentary interventions to date have been limited by short durations. Therefore, we conducted a 12 week randomized controlled trial design comparing a treatment group to a no treatment wait-list control group. We recruited apparently healthy but physically inactive (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass index (BMI) $\geq$ 25.0 kg/m^2) adults working in full-time (reporting minimum of 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting). Participants were required to gain permission from their supervisor prior to enrollment. Research staff members screened participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer. Participants were not compensated for participation in the study. Experimental protocols were approved by the University and Medical Center Institutional Review Board and voluntary written informed consent was obtained from each participant.

Participants of all races and ethnic backgrounds working at a large southern university were passively recruited through email advertisements placed on an electronic mailing list serve that served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were excluded from participation due to: not meeting eligibility criteria which primarily consisted of not meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using an online random sequence generator.[21] Participants were assigned to one of two groups by a research staff member not involved in data collection based on the order in which they enrolled into the study. A total of 49 participants deemed interested and eligible for participation were randomized to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40 participants completed all baseline and post-intervention assessments. Nine participants were lost to follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention participants and 17 control participants (see Table 1). More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

[Figure 1 here]

Group Descriptions

Wait List Control Group

Participants randomized to the wait-list control group were asked to maintain their current behaviors for 12 weeks at which time they were given the option to receive the intervention treatment materials.

Intervention Group

The primary intent of the intervention was to encourage participants to reduce their time spent sedentary. The name used to promote the study on advertisements and study materials was "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height, 20" length) device that has been demonstrated as acceptable for use during sedentary office work [10]. Because participants were sedentary employees working in professional environments, the rationale for providing them pedal machines at work was to allow them to engage in light intensity activity (i.e. active sitting) that they could perform for long periods throughout the day without causing them to perspire. The pedal machine is accompanied by a PC interface and software package that allows for objective monitoring of individual pedal activity. This software also provides the user with real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the pedal machine to each participant's worksite, downloaded the pedal tracking software to the participant's work computer, and worked with the participant to identify the most feasible set up. Intervention participants were asked to keep the pedal machine connected to their PC during all working hours. Intervention participants were required to gain clearance to use the pedal machines and software at their work prior to participation. No additional interaction between the research staff and participant's supervisors occurred during the course of the study. Participants were located in 18 different buildings across campus. No participants worked within visible proximity of each other.

Intervention participants were also provided access to a motivational website that was individually customized to the local culture of the worksite of which participants were recruited (Figure 2). Examples of customization included posting local images and messages specific to the local institution. The content of the intervention focused primarily on reducing time spent sedentary (both increasing active sitting via pedaling and taking breaks from sitting). Example messages included "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at work although some messages broadly targeted sedentary time in general and could have impacted sedentary time outside of work. Messages were theory based targeting constructs of the Social Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived environment. For example, participants were prompted via daily email messages to self-monitor their daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on the website was used to fuel a virtual competition (aimed at building social support) in which small groups of intervention participants (4-5 per group) collectively traveled across America. Participants were also emailed three theory-based motivational messages each week targeting goal setting, self-efficacy, and perceived environment. Specific goals were not set for intervention participants, rather participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook, participants were able to post profile photos and status updates on a newsfeed and send messages to members of their small groups further fostering social support.

[Figure 2 here]

Measures

All measures were collected at baseline and post-intervention (12 weeks) in a controlled laboratory setting by two staff members blinded to participant's group assignment. The two staff members were provided specific measurement duties to ensure each measure was collected by the same staff member at both baseline and post-intervention. The primary outcome was daily sedentary time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations, Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the monitor during all wakeful hours for seven consecutive days and keep track of wear time using an activity log. Days in which participants wore the monitors for less than 10 hours were excluded from final analysis.. The threshold for sedentary (0 steps/min) was based on the recommendation provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute depending on height and stride length[26].

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively), HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65% respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill walking test which had been previously demonstrated as a valid estimate of total aerobic fitness amongst middle-aged adults.[29]

Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was assessed objectively via the activity tracking software. Pedal compliance data was downloaded directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g., number of website logins, number of steps logged on the website) was assessed objectively at the end of 12 weeks via a backend tracking database made available by the website administrators. In order to assess which components of the intervention participants 'perceived' as helpful for reducing their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention completers. Participants rated each intervention component using a five point Likert scale.

Design/Statistical Analysis

A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80% power, at α=0.05, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was identified as a reasonable estimate based on our previous study in which participants used the same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means (SD) were used to describe data where appropriate. This study was not powered to detect differences in the measured cardiometabolic risk factors. These measures were collected as secondary outcomes and to inform future trials.

The paired samples t-test was used to determine any within group differences at baseline and post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups at post-intervention. Baseline values of interest were included as covariates in the model for all continuous variables consistent with recommended statistical procedures [30]. The underlying assumption no between group differences at baseline was confirmed for all measures by one way ANOVA. Finally, the 95% confidence interval (CI) for the mean differences of all primary and secondary outcomes of interest is presented.

RESULTS

Baseline characteristics of both groups are presented in Table 1. Overall, participants were middle-aged and mostly classified as obese. More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Differential drop out was observed over the course of the study, although sensitivity analyses indicate no differences between those that dropped and those that completed the study for measures of age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

Table 1. Baseline characteristics by group Mean ± S.D. (N=40)

	Control Group N=17	Intervention Group N=23	All (N=40)
Age (years)	47.6(9.9)	42.6(8.9)	44.7(9.6)
Female %	94.1%	86.9%	90%
Height (in)	65.2(3.2)	65.4(3.4)	65.4(3.4)
Weight (lbs)	201.3(30.2)	194.1(34.9)	197.2(32.8)
Body Mass Index (BMI)	33.2(4.5)	31.7(4.9)	32.4(4.8)
Non-Hispanic White (%)	76.5%	63.6%	70.0%
College Graduate (%)	71.0%	86.0%	78.5%

Income >$40,000 (%)	62.5%	63.6%	63.0%
Job Category (%)			
Professional/Executive	35.0%	52.0%	45.0%
Administrative	65.0%	48.0%	55.0%

Table 2 illustrates monitor wear time for both group at each time point and changes in the primary outcomes of sedentary and physical activity behaviors for both groups. No between group differences or within group differences were observed for monitor wear time at either baseline or post-intervention. No differences were observed for any sedentary or physical activity measures at baseline. A significant intervention effect favoring the intervention group (95% CI, -0.99, 118.4 minutes/day) was observed for absolute number of daily sedentary minutes after adjusting for baseline sedentary time and monitor wear time. Intervention effects reached near significance for both percent daily time spent sedentary (95% CI, -6.8%, -0.6%) and percent time spent in moderate intensity physical activity (95% CI, 0.0, 2.6%) (see Table 2).

