



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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2 1 **Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial**
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5
6 3 **Corresponding Author:**
7

8 4 Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House
9
10 5 E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu
11
12 6

13
14
15 7 **Co-Authors:**
16

17 8 Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay,
18
19 9 Ontario, Canada
20

21 10 Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA
22

23 11 Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
24

25 12 Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
26
27 13

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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/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. 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.

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2 55 • We hypothesized that the intervention group would significantly reduce daily sedentary time
3
4 56 and select cardiometabolic disease risk factors compared to the wait-list control group after 12
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6 57 weeks.
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8
9 58 • As an exploratory aim, we conducted a process evaluation to explore intervention compliance
10
11 59 and identify helpful components of the intervention.
12

13 60 **Key messages**

- 14
15 61 • This multicomponent intervention resulted in significant reductions in time spent sedentary
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17 62 and waist circumference when comparing the intervention group to the wait list control
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20 63 group.
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22 64 • The present study builds upon past studies as our study was among the first to demonstrate
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24 65 significant reductions in objectively measured sedentary time when compared to a control
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26 66 group.
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28
29 67 • The findings of this study are important given the paucity of research in this area and
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31 68 growing evidence demonstrating the importance of limiting daily sedentary time for
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33 69 reducing risk of chronic diseases.
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35 70 **Strengths**

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38 71 • Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a
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40 72 primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3)
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42 73 conducted a 12 week trial which extends previous sedentary interventions that have typically
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44 74 been of brief durations; 4) measured Cardiometabolic risk factors; and 5) conducted a process
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46 75 evaluation to identify features of the intervention that worked particularly well.
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48 76 **Limitations**

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51 77 • Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of
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53 78 middle-aged females working at a single institution which limits generalizability; and 2)
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55 79 differential drop out, although follow-up analyses indicate no differences between those that
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2 80 dropped and those that completed amongst the control group for age (P=0.40), BMI (P=0.52),
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4 81 or daily sedentary time (P=0.22).
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10 84 INTRODUCTION

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13 85 Prolonged sedentary behavior is an independent risk factor for multiple chronic health
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15 86 outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic
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17 87 syndrome[5] and obesity.[6] Conversely, evidence suggests breaking up prolonged periods of
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19 88 sedentary behavior may result in cardiometabolic health benefits, independent of more intense
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21 89 physical activity, including reductions in waist circumference,[7 8] body mass index (BMI), fasting
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23 90 glucose and triglyceride levels.[8] However, to date, few interventions have been conducted to
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25 91 reduce sedentary behaviors of adults.[9]
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28 92 Adults working in full-time sedentary jobs are at particular risk for being sedentary as they
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30 93 often spend more than 75% of work time sitting[10 11]. Currently, more than 27% of the U.S. labor
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32 94 force works in low-activity occupations.[12] The observed decline in occupational energy expenditure
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34 95 (~100 kcals/day) over the past 50 years has been identified as a key contributor to the observed
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36 96 increase in mean body mass amongst U.S. adults over the same time period.[13] Traditional
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38 97 behaviorally focused worksite interventions have focused primarily on increasing physical activity and
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40 98 have resulted in modest effect sizes (Cohen's $d = 0.21-0.22$).[14 15] In a shift away from behaviorally
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42 99 focused approaches, studies grounded in social ecological theory[16] have begun testing the effect of
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44 100 modifying the work environment to reduce occupational sedentary time. However, to date, only a
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46 101 handful of worksite interventions have been conducted to reduce sedentary time, most of which have
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48 102 not demonstrated effectiveness.[17] Of the sedentary worksite interventions that have been
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50 103 conducted, most have been limited by self-report methods of sedentary time[17] and/or short
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52 104 intervention durations[18 19]. Overall, there is a need for interventions aimed specifically at reducing
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54 105 sedentary time amongst adults. The worksite is an ideal setting for delivering such interventions.
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2 106 In a study testing the feasibility of modifying the work environment as a means of reducing
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4 107 occupational sedentary time, our team provided portable pedal machines (MagneTrainer, 3D
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6 108 Innovations) to 18 sedentary desk workers for four weeks [10]. Participants rated the pedal machines
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8 109 as feasible for use while completing their work. Further, despite a lack of any accompanying
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10 110 behavioral intervention, participants used the pedal machines on 61% of all work days for an average
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12 111 of 23.4 minutes per day. Although these results are promising, it is possible the addition of a
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14 112 motivational behavioral intervention could result in increased pedaling compliance and reduced
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16 113 sedentary time.
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19 114 The primary aim of this study was to test the effectiveness of a multicomponent intervention
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21 115 for reducing daily sedentary time and improving cardiometabolic risk factors amongst a sample of
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23 116 sedentary, overweight, full-time working adults compared to a waitlist control. We hypothesized that
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25 117 the intervention group would significantly reduce daily sedentary time and select cardiometabolic
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27 118 disease risk factors compared to the wait-list control group after 12 weeks. As an exploratory aim, we
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29 119 conducted a process evaluation to explore intervention compliance and identify helpful components
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31 120 of the intervention.
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36 122 **METHODS**

37 123 **Subjects and Design**

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41 125 We utilized a 12 week randomized controlled trial design comparing a treatment group to a no
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43 126 treatment waitlist control group. We recruited apparently healthy but sedentary (self-reporting less
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45 127 than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass
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47 128 index (BMI) ≥ 25.0 kg/m²) adults working in full-time (minimum of 35.0+ hours/week) sedentary/desk-
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49 129 dependent occupations (reporting minimum of 75% of working time spent sitting). Participants of all
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51 130 races and ethnic backgrounds working at a large southern university were passively recruited through
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53 131 email advertisements placed on an electronic mailing list serve. Research staff members screened
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55 132 participants for eligibility by telephone. Exclusionary criteria included: 1) limitations with or
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2 133 contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive impairment, psychosis,
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4 134 or other diagnosed psychological illness (with the exception of depression and anxiety); 4) currently
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6 135 using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart failure or cancer.
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9 136 Participants were not compensated for participation in the study. Experimental protocols were
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11 137 approved by the University and Medical Center Institutional Review Board and voluntary informed
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13 138 consent was obtained from each participant.