Table 2. Absolute and relative time spent in sedentary and physical activity behaviors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Monitor Wear Time (Min/day)					0.15
Control	829.6(93.5)	869.5(94.1)		0.10	
Intervention	867.1(142.8)	827.2(71.9)		0.42	
Minutes Sedentary (Min/day)					0.01**
Control	544.2(76.9)	599.7(106.6)	+55.5 (2.8, 108.1)	0.04*	
Intervention	584.9(136.1)	526.1(77.3)	-58.7 (-118.4, 0.99)	0.04*	
% Time Sedentary					0.06
Control	65.7(7.5)	67.5(8.0)	-1.8% (-2.7%, 6.3%)	0.41	
Intervention	67.6(7.2)	63.9(7.9)	-3.7% (-6.8%, -0.6%)	0.02*	
Minutes Light (Min/day)					0.64
Control	265.7(84.0)	262.2(70.8)	- 3.5 (-45.6, 38.6)	0.86	
Intervention	263.9(69.5)	270.3(69.5)	+6.4 (-18.7, 31.5)	0.6	

% Time Light					0.16
Control	31.9(8.1)	30.3(8.4)	-1.6% (-6.0%, 2.8%)	0.46	
Intervention	30.6(8.2)	32.7(7.6)	2.1% (-0.8%, 4.9%)	0.15	
Minutes Moderate (Min/day)					0.13
Control	18.6(25.2)	17.4(23.7)	-1.2 (-4.9, 2.4)	0.5	
Intervention	14.5(18.5)	23.3(28.0)	+8.8 (-1.6, 19.2)	0.09	
% Time Moderate					0.06
Control	2.3(3.2)	2.0(2.9)	-0.3% (-0.7%, 0.2%)	0.21	
Intervention	1.5(1.5)	2.8(3.4)	+1.3% (0.0%, 2.6%)	0.04*	
Minutes Vigorous (Min/day)					0.33
Control	1.2(2.6)	1.5(2.7)	+0.4 (-0.2, 0.9)	0.19	
Intervention	2.7(6.4)	4.9(10.9)	+2.2 (-2.7, 7.0)	0.37	
% Time Vigorous					0.25
Control	0.1(0.3)	0.2(0.3)	0.0% (0.0%, 0.1%)	0.32	
Intervention	0.3(0.6)	0.6(1.3)	+0.3% (-0.3, 0.9%)	0.26	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA)

[*] p < 0.05 for within group change from baseline (paired t-test)

** p<0.05 for between group differences at post-intervention (ANCOVA)

Table 3 illustrates changes in the secondary outcomes of cardiometabolic risk factors for both groups. A significant intervention effect was observed for waist circumference p=0.03 after adjusting for baseline values (Table 3). No significant intervention effects were observed for any other cardiometabolic risk factors.

Table 3. Cardiometabolic risk factors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Weight (lbs)					0.58
Control	201.4(30.2)	202.4(30.5)	+1.0 (-1.0, 3.0)	0.31	
Intervention	194.2(34.9)	194.4(34.5)	+0.2 (-2.3, 2.7)	0.86	
BMI (kg/m2)					0.76
Control	33.2(4.5)	33.4(4.6)	+0.2 (-0.1, 0.5)	0.21	
Intervention	31.8(5.0)	31.9(5.0)	-0.1 (-0.3, 0.5)	0.57	
Systolic BP (mmHg)					0.70
Control	117.1(13.0)	117.5(12.8)	-0.8 (-5.0, 3.6)	0.71	

Intervention	120.0(13.8)	115.7(10.8)	-4.3 (-8.0, -0.7)	0.02*	
Diastolic BP (mmHg)					0.51
Control	72.8(10.3)	73.2(10.6)	-0.1 (-5.0, 4.8)	0.96	
Intervention	78.2(10.3)	75.4(7.4)	-2.8 (-6.2, 0.7)	0.11	
Waist Circumference (cm)					0.03**
Control	92.9(11.1)	93.9(10.8)	+1.0 (-0.7, 2.7)	0.22	
Intervention	92.6(11.2)	91.6(11.3)	-1.0 (-2.1, 0.3)	0.06	
Estimated V02 (ml/kg/min)					0.10
Control	29.6(2.5)	30.0(2.6)	+0.3 (-0.1, 0.8)	0.14	
Intervention	30.8(5.1)	31.1(4.6)	+0.3 (-0.6, 1.1)	0.53	
Total Cholesterol (mg/dL)					0.83
Control	184.4(25.9)	185.0(18.9)	-0.8 (-15.1, 13.4)	0.91	
Intervention	191.4(26.3)	189.7(27.0)	+0.7 (-5.9, 7.2)	0.83	
HDL (mg/dL)					0.65
Control	47.6(18.4)	46.7(18.9)	-0.9 (-6.8, 5.1)	0.76	
Intervention	45.7(17.6)	43.7(16.4)	-2.1 (-8.1, 3.4)	0.46	
LDL (mg/dL)					0.96
Control	111.2(32.1)	120.2(25.3)	+5.4 (-11.3, 22.1)	0.50	
Intervention	119.4(23.2)	116.7(29.4)	-3.7 (-12.8, 5.4)	0.41	
Triglycerides					0.91
Control	130.6(65.4)	131.0(59.9)	+4.7 (-24.0, 33.3)	0.73	
Intervention	98.4(45.2)	118.4(57.3)	+18.3 (-0.1, 36.7)	0.05	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] $p < 0.05$ for within group change from baseline (paired t-test)

** $p<0.05$ for between group differences at post-intervention (ANCOVA)

A total of 23 participants completed the intervention and provided compliance data (see Table 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they had access to the website (including weekends) (Table 4). Intervention participants also logged an average of 7945 $\pm$ 4634 steps per day on the website over the 12 weeks. Participants pedaled an average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding weekends). Participants pedaled an average of 31.1$\pm$31.6 minutes per day on the days they used the pedal machines and for an average of 16.1$\pm$17.2 minutes per pedaling bout

Table 4. Intervention compliance measures amongst Intervention completers (N=23).