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15 139 A total of 192 people responded to our advertisements of which 143 were excluded from
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17 140 participation due to: not meeting eligibility criteria (N=120); declined to participate (N=19); or other
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19 141 reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using
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21 142 the an online random sequence generator.[20] Participants were assigned to one of two groups by a
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23 143 research staff member not involved in data collection based on the order in which they enrolled into
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26 144 the study. A total of 49 participants deemed interested and eligible for participation were randomized
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28 145 to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40
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30 146 participants completed all baseline and post-intervention assessments. Nine participants were lost to
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32 147 follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention
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34 148 participants and 17 control participants (see Table 1). More than half of all participants were college
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36 149 educated, reported an annual income greater than \$40,000 and reported being non-Hispanic/White.
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39 150 Participants were enrolled and completed all testing sessions between June 2011 and June 2012.
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43 152 [Figure 1 here]
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49 155 **Group Descriptions**

50 156 51 52 157 *Wait List Control Group* 53 54 55 56 57 58 59 60

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2 158 Participants randomized to the wait list control group were asked to maintain their current
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4 159 behaviors for 12 weeks at which time they were given the option to receive the intervention treatment
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6 160 materials.
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11 162 *Intervention Group*

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13 163 The intervention comprised of three primary components: 1) access to a portable pedal
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15 164 machine (MagneTrainer, 3D Innovations, Greeley, CO) at their worksite (Figure 2); 2) access to an
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17 165 internet-delivered motivational intervention (Walker Tracker, Portland, OR); and 3) a pedometer
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19 166 (Omron HJ-150). The pedal machine is a portable (18" height, 20" length) device that has been
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21 167 demonstrated as acceptable for use during sedentary office work [10] (Figure 2). The pedal machine
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23
24 168 is accompanied by a PC interface and software package that allows for objective monitoring of
25
26 169 individual pedal activity. This software also provides the user with real-time feedback via a display
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28 170 monitor on pedal time, distance, speed and caloric expenditure. The research team delivered the
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30 171 pedal machine to each participant's worksite, downloaded the pedal tracking software to the
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32 172 participant's work computer, and worked with the participant to identify the most feasible set up.
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34
35 173 Intervention participants were asked to keep the pedal machine connected to their PC during all
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37 174 working hours.

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39 175 Intervention participants were also provided access to a motivational website that was
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41 176 individually customized to the local culture of the worksite of which participants were recruited (Figure
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43 177 4). Examples of customization included posting local images and messages specific to the local
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45 178 institution. The content of the intervention targeted constructs of the Social Cognitive Theory[21]
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47 179 including self-monitoring, social support, self-efficacy, and perceived environment. For example,
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50 180 participants were prompted via daily email messages to self-monitor their daily pedal time and daily
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52 181 steps (via pedometer) on the website. The activity participants logged on the website was used to fuel
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54 182 a virtual competition (aimed at building social support) in which small groups of intervention
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56 183 participants (4-5 per group) collectively traveled across America (Figure 2). Participants were also
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58 184 emailed three theory-based motivational messages each week targeting goal setting, self-efficacy,
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2 185 and perceived environment. Specific goals were not set for intervention participants, rather
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4 186 participants received advice on how to set goals and suggestions for daily pedaling time (e.g. “Try
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6 187 fitting in 10 minutes of pedaling during your lunch today.”) Finally, using a forum similar to Facebook,
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8 188 participants were able to post profile photos and status updates on a newsfeed and send messages
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10 189 to members of their small groups further fostering social support.
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15 191 [Figure 2 here]
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19 193 **Measures**

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21 194 All measures were collected at baseline and post-intervention (12 weeks) in a controlled
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23 195 laboratory setting by two staff members blinded to participant’s group assignment. The primary
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25 196 outcome was daily sedentary time as measured objectively by the StepWatch (Orthocare Innovations,
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27 197 Mountlake Terrace, Wash, USA). The StepWatch is an ankle monitor that has been demonstrated as
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29 198 a reliable[22] and accurate measure of light intensity walking[23] and pedaling.[24] Participants were
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31 199 asked to wear the monitor during all wakeful hours for seven consecutive days. Days in which
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33 200 participants wore the monitors for less than 10 hours were excluded from final analysis. Intervention
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35 201 participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%) days for 14.5 hours/day
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37 202 while control participants wore the monitor an average of 5.5 days (78.6%) for 13.8 hours/day.
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41 203 Blood pressure was measured with a stethoscope and sphygmomanometer using standard
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43 204 techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass
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45 205 was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade
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47 206 digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in
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49 207 duplicate with a standard Gulick measuring tape according to standard procedures.[25] Fasting blood
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51 208 lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger
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53 209 stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been
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55 210 demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively),
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57 211 HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%
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1
2 212 respectively).[26] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill
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4 213 walking test which had been previously demonstrated as a valid estimate of total aerobic fitness
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6 214 amongst middle-aged adults.[27]
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8
9 215 Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was
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11 216 assessed objectively via the activity tracking software. Pedal compliance data was downloaded
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13 217 directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g.,
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15 218 number of website logins, number of steps logged on the website) was assessed objectively at the
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17 219 end of 12 weeks via a backend tracking database made available by the website administrators. In
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19 220 order to assess which components of the intervention participants 'perceived' as helpful for reducing
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21 221 their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention
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23 222 completers. Participants rated each intervention component using a five point Likert scale.
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28 224 **Design/Statistical Analysis**