	Mean/%	S.D.
Web Compliance % (Days Logged in/Days with Access)	71.3	35.7
Average Steps Logged Per Day	7945	4634
Average Days Pedaled Over 12 Weeks	22.6	17.6
Pedal Compliance % (Days Pedaled/Days with Access)	37.7	29.3
Average Pedal Bouts/Day	1.9	0.9
Average Minutes Pedaled/Day Used	31.1	31.6
Average Minutes Pedaled/Pedal Bout	16.1	17.2

When asked to rate the helpfulness of each intervention feature for reducing their sedentary time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity on the website as "extremely helpful" (median Likert score = 5.0; Table 5). Participants rated the email reminders to log daily activity and access to the pedal machine as "quite helpful" (median Likert score = 4.0; Table 5).

Table 5: Quartile and median Likert scale responses (1=Not at all helpful; 2=A little helpful; 3=moderately helpful; 4=Quite helpful; 5=Extremely helpful) on helpfulness of individual intervention components for reducing sedentary time (N=23).

Please rate how helpful each of the following intervention components was in reducing your daily sedentary time.	Likert Scale		
	Q1	Median	Q3
Pedal machine biofeedback display (minutes pedaled, calories burned, etc.)	4.0	5.0	5.0
Wearing the pedometer	4.0	5.0	5.0
Self-monitoring daily steps and pedal time on the website	4.0	5.0	5.0
Email reminders to log physical activity on website	4.0	4.0	5.0

Access to pedal exercise machine at work	4.0	4.0	5.0
'Walk Across America' Group Challenge on website	3.0	3.0	5.0
Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8

DISCUSSION

The primary findings of this study suggest that this multicomponent intervention resulted in significant time spent sedentary in a small sample of inactive, overweight employees. The decreased sedentary time observed among the intervention group appears to be have been at least partially replaced by an increase in moderate intensity activity. Our findings are important as the present study was among the first worksite interventions to promote 'active sitting' as a means of reducing sedentary time. Further, the present study was conducted over a longer duration (12 weeks) compared to similar trials [19 31] which is necessary in order to determine whether the intervention instills habitual behavior change and/or whether such behavior change results in changes in cardiometabolic outcomes. While longer trials are necessary to confirm whether sedentary employees will adhere to such an intervention, process evaluation data suggests participants engaged with the intervention and maintained engagement through the 12 weeks. This study also utilized an objective measure of sedentary/physical activity behavior whereas many previous interventions have relied upon self-report measures of sedentary time[17]. The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group. This is important, as it has been suggested that decreasing sedentary time can result in improved health benefits independent of physical activity.[2 32-34]

Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention that included educational materials on sedentary health risks and tips to reduce sedentary time.[31]

353 However, this study did not include a control group. In a study that did include a control group, Evans et al. found no between group differences in objectively measured sitting time after five days of point-of-choice software reminders to stand up every 30 minutes while at work.[19]

We also observed a significant intervention effect for waist circumference. This finding is important as waist circumference has been shown to predict mortality amongst adults with coronary artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist circumference to be sensitive to change in the absence of changes in other measures of adiposity[36] as well as studies reporting interruptions from sedentary time to be associated with waist circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical activity program which demonstrated modest improvements in daily steps and waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk reduction.

Participant compliance to the website overall was high with participants logging into the website an average of 71% of all intervention days. This is important as past internet-delivered intervention studies have identified engagement to be a challenge [38 39] and a predictor of intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high website compliance in the present study may be due to the tailoring of the website to include locally relevant images and messages and/or the regular email messages.

Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day) was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These findings suggest the added motivational intervention, which included suggestions for setting goals and finding time to pedal each day, resulted in improved daily compliance that was sustained over a longer duration. Despite the logistical limitation of the portable pedal machine when paired with standard height desks (i.e., many participants reported their knees hit the underside of their desk while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize compliance with such portable pedal machines in future studies, it is recommended these devices be paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

Intervention participants reported features that provided feedback including the pedal machine tracking software, pedometers and self-monitoring daily activity on the website (which was immediately followed by a graph illustrating the individual's daily progress) as the most helpful features for reducing their daily sedentary time. This information is important and could be used to inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

The main limitation of the study was the limited generalizability due to a small sample size that comprised primarily of middle-aged females working at a single institution. We also experienced differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age, BMI, or daily sedentary time.

The present study is among the first interventions conducted within the worksite aimed specifically at reducing daily sedentary time to demonstrate between group differences in objectively measured sedentary time. Compliance with the motivational website was high while compliance with the pedal machine was moderate. These findings are promising considering the relatively low cost of the intervention which cost a total of $180 (pedal machine and software, pedometer, access to website) per participant. While an intervention effect was observed for waist circumference, no between group differences were observed for any other cardiometabolic risk factors. More sedentary focused interventions are needed to examine whether reducing sedentary time can be sustained long-term and whether long-term changes result in significant reductions in risk for chronic diseases.

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Contributorship Statement:

- Dr. Lucas Carr was responsible for the design of the study and led the manuscript preparation.
- Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript preparation.
- Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for leading the intervention which included duties of interacting with participants on a daily basis.
- Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation and were responsible for collecting data at the baseline and post-intervention time points.

Data Sharing

- No additional data available.

Figure Legend

Figure 1. Sequence of events and recruitment/enrollment schematic. Study was coordinated at East Carolina University, Greenville, NC, from June 2011-June 2012.

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.

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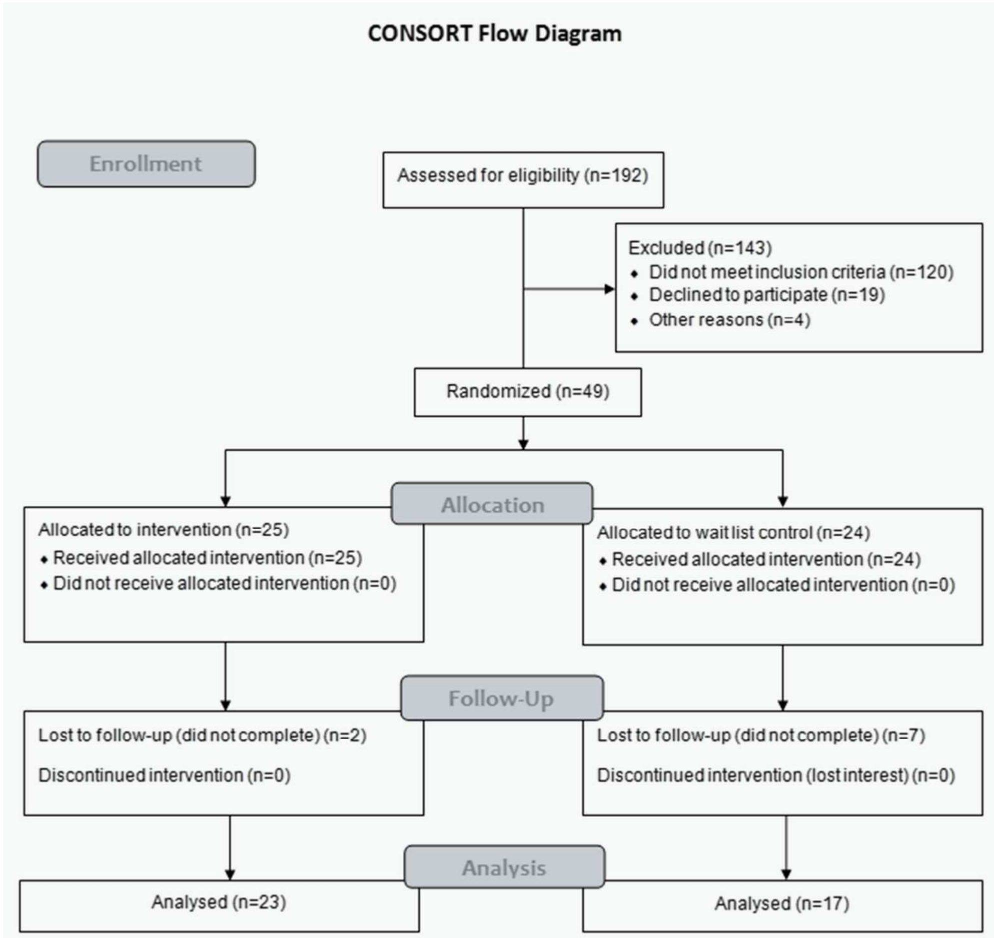

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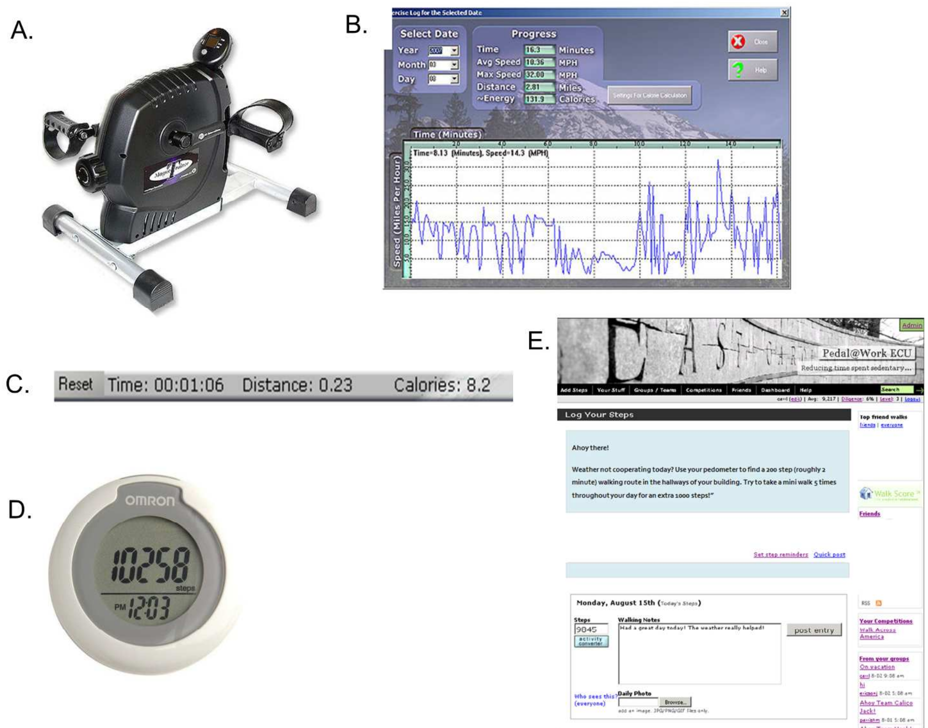

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.
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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3-4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	NA
Participants	4a	Eligibility criteria for participants	4-5
	4b	Settings and locations where the data were collected	7
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	7
	6b	Any changes to trial outcomes after the trial commenced, with reasons	NA
Sample size	7a	How sample size was determined	8
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	5
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	5
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	5
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5

Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	5&7
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	NA
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	5
	13b	For each group, losses and exclusions after randomisation, together with reasons	5
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	5
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1 (p.9)
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	5
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	8-13
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	8-13
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	15
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	15
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	13-16
Other information			
Registration	23	Registration number and name of trial registry	ClinicalTrials.gov (NCT01371084)
Protocol	24	Where the full trial protocol can be accessed, if available	Oak Ridge Associated Universities

Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	Grant (#212112)

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial

Corresponding Author:

Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu

Co-Authors:

Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay, Ontario, Canada

Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA

Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA

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ABSTRACT

Objectives: To test the efficacy of a multicomponent technology intervention for reducing daily sedentary time and improving cardiometabolic disease risk amongst sedentary, overweight university employees.