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30 225 Baseline descriptive and independent variables were analyzed by one-way analysis of
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32 226 variance (ANOVA) (see Table 1). The sample size was calculated to detect, with 80% power, at
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34 227 $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference was
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36 228 identified as a reasonable estimate based on our previous study in which participants used the pedal
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38 229 machines an average of 23 minutes/day without a motivational intervention.[10] All outcome
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40 230 measures were evaluated before and after the 12-week experimental period within and between
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42 231 groups by two-way (group \times time) repeated measures ANOVA. When indicated by a significant F
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44 232 value, post hoc procedures were performed (Tukey). Cohen's *d* effect size[28] was computed to
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46 233 assess the magnitude of change for primary outcomes. Statistical significance was set *a priori* at
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48 234 $P<0.05$.
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54 236 **RESULTS**

55
56 237 Baseline characteristics of both groups are presented in Table 1. There were no significant
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58 238 differences found between the Control and Intervention groups for age ($P=0.10$), gender ($P=0.46$),
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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 \pm S.D. (N=40)

	Control Group N=17	Intervention Group N=23	P-value
Age (years)	47.6 \pm 9.9	42.6 \pm 8.9	0.10
Female %	94.1%	86.9%	0.46
Height (in)	65.2 \pm 3.2	65.4 \pm 3.4	0.89
Weight (lbs)	201.3 \pm 30.2	194.1 \pm 34.9	0.50
Body Mass Index (BMI)	33.2 \pm 4.5	31.7 \pm 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)		P	d
	Baseline	12 Weeks	Baseline	12 Weeks		
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 \pm S.D.

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

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

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2 285 A total of 23 participants completed the intervention and provided compliance data (see Table
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4 286 4). Intervention participants logged on to the website an average of 71.3% (59.8 days) of all days they
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6 287 had access to the website (including weekends) (Table 4). Intervention participants also logged an
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9 288 average of 7945 ± 4634 steps per day on the website over the 12 weeks. Participants pedaled an
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11 289 average of 37.7% (22.6 days) of all days they had access to the pedal machine (excluding
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13 290 weekends). Participants pedaled an average of 31.1 ± 31.6 minutes per day on the days they used the
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15 291 pedal machines and for an average of 16.1 ± 17.2 minutes per pedaling bout
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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

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43 294 When asked to rate the helpfulness of each intervention feature for reducing their sedentary
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45 295 time, participants rated the pedal machine biofeedback display, the pedometer, self-monitoring activity
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47 296 on the website as “extremely helpful” (median Likert score = 5.0; Table 5). Participants rated the email
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49 297 reminders to log daily activity and access to the pedal machine as “quite helpful” ((median Likert score
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51 298 = 5.0; Table 5).
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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 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

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2 315 specifically targeted reducing sedentary time.[17] Of the interventions that have been conducted in
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4 316 the worksite, most have relied upon self-report measures of sedentary time[17] and have been
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6 317 conducted over a relatively short duration[18 19]. Our study utilized an objective measure of
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8 318 sedentary behavior and was conducted over 12 weeks. The present study builds upon past studies as
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10
11 319 our study was among the first to demonstrate significant reductions in objectively measured sedentary
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13 320 time when compared to a control group. This is important, as it has been suggested that decreasing
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15 321 sedentary time can result in improved health benefits independent of physical activity.[2 29-31]
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17 322 Sedentary time amongst the intervention group was reduced by an average of 59 minutes/day
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19 323 or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle
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21 324 et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention
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23 325 that included educational materials on sedentary health risks and tips to reduce sedentary time.[19]
24
25 326 However, this study did not include a control group. In a study that did include a control group, Evans
26
27 327 et al. found no between group differences in objectively measured sitting time after five days of point-
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29 328 of-choice software reminders to stand up every 30 minutes while at work.[18]
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32 329 We also observed a group x time interaction effect for waist circumference. This finding is
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34 330 important as waist circumference has been shown to predict mortality amongst adults with coronary
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36 331 artery disease.[32] Confidence in this finding is strengthened by past studies that have reported
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38 332 higher levels of sedentary behavior to be associated with a higher waist circumference[33] and
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40 333 interruptions from sedentary time to be associated with reduced waist circumference levels.[8]
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42 334 Furthermore, this finding is consistent with findings of a previous 16-week internet-delivered physical
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44 335 activity program which demonstrated modest improvements in daily steps and waist
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46 336 circumference.[34] The lack of changes in other cardiometabolic risk factors may be due to the low
47
48 337 intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration are
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50 338 needed to determine whether reducing sedentary time results in cardiometabolic risk reduction.
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54 339 Participant compliance to the website overall was high with participants logging into the
55
56 340 website an average of 71% of all intervention days. This is important as past internet-delivered
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58 341 intervention studies have identified engagement to be a challenge [35 36] and a predictor of
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2 342 intervention success.[37] By comparison, Lewis et al. reported participants logged on to a physical
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4 343 activity website a median number of 50 times (13.7%) over 12 months.[38] Reasons for such high
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6 344 website compliance in the present study may be due to the tailoring of the website to include locally
7
8 345 relevant images and messages.

10
11 346 Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day)
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13 347 was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These
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15 348 findings suggest the added motivational intervention, which included suggestions for setting goals and
16
17 349 finding time to pedal each day, resulted in improved daily compliance that was sustained over a
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19 350 longer duration. Despite the logistical limitation of the portable pedal machine when paired with
20
21 351 standard height desks (i.e., many participants reported their knees hit the underside of their desk
22
23 352 while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize
24
25 353 compliance with such portable pedal machines in future studies, it is recommended these devices be
26
27 354 paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

29
30 355 Intervention participants reported features that provided feedback including the pedal machine
31
32 356 tracking software, pedometers and self-monitoring daily activity on the website (which was
33
34 357 immediately followed by a graph illustrating the individual's daily progress) as the most helpful
35
36 358 features for reducing their daily sedentary time. This information is important and could be used to
37
38 359 inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past
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40 360 studies which have found biofeedback as a useful tool to improve health behaviors.[39 40]

42
43 361 The main limitation of the study was the limited generalizability due to a small sample size that
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45 362 comprised primarily of middle-aged females working at a single institution. We also experienced
46
47 363 differential drop out, although follow-up analyses indicate no differences between those that dropped
48
49 364 and those that completed amongst the control group for age ($P=0.40$), BMI ($P=0.52$), or daily
50
51 365 sedentary time ($P=0.22$).

53
54 366 The present study is among the first interventions aimed specifically at reducing daily
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56 367 sedentary time to demonstrate between group differences in objectively measured sedentary time.
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58 368 Compliance with the motivational website was high while compliance with the pedal machine was
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2 369 moderate. While a group x time interaction was found for waist circumference, no between group
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4 370 differences were observed for any other cardiometabolic risk factors. More sedentary focused
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6 371 interventions are needed to examine whether reducing sedentary time can be sustained long-term
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8
9 372 and whether long-term changes result in significant reductions in risk for chronic diseases.

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11 373
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17 376
18
19 377 **Competing Interests:** All authors have completed the ICMJE uniform disclosure form at
20
21 www.icmje.org/coi_disclosure.pdf and declare: no financial support from the funder Oak Ridge
22 378 Associated Universities for the submitted work, no financial relationships with any organizations that
23
24 379 might have an interest in the submitted work in the previous three years, and no other relationships or
25
26 380 activities that could appear to have influenced the submitted work.”
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31 382 **Contributorship Statement:**

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35 383
 - Dr. Lucas Carr was responsible for the design of the study and lead the manuscript

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37 384 preparation.

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39 385
 - Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript

40
41 386 preparation.

42
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44 387
 - Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for

45
46 388 leading the intervention which included duties of interacting with participants on a daily basis.

47
48 389
 - Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation

49
50 390 and were responsible for collecting data at the baseline and post-intervention time points.

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54 391 **Data Sharing**

- 55 392
 - Extra data is available by emailing Dr. Lucas Carr at lucas-carr@uiowa.edu.

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2 395 **Figure Legend**
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6 397 **Figure 1.** Sequence of events and recruitment/enrollment schematic. Study was coordinated at East
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9 398 Carolina University, Greenville, NC, from June 2011-June 2012.
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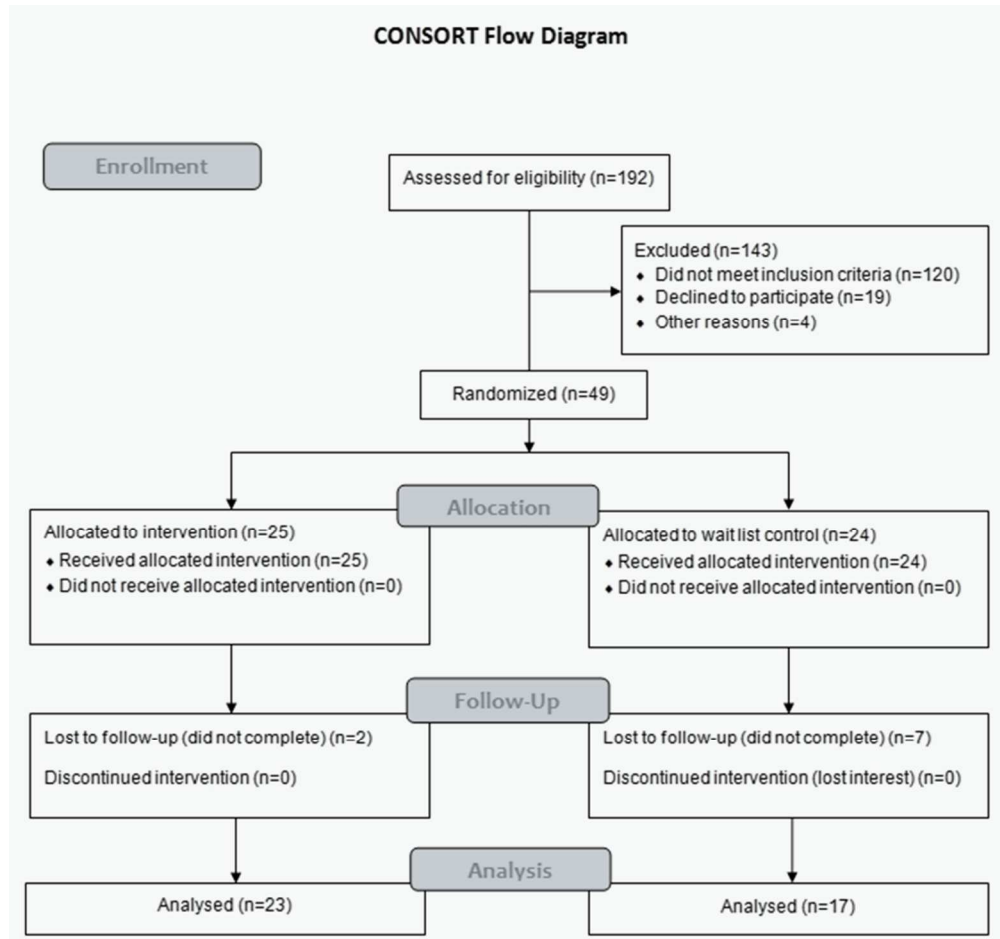
11 399
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13 400 **Figure 2.** Images of intervention features: A. Portable pedal machine, B. Pedal machine activity
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15 401 tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot
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17 402 of the Walk Across American group challenge.
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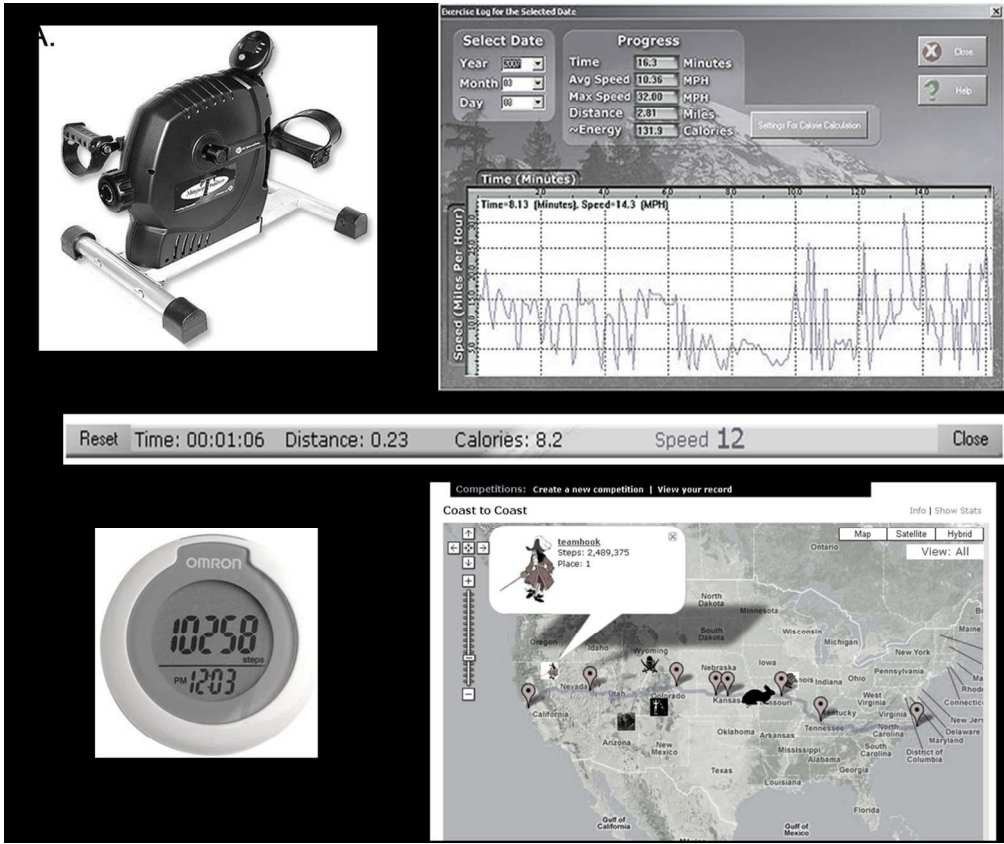
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For peer review only