Design: Blinded, randomized controlled trial

Setting: A large south eastern university in the U.S.

Participants: Forty-nine middle-aged, primarily female, sedentary and overweight adults working in sedentary jobs enrolled in the study. A total of 40 participants completed the study.

Interventions: Participants were randomized to either: 1) an intervention group (N=23; 47.6+9.9 yrs; 94.1% female; 33.2+4.5 kg/m2); 2) or wait list control group (N=17; 42.6+8.9 yrs; 86.9% female; 31.7+4.9 kg/m2). The intervention group received a theory-based, internet-delivered program, a portable pedal machine at work and a pedometer for 12 weeks. The wait-list control group maintained their behaviors for 12 weeks.

Outcome measures: Primary (sedentary and physical activity behavior measured objectively via StepWatch) and secondary (heart rate, blood pressure, height, weight, waist circumference, percent body fat, cardiorespiratory fitness, fasting lipids) outcomes were measured at baseline and post-intervention (12 weeks). Exploratory outcomes including intervention compliance and process evaluation measures were also assessed post-intervention.

Results: Compared to controls, the intervention group reduced daily sedentary time (mean change (95%CI): -58.7 min/day (-118.4, 0.99; $p<0.01$)) after adjusting for baseline values and monitor wear time. Intervention participants logged onto the website 71.3% of all intervention days, used the pedal machine 37.7% of all working intervention days, and pedaled an average of 31.1 minutes/day.

Conclusions: These findings suggest the intervention was engaging and resulted in reductions in daily sedentary time amongst full-time sedentary employees. These findings hold public health significance due to the growing number of sedentary jobs and the potential of these technologies in large-scale worksite programs.

Trial Registration: ClinicalTrials.gov #NCT01371084

Article focus

- The primary aim of this study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time ~~and improving cardiometabolic risk factors~~ amongst a sample of sedentary, overweight, full-time working adults compared to a waitlist control.
- We hypothesized that the intervention group would significantly reduce daily sedentary time ~~and select cardiometabolic disease risk factors~~ compared to the wait-list control group after 12 weeks.
- As a secondary aim, we tested the effectiveness of this intervention for improving several cardiometabolic risk factors including adiposity, blood pressure, estimated aerobic fitness and blood lipids.
- As an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

Key messages

- This multicomponent intervention resulted in significant reductions in time spent sedentary and waist circumference when comparing the intervention group to the wait list control group.
- The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group.
- The findings of this study are important given the paucity of research in this area and growing evidence demonstrating the importance of limiting daily sedentary time for reducing risk of chronic diseases.

Strengths

- Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3) conducted a 12 week trial which extends previous sedentary interventions that have typically been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process evaluation to identify features of the intervention that worked particularly well.

Limitations

- Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of middle-aged females working at a single institution which limits generalizability; and 2) differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

INTRODUCTION

Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day may be effective for improving various cardiometabolic disease risk factors .[7 8]The modern workplace has been identified as a setting in which individuals engage in prolonged bouts of sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional behaviorally focused worksite interventions have focused primarily on increasing physical activity and have resulted in modest effect sizes (Cohen's d = 0.21-0.22).[14 15] In a shift away from behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of modifying the work environment to reduce occupational sedentary time.

To date, only a handful of sedentary interventions have been conducted in the worksite. While many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies conducted in the worksite have been limited by the use of self-report measures of sedentary time and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and the possible desire/need of many employers and employees to remain seated while completing their work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a means for reducing sedentary time.

In a previous study testing the feasibility of modifying the work environment as a means of reducing occupational sedentary time through promoting active sitting, our team provided portable pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10]. Importantly, participants rated the pedal machines as feasible and acceptable for use while completing their work. Further, despite a lack of any accompanying behavioral intervention, participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per day. Although these results are promising, it is possible the addition of a motivational behavioral intervention could result in increased pedaling compliance and reduced sedentary time.

The primary aim of the present study was to test the effectiveness of a multicomponent intervention for reducing daily sedentary time ~~and improving cardiometabolic risk factors~~ amongst a sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We hypothesized that the intervention group would significantly reduce daily sedentary time ~~and select cardiometabolic disease risk factors~~ compared to the wait-list control group after 12 weeks. As a secondary aim, we tested the effectiveness of intervention on cardiometabolic risk factors including measures of adiposity, blood pressure, estimated aerobic fitness and blood lipids. We hypothesized the intervention group would reduce their overall cardiometabolic disease risk compared to the wait-list control group. Finally, as an exploratory aim, we conducted a process evaluation to explore intervention compliance and identify helpful components of the intervention.

METHODS

Subjects and Design

Many sedentary interventions to date have been limited by short durations. Therefore, we conducted a 12 week randomized controlled trial design comparing a treatment group to a no treatment wait-list control group. We recruited apparently healthy but physically inactive ~~sedentary~~ (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass index (BMI) $\geq$ 25.0 kg/m^2) adults working in full-time (reporting minimum of 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting). Participants were required to gain permission from their supervisor prior to enrollment. Research staff members screened participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer. Participants were not compensated for participation in the study. Experimental protocols were approved by the University and Medical Center Institutional Review Board and voluntary written informed consent was obtained from each participant.

Participants of all races and ethnic backgrounds working at a large southern university were passively recruited through email advertisements placed on an electronic mailing list serve that served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were excluded from participation due to: not meeting eligibility criteria which primarily consisted of not meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using an online random sequence generator.[21] Participants were assigned to one of two groups by a research staff member not involved in data collection based on the order in which they enrolled into the study. A total of 49 participants deemed interested and eligible for participation were randomized to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40 participants completed all baseline and post-intervention assessments. Nine participants were lost to follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention participants and 17 control participants (see Table 1). More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

[Figure 1 here]

Group Descriptions

Wait List Control Group

Participants randomized to the wait-list control group were asked to maintain their current behaviors for 12 weeks at which time they were given the option to receive the intervention treatment materials.