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

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2	Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how
3			5&7
4		11b	If relevant, description of the similarity of interventions
5			NA
6	Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes
7		12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses
8			NA
9	Results		
10	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
11		13b	For each group, losses and exclusions after randomisation, together with reasons
12			5
13	Recruitment	14a	Dates defining the periods of recruitment and follow-up
14		14b	Why the trial ended or was stopped
15			5
16	Baseline data	15	A table showing baseline demographic and clinical characteristics for each group
17	Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups
18			Table 1 (p.9)
19			5
20	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)
21		17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended
22			8-13
23	Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory
24			NA
25			8-13
26	Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)
27			NA
28	Discussion		
29	Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses
30	Generalisability	21	Generalisability (external validity, applicability) of the trial findings
31	Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence
32			15
33			15
34			13-16
35	Other information		
36	Registration	23	Registration number and name of trial registry
37			ClinicalTrials.gov (NCT01371084)
38			4)
39	Protocol	24	Where the full trial protocol can be accessed, if available
40			Oak Ridge Associated Universities
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44	CONSORT 2010 checklist		
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Grant
(#212112)

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5 Funding 25 Sources of funding and other support (such as supply of drugs), role of funders
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8 *We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the
9 items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological
10 treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist,
11 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}

¹Centers for Behavioral and Preventive Medicine, The Miriam Hospital, Providence, Rhode Island, USA

²Department of Exercise and Sport Science, East Carolina University, Greenville, North Carolina, USA

³Program 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; carrlj@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

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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/m²; 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 were 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/m²) 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 protocol²⁹ 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

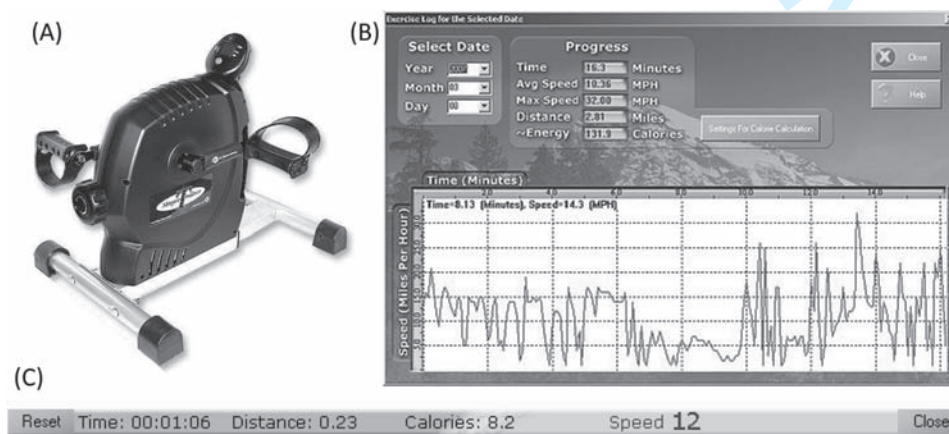


Figure 1 (A) The portable pedal exercise machine. (B) A screenshot of the exercise log, which provides feedback on pedal use activity per day. (C) A screenshot of the real-time monitor, which provides real-time feedback to the user.

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(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 pedalling 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/m²) 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 \pm SD and ranges of pedal time, pedal speed, distance pedalled and caloric expenditure

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

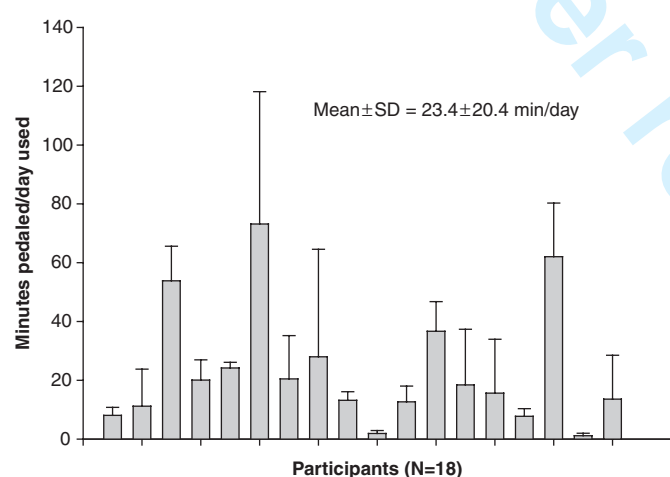
Data were downloaded using the FitXF exercise tracking software.

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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

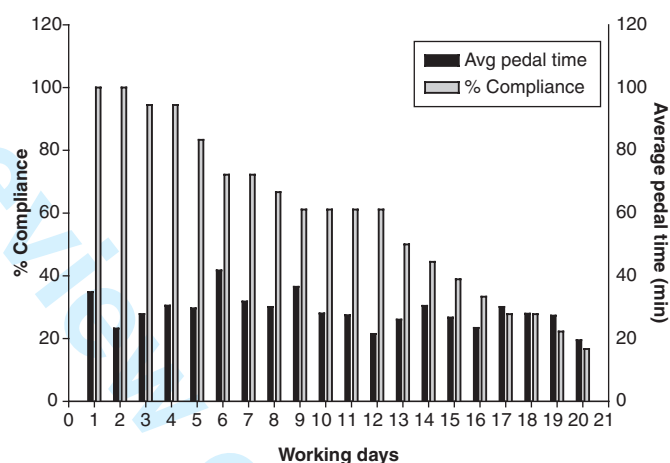
Do you agree or disagree with the following statement?	Q1	Median	Q3
If offered to me by my employer, I would use the machine while at work	4.3	5.0	5.0
My physical activity increased while at work as a result of the machine	3.0	4.0	5.0
My physical activity increased outside of work as a result of the 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).

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

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

serve as a means to monitor employee participation in work-site 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.

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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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Competing interests None.

Patient consent Obtained.

Ethics approval This study was conducted with the approval of the Miriam Hospital, Providence, Rhode Island, USA.

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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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Keywords:	sedentary, worksite, technology

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4 2
5
6 3 **Corresponding Author:**
7

8 4 Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House
9 5 E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu
10
11
12 6

13
14
15 7 **Co-Authors:**
16

17 8 Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay,
18 9 Ontario, Canada
19

20
21 10 Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA
22

23 11 Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
24

25
26 12 Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
27
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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/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. 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.

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2 54 • We hypothesized that the intervention group would significantly reduce daily sedentary time
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4 55 and select cardiometabolic disease risk factors compared to the wait-list control group after 12
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6 56 weeks.
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9 57 • As an exploratory aim, we conducted a process evaluation to explore intervention compliance
10
11 58 and identify helpful components of the intervention.
12

13 59 **Key messages**

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15 60 • This multicomponent intervention resulted in significant reductions in time spent sedentary
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17 61 and waist circumference when comparing the intervention group to the wait list control
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20 62 group.
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22 63 • The present study builds upon past studies as our study was among the first to demonstrate
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24 64 significant reductions in objectively measured sedentary time when compared to a control
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26 65 group.
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29 66 • The findings of this study are important given the paucity of research in this area and
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31 67 growing evidence demonstrating the importance of limiting daily sedentary time for
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33 68 reducing risk of chronic diseases.
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35 69 **Strengths**

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38 70 • Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a
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40 71 primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3)
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42 72 conducted a 12 week trial which extends previous sedentary interventions that have typically
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44 73 been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process
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46 74 evaluation to identify features of the intervention that worked particularly well.
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48 75 **Limitations**

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51 76 • Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of
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53 77 middle-aged females working at a single institution which limits generalizability; and 2)
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55 78 differential drop out, although follow-up analyses indicate no differences between those that
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2 79 dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time
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4 80 (P=0.32).
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10 83 INTRODUCTION

13 84 Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic
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15 85 health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic
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17 86 syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting
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19 87 and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day
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21 88 may be effective for improving various cardiometabolic disease risk factors .[7 8]The modern
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23 89 workplace has been identified as a setting in which individuals engage in prolonged bouts of
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25 90 sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary
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27 91 as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S.
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29 92 labor force works in low-activity occupations.[12] The observed decline in occupational energy
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31 93 expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the
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33 94 observed increase in mean body mass amongst U.S. adults over the same time period.[13]
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35 95 Traditional behaviorally focused worksite interventions have focused primarily on increasing physical
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37 96 activity and have resulted in modest effect sizes (Cohen's $d = 0.21-0.22$).[14 15] In a shift away from
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39 97 behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing
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41 98 the effect of modifying the work environment to reduce occupational sedentary time.
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45 99 To date, only a handful of sedentary interventions have been conducted in the worksite. While
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47 100 many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials
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49 101 have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies
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51 102 conducted in the worksite have been limited by the use of self-report measures of sedentary time
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53 103 and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted
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55 104 reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and
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57 105 the possible desire/need of many employers and employees to remain seated while completing their
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2 106 work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a
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4 107 means for reducing sedentary time.