Intervention Group

The primary intent of the intervention was to encourage participants to reduce their time spent sedentary. The name used to promote the study on advertisements and study materials was "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height, 20" length) device that has been demonstrated as acceptable for use during sedentary office work [10]. Because participants were sedentary employees working in professional environments, the rationale for providing them pedal machines at work was to allow them to engage in light intensity activity (i.e. active sitting) that they could perform for long periods throughout the day without causing them to perspire. The pedal machine is accompanied by a PC interface and software package that allows for objective monitoring of individual pedal activity. This software also provides the user with real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the pedal machine to each participant's worksite, downloaded the pedal tracking software to the participant's work computer, and worked with the participant to identify the most feasible set up. Intervention participants were asked to keep the pedal machine connected to their PC during all working hours. Intervention participants were required to gain clearance to use the pedal machines and software at their work prior to participation. No additional interaction between the research staff and participant's supervisors occurred during the course of the study. Participants were located in 18 different buildings across campus. No participants worked within visible proximity of each other.

Intervention participants were also provided access to a motivational website that was individually customized to the local culture of the worksite of which participants were recruited (Figure 2). Examples of customization included posting local images and messages specific to the local institution. The content of the intervention focused primarily on reducing time spent sedentary (both increasing active sitting via pedaling and taking breaks from sitting). Example messages included "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at work although some messages broadly targeted sedentary time in general and could have impacted sedentary time outside of work. Messages were theory based targeting constructs of the Social Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived environment. For example, participants were prompted via daily email messages to self-monitor their daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on the website was used to fuel a virtual competition (aimed at building social support) in which small groups of intervention participants (4-5 per group) collectively traveled across America. Participants were also emailed three theory-based motivational messages each week targeting goal setting, self-efficacy, and perceived environment. Specific goals were not set for intervention participants, rather participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook, participants were able to post profile photos and status updates on a newsfeed and send messages to members of their small groups further fostering social support.

[Figure 2 here]

Measures

All measures were collected at baseline and post-intervention (12 weeks) in a controlled laboratory setting by two staff members blinded to participant's group assignment. The two staff members were provided specific measurement duties to ensure each measure was collected by the same staff member at both baseline and post-intervention. The primary outcome was daily sedentary time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations, Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the monitor during all wakeful hours for seven consecutive days and keep track of wear time using an activity log. Days in which participants wore the monitors for less than 10 hours were excluded from final analysis.~~ Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%) days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for 13.8 hours/day~~. The threshold for sedentary (0 steps/min) was based on the recommendation provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute depending on height and stride length[26].

Blood pressure was measured with a stethoscope and sphygmomanometer using standard techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively), HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65% respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill walking test which had been previously demonstrated as a valid estimate of total aerobic fitness amongst middle-aged adults.[29]

Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was assessed objectively via the activity tracking software. Pedal compliance data was downloaded directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g., number of website logins, number of steps logged on the website) was assessed objectively at the end of 12 weeks via a backend tracking database made available by the website administrators. In order to assess which components of the intervention participants 'perceived' as helpful for reducing their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention completers. Participants rated each intervention component using a five point Likert scale.

Design/Statistical Analysis

A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80% power, at α=0.05, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was identified as a reasonable estimate based on our previous study in which participants used the same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means (SD) were used to describe data where appropriate. This study was not powered to detect differences in the measured cardiometabolic risk factors. These measures were collected as secondary outcomes and to inform future trials.

The paired samples t-test was used to determine any within group differences at baseline and post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups at post-intervention. Baseline values of interest were included as covariates in the model for all continuous variables consistent with recommended statistical procedures [30]. The underlying assumption no between group differences at baseline was confirmed for all measures by one way ANOVA. Finally, the 95% confidence interval (CI) for the mean differences of all primary and secondary outcomes of interest is presented.

RESULTS

Baseline characteristics of both groups are presented in Table 1. Overall, participants were middle-aged and mostly classified as obese. More than half of all participants were college educated, reported an annual income greater than $40,000 and reported being non-Hispanic/White. Differential drop out was observed over the course of the study, although sensitivity analyses indicate no differences between those that dropped and those that completed the study for measures of age (P=0.48), BMI (P=0.63), or daily sedentary time (P=0.32).

Table 1. Baseline characteristics by group Mean ± S.D. (N=40)

	Control Group N=17	Intervention Group N=23	All (N=40)
Age (years)	47.6(9.9)	42.6(8.9)	44.7(9.6)
Female %	94.1%	86.9%	90%
Height (in)	65.2(3.2)	65.4(3.4)	65.4(3.4)
Weight (lbs)	201.3(30.2)	194.1(34.9)	197.2(32.8)
Body Mass Index (BMI)	33.2(4.5)	31.7(4.9)	32.4(4.8)

Non-Hispanic White (%)	76.5%	63.6%	70.0%
College Graduate (%)	71.0%	86.0%	78.5%
Income >$40,000 (%)	62.5%	63.6%	63.0%
Job Category (%)			
Professional/Executive	35.0%	52.0%	45.0%
Administrative	65.0%	48.0%	55.0%

Table 2 illustrates monitor wear time for both group at each time point and changes in the primary outcomes of sedentary and physical activity behaviors for both groups. No between group differences or within group differences were observed for monitor wear time at either baseline or post-intervention. -No differences were observed for any sedentary or physical activity measures at baseline. A significant intervention effect favoring the intervention group (95% CI, -0.99, 118.4 minutes/day) was observed for absolute number of daily sedentary minutes after adjusting for baseline sedentary time and monitor wear time. Intervention effects reached near significance for both percent daily time spent sedentary (95% CI, -6.8%, -0.6%) and percent time spent in moderate intensity physical activity (95% CI, 0.0, 2.6%) (see Table 2).