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6 108 In a previous study testing the feasibility of modifying the work environment as a means of
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8 109 reducing occupational sedentary time through promoting active sitting, our team provided portable
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10 110 pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10].
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12 111 Importantly, participants rated the pedal machines as feasible and acceptable for use while
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14 112 completing their work. Further, despite a lack of any accompanying behavioral intervention,
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16 113 participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per
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18 114 day. Although these results are promising, it is possible the addition of a motivational behavioral
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20 115 intervention could result in increased pedaling compliance and reduced sedentary time.
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24 116 The primary aim of the present study was to test the effectiveness of a multicomponent
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26 117 intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a
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28 118 sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We
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30 119 hypothesized that the intervention group would significantly reduce daily sedentary time and select
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32 120 cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks. As an
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34 121 exploratory aim, we conducted a process evaluation to explore intervention compliance and identify
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36 122 helpful components of the intervention.
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40 124 **METHODS**

41 125 **Subjects and Design**

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48 127 Many sedentary interventions to date have been limited by short durations. Therefore, we
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50 128 conducted a 12 week randomized controlled trial design comparing a treatment group to a no
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52 129 treatment wait-list control group. We recruited apparently healthy but sedentary (self-reporting less
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54 130 than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass
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56 131 index (BMI) ≥ 25.0 kg/m²) adults working in full-time (reporting minimum of 35.0+ hours/week)
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58 132 sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting).
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2 133 Participants were required to gain permission from their supervisor prior to enrollment. Research staff
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4 134 members screened participants for eligibility by telephone. Exclusionary criteria included: 1)
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6 135 limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive
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8 136 impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and
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10 137 anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart
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12 138 failure or cancer. Participants were not compensated for participation in the study. Experimental
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14 139 protocols were approved by the University and Medical Center Institutional Review Board and
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16 140 voluntary written informed consent was obtained from each participant.
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20 141 Participants of all races and ethnic backgrounds working at a large southern university were
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22 142 passively recruited through email advertisements placed on an electronic mailing list serve that
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24 143 served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were
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26 144 excluded from participation due to: not meeting eligibility criteria which primarily consisted of not
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28 145 meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other
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30 146 reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using
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32 147 an online random sequence generator.[21] Participants were assigned to one of two groups by a
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34 148 research staff member not involved in data collection based on the order in which they enrolled into
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36 149 the study. A total of 49 participants deemed interested and eligible for participation were randomized
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38 150 to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40
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40 151 participants completed all baseline and post-intervention assessments. Nine participants were lost to
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42 152 follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention
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44 153 participants and 17 control participants (see Table 1). More than half of all participants were college
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46 154 educated, reported an annual income greater than \$40,000 and reported being non-Hispanic/White.
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48 155 Participants were enrolled and completed all testing sessions between June 2011 and June 2012.
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57 58 159 **Group Descriptions** 59 60

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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

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2 187 located in 18 different buildings across campus. No participants worked within visible proximity of
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4 188 each other.

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6 189 Intervention participants were also provided access to a motivational website that was
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9 190 individually customized to the local culture of the worksite of which participants were recruited (Figure
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11 191 2). Examples of customization included posting local images and messages specific to the local
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13 192 institution. The content of the intervention focused primarily on reducing time spent sedentary (both
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15 193 increasing active sitting via pedaling and taking breaks from sitting). Example messages included
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17 194 "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up
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19 195 burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at
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21 196 work although some messages broadly targeted sedentary time in general and could have impacted
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24 197 sedentary time outside of work. Messages were theory based targeting constructs of the Social
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26 198 Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived
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28 199 environment. For example, participants were prompted via daily email messages to self-monitor their
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30 200 daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on
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32 201 the website was used to fuel a virtual competition (aimed at building social support) in which small
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34 202 groups of intervention participants (4-5 per group) collectively traveled across America. Participants
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36 203 were also emailed three theory-based motivational messages each week targeting goal setting, self-
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38 204 efficacy, and perceived environment. Specific goals were not set for intervention participants, rather
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40 205 participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try
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42 206 fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook,
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44 207 participants were able to post profile photos and status updates on a newsfeed and send messages
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46 208 to members of their small groups further fostering social support.
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56 212 **Measures**
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2 213 All measures were collected at baseline and post-intervention (12 weeks) in a controlled
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4 214 laboratory setting by two staff members blinded to participant's group assignment. The two staff
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6 215 members were provided specific measurement duties to ensure each measure was collected by the
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8 216 same staff member at both baseline and post-intervention. The primary outcome was daily sedentary
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10 217 time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations,
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12 218 Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn
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14 219 on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the
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16 220 StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for
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18 221 steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both
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20 222 sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The
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22 223 StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when
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24 224 compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the
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26 225 monitor during all wakeful hours for seven consecutive days and keep track of wear time using an
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28 226 activity log. Days in which participants wore the monitors for less than 10 hours were excluded from
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30 227 final analysis. Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%)
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32 228 days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for
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34 229 13.8 hours/day. The threshold for sedentary (0 steps/min) was based on the recommendation
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36 230 provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75
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38 231 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work
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40 232 which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute
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42 233 depending on height and stride length[26].