Table 2. Absolute and relative time spent in sedentary and physical activity behaviors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Monitor Wear Time (Min/day)					0.15
Control	829.6(93.5)	869.5(94.1)		0.10	
Intervention	867.1(142.8)	827.2(71.9)		0.42	
Minutes Sedentary (Min/day)					<0.01**
Control	544.2(76.9)	599.7(106.6)	+55.5 (2.8, 108.1)	0.04*	
Intervention	584.9(136.1)	526.1(77.3)	-58.7 (-118.4, 0.99)	0.04*	
% Time Sedentary					0.06
Control	65.7(7.5)	67.5(8.0)	-1.8% (-2.7%, 6.3%)	0.41	
Intervention	67.6(7.2)	63.9(7.9)	-3.7% (-6.8%, -0.6%)	0.02*	

Minutes Light (Min/day)					0.64
Control	265.7(84.0)	262.2(70.8)	- 3.5 (-45.6, 38.6)	0.86	
Intervention	263.9(69.5)	270.3(69.5)	+6.4 (-18.7, 31.5)	0.6	
% Time Light					0.16
Control	31.9(8.1)	30.3(8.4)	-1.6% (-6.0%, 2.8%)	0.46	
Intervention	30.6(8.2)	32.7(7.6)	2.1% (-0.8%, 4.9%)	0.15	
Minutes Moderate (Min/day)					0.13
Control	18.6(25.2)	17.4(23.7)	-1.2 (-4.9, 2.4)	0.5	
Intervention	14.5(18.5)	23.3(28.0)	+8.8 (-1.6, 19.2)	0.09	
% Time Moderate					0.06
Control	2.3(3.2)	2.0(2.9)	-0.3% (-0.7%, 0.2%)	0.21	
Intervention	1.5(1.5)	2.8(3.4)	+1.3% (0.0%, 2.6%)	0.04*	
Minutes Vigorous (Min/day)					0.33
Control	1.2(2.6)	1.5(2.7)	+0.4 (-0.2, 0.9)	0.19	
Intervention	2.7(6.4)	4.9(10.9)	+2.2 (-2.7, 7.0)	0.37	
% Time Vigorous					0.25
Control	0.1(0.3)	0.2(0.3)	0.0% (0.0%, 0.1%)	0.32	
Intervention	0.3(0.6)	0.6(1.3)	+0.3% (-0.3, 0.9%)	0.26	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA)

[*] p < 0.05 for within group change from baseline (paired t-test)

** p<0.05 for between group differences at post-intervention (ANCOVA)

Table 3 illustrates changes in the secondary outcomes of cardiometabolic risk factors for both groups. A significant intervention effect was observed for waist circumference p=0.03 after adjusting for baseline values (Table 3). No significant intervention effects were observed for any other cardiometabolic risk factors.

Table 3. Cardiometabolic risk factors at baseline and post-intervention for Control (N=17) and Intervention (N=23) participants. Data presented as Mean(SD).

	Baseline	Post-Intervention	Mean Difference[a] (95% CI)	Within Group P value	Between Group P value (Post)
Weight (lbs)					0.58
Control	201.4(30.2)	202.4(30.5)	+1.0 (-1.0, 3.0)	0.31	
Intervention	194.2(34.9)	194.4(34.5)	+0.2 (-2.3, 2.7)	0.86	
BMI (kg/m2)					0.76
Control	33.2(4.5)	33.4(4.6)	+0.2 (-0.1, 0.5)	0.21	

Intervention	31.8(5.0)	31.9(5.0)	-0.1 (-0.3, 0.5)	0.57	
Systolic BP (mmHg)					0.70
Control	117.1(13.0)	117.5(12.8)	-0.8 (-5.0, 3.6)	0.71	
Intervention	120.0(13.8)	115.7(10.8)	-4.3 (-8.0, -0.7)	0.02*	
Diastolic BP (mmHg)					0.51
Control	72.8(10.3)	73.2(10.6)	-0.1 (-5.0, 4.8)	0.96	
Intervention	78.2(10.3)	75.4(7.4)	-2.8 (-6.2, 0.7)	0.11	
Waist Circumference (cm)					0.03**
Control	92.9(11.1)	93.9(10.8)	+1.0 (-0.7, 2.7)	0.22	
Intervention	92.6(11.2)	91.6(11.3)	-1.0 (-2.1, 0.3)	0.06	
Estimated V02 (ml/kg/min)					0.10
Control	29.6(2.5)	30.0(2.6)	+0.3 (-0.1, 0.8)	0.14	
Intervention	30.8(5.1)	31.1(4.6)	+0.3 (-0.6, 1.1)	0.53	
Total Cholesterol (mg/dL)					0.83
Control	184.4(25.9)	185.0(18.9)	-0.8 (-15.1, 13.4)	0.91	
Intervention	191.4(26.3)	189.7(27.0)	+0.7 (-5.9, 7.2)	0.83	
HDL (mg/dL)					0.65
Control	47.6(18.4)	46.7(18.9)	-0.9 (-6.8, 5.1)	0.76	
Intervention	45.7(17.6)	43.7(16.4)	-2.1 (-8.1, 3.4)	0.46	
LDL (mg/dL)					0.96
Control	111.2(32.1)	120.2(25.3)	+5.4 (-11.3, 22.1)	0.50	
Intervention	119.4(23.2)	116.7(29.4)	-3.7 (-12.8, 5.4)	0.41	
Triglycerides					0.91
Control	130.6(65.4)	131.0(59.9)	+4.7 (-24.0, 33.3)	0.73	
Intervention	98.4(45.2)	118.4(57.3)	+18.3 (-0.1, 36.7)	0.05	

[a] Mean change from baseline (95% confidence interval), adjusted for baseline value (ANCOVA

[*] p < 0.05 for within group change from baseline (paired t-test)

** p<0.05 for between group differences at post-intervention (ANCOVA)

A total of 23 participants completed the intervention and provided compliance data (see Table 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they had access to the website (including weekends) (Table 4). Intervention participants also logged an average of 7945 $\pm$ 4634 steps per day on the website over the 12 weeks. Participants pedaled an average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding weekends). Participants pedaled an average of 31.1$\pm$31.6 minutes per day on the days they used the pedal machines and for an average of 16.1$\pm$17.2 minutes per pedaling bout

Table 4. Intervention compliance measures amongst Intervention completers (N=23).

	Mean/%	**S.D.**
Web Compliance % (Days Logged in/Days with Access)	71.3	35.7
Average Steps Logged Per Day	7945	4634
Average Days Pedaled Over 12 Weeks	22.6	17.6
Pedal Compliance % (Days Pedaled/Days with Access)	37.7	29.3
Average Pedal Bouts/Day	1.9	0.9
Average Minutes Pedaled/Day Used	31.1	31.6
Average Minutes Pedaled/Pedal Bout	16.1	17.2

When asked to rate the helpfulness of each intervention feature for reducing their sedentary time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity on the website as "extremely helpful" (median Likert score = 5.0; Table 5). Participants rated the email reminders to log daily activity and access to the pedal machine as "quite helpful" (median Likert score = 4.0; Table 5).

Table 5: Quartile and median Likert scale responses (1=Not at all helpful; 2=A little helpful; 3=moderately helpful; 4=Quite helpful; 5=Extremely helpful) on helpfulness of individual intervention components for reducing sedentary time (N=23).

Please rate how helpful each of the following intervention components was in reducing your daily sedentary time.	Likert Scale		
	Q1	Median	Q3
Pedal machine biofeedback display (minutes pedaled, calories burned, etc.)	4.0	5.0	5.0
Wearing the pedometer	4.0	5.0	5.0
Self-monitoring daily steps and pedal time on the website	4.0	5.0	5.0

Email reminders to log physical activity on website	4.0	4.0	5.0
Access to pedal exercise machine at work	4.0	4.0	5.0
'Walk Across America' Group Challenge on website	3.0	3.0	5.0
Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8

DISCUSSION

The primary findings of this study suggest that this multicomponent intervention resulted in significant time spent sedentary in a small sample of inactive, overweight employees. The decreased sedentary time observed among the intervention group appears to be have been at least partially replaced by an increase in moderate intensity activity. Our findings are important as the present study was among the first worksite interventions to promote ‘active sitting’ as a means of reducing sedentary time. Further, the present study was conducted over a longer duration (12 weeks) compared to similar trials [19 31] which is necessary in order to determine whether the intervention instills habitual behavior change and/or whether such behavior change results in changes in cardiometabolic outcomes. While longer trials are necessary to confirm whether sedentary employees will adhere to such an intervention, process evaluation data suggests participants engaged with the intervention and maintained engagement through the 12 weeks. This study also utilized an objective measure of sedentary/physical activity behavior whereas many previous interventions have relied upon self-report measures of sedentary time[17]. The present study builds upon past studies as our study was among the first to demonstrate significant reductions in objectively measured sedentary time when compared to a control group. This is important, as it has been suggested that decreasing sedentary time can result in improved health benefits independent of physical activity.[2 32-34]

Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention that included educational materials on sedentary health risks and tips to reduce sedentary time.[31] However, this study did not include a control group. In a study that did include a control group, Evans et al. found no between group differences in objectively measured sitting time after five days of point-of-choice software reminders to stand up every 30 minutes while at work.[19]

We also observed a significant intervention effect for waist circumference. This finding is important as waist circumference has been shown to predict mortality amongst adults with coronary artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist circumference to be sensitive to change in the absence of changes in other measures of adiposity[36] as well as studies reporting interruptions from sedentary time to be associated with waist circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical activity program which demonstrated modest improvements in daily steps and waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk reduction.

Participant compliance to the website overall was high with participants logging into the website an average of 71% of all intervention days. This is important as past internet-delivered intervention studies have identified engagement to be a challenge [38 39] and a predictor of intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high website compliance in the present study may be due to the tailoring of the website to include locally relevant images and messages and/or the regular email messages.

Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day) was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These findings suggest the added motivational intervention, which included suggestions for setting goals and finding time to pedal each day, resulted in improved daily compliance that was sustained over a longer duration. Despite the logistical limitation of the portable pedal machine when paired with standard height desks (i.e., many participants reported their knees hit the underside of their desk while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize compliance with such portable pedal machines in future studies, it is recommended these devices be paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

Intervention participants reported features that provided feedback including the pedal machine tracking software, pedometers and self-monitoring daily activity on the website (which was immediately followed by a graph illustrating the individual's daily progress) as the most helpful features for reducing their daily sedentary time. This information is important and could be used to inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

The main limitation of the study was the limited generalizability due to a small sample size that comprised primarily of middle-aged females working at a single institution. We also experienced differential drop out, although follow-up analyses indicate no differences between those that dropped and those that completed for age, BMI, or daily sedentary time.

The present study is among the first interventions conducted within the worksite aimed specifically at reducing daily sedentary time to demonstrate between group differences in objectively measured sedentary time. Compliance with the motivational website was high while compliance with the pedal machine was moderate. These findings are promising considering the relatively low cost of the intervention which cost a total of $180 (pedal machine and software, pedometer, access to website) per participant. While an intervention effect was observed for waist circumference, no between group differences were observed for any other cardiometabolic risk factors. More sedentary focused interventions are needed to examine whether reducing sedentary time can be sustained long-term and whether long-term changes result in significant reductions in risk for chronic diseases.

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Contributorship Statement:

- Dr. Lucas Carr was responsible for the design of the study and led the manuscript preparation.
- Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript preparation.
- Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for leading the intervention which included duties of interacting with participants on a daily basis.
- Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation and were responsible for collecting data at the baseline and post-intervention time points.

Data Sharing

- Extra data is available by emailing Dr. Lucas Carr at lucas-carr@uiowa.edu.

Figure Legend

Figure 1. Sequence of events and recruitment/enrollment schematic. Study was coordinated at East Carolina University, Greenville, NC, from June 2011-June 2012.

Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.

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