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44 234 Blood pressure was measured with a stethoscope and sphygmomanometer using standard
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46 235 techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass
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48 236 was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade
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50 237 digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in
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52 238 duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood
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54 239 lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger
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2 240 stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been
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4 241 demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively),
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6 242 HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%
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8 243 respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill
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10 244 walking test which had been previously demonstrated as a valid estimate of total aerobic fitness
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12 245 amongst middle-aged adults.[29]
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15 246 Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was
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17 247 assessed objectively via the activity tracking software. Pedal compliance data was downloaded
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19 248 directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g.,
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21 249 number of website logins, number of steps logged on the website) was assessed objectively at the
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23 250 end of 12 weeks via a backend tracking database made available by the website administrators. In
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25 251 order to assess which components of the intervention participants 'perceived' as helpful for reducing
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27 252 their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention
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29 253 completers. Participants rated each intervention component using a five point Likert scale.
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34 255 **Design/Statistical Analysis**

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37 256 A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80%
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39 257 power, at $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference
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41 258 was identified as a reasonable estimate based on our previous study in which participants used the
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43 259 same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means
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45 260 (SD) were used to describe data where appropriate.

47 261 The paired samples t-test was used to determine any within group differences at baseline and
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49 262 post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups
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51 263 at post-intervention. Baseline values of interest were included as covariates in the model for all
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53 264 continuous variables consistent with recommended statistical procedures [30]. The underlying
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55 265 assumption no between group differences at baseline was confirmed for all measures by one way
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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 \pm S.D. (N=40)

	Control Group	Intervention Group	All
	N=17	N=23	(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 V_{O2} (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

1
2 330 behavior whereas many previous interventions have relied upon self-report measures of sedentary
3
4 331 time[17]. The present study builds upon past studies as our study was among the first to demonstrate
5
6 332 significant reductions in objectively measured sedentary time when compared to a control group. This
7
8 333 is important, as it has been suggested that decreasing sedentary time can result in improved health
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10 334 benefits independent of physical activity.[2 32-34]

13 335 Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day
14
15 336 or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle
16
17 337 et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention
18
19 338 that included educational materials on sedentary health risks and tips to reduce sedentary time.[31]
20
21 339 However, this study did not include a control group. In a study that did include a control group, Evans
22
23 340 et al. found no between group differences in objectively measured sitting time after five days of point-
24
25 341 of-choice software reminders to stand up every 30 minutes while at work.[19]

28 342 We also observed a significant intervention effect for waist circumference. This finding is
29
30 343 important as waist circumference has been shown to predict mortality amongst adults with coronary
31
32 344 artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist
33
34 345 circumference to be sensitive to change in the absence of changes in other measures of adiposity[36]
35
36 346 as well as studies reporting interruptions from sedentary time to be associated with waist
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38 347 circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-
39
40 348 delivered physical activity program which demonstrated modest improvements in daily steps and
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42 349 waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the
43
44 350 low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration
45
46 351 are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk
47
48 352 reduction.

52 353 Participant compliance to the website overall was high with participants logging into the
53
54 354 website an average of 71% of all intervention days. This is important as past internet-delivered
55
56 355 intervention studies have identified engagement to be a challenge [38 39] and a predictor of
57
58 356 intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical
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1
2 357 activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high
3
4 358 website compliance in the present study may be due to the tailoring of the website to include locally
5
6 359 relevant images and messages and/or the regular email messages.
7

8
9 360 Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day)
10
11 361 was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These
12
13 362 findings suggest the added motivational intervention, which included suggestions for setting goals and
14
15 363 finding time to pedal each day, resulted in improved daily compliance that was sustained over a
16
17 364 longer duration. Despite the logistical limitation of the portable pedal machine when paired with
18
19 365 standard height desks (i.e., many participants reported their knees hit the underside of their desk
20
21 366 while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize
22
23 367 compliance with such portable pedal machines in future studies, it is recommended these devices be
24
25
26 368 paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.
27

28 369 Intervention participants reported features that provided feedback including the pedal machine
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30 370 tracking software, pedometers and self-monitoring daily activity on the website (which was
31
32 371 immediately followed by a graph illustrating the individual's daily progress) as the most helpful
33
34 372 features for reducing their daily sedentary time. This information is important and could be used to
35
36 373 inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past
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38 374 studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]
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40

41 375 The main limitation of the study was the limited generalizability due to a small sample size that
42
43 376 comprised primarily of middle-aged females working at a single institution. We also experienced
44
45 377 differential drop out, although follow-up analyses indicate no differences between those that dropped
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47 378 and those that completed for age, BMI, or daily sedentary time.
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49

50 379 The present study is among the first interventions conducted within the worksite aimed
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52 380 specifically at reducing daily sedentary time to demonstrate between group differences in objectively
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54 381 measured sedentary time. Compliance with the motivational website was high while compliance with
55
56 382 the pedal machine was moderate. These findings are promising considering the relatively low cost of
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58 383 the intervention which cost a total of \$180 (pedal machine and software, pedometer, access to
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1
2 384 website) per participant. While an intervention effect was observed for waist circumference, no
3
4 385 between group differences were observed for any other cardiometabolic risk factors. More sedentary
5
6 386 focused interventions are needed to examine whether reducing sedentary time can be sustained
7
8 387 long-term and whether long-term changes result in significant reductions in risk for chronic diseases.
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11 388
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16

17 391
18
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20
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22 393
23 394 Associated Universities for the submitted work, no financial relationships with any organizations that
24
25 395 might have an interest in the submitted work in the previous three years, and no other relationships or
26
27 396 activities that could appear to have influenced the submitted work.
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31 397 **Contributorship Statement:**
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- 34
35 398 • Dr. Lucas Carr was responsible for the design of the study and lead the manuscript
36
37 399 preparation.
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39 400 • Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript
40
41 401 preparation.
42
43 402 • Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for
44
45 403 leading the intervention which included duties of interacting with participants on a daily basis.
46
47 404 • Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation
48
49 405 and were responsible for collecting data at the baseline and post-intervention time points.
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53 406 **Data Sharing**
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55 407

- 56 408 • Extra data is available by emailing Dr. Lucas Carr at lucas-carr@uiowa.edu.
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2 410 **Figure Legend**

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6 412 **Figure 1.** Sequence of events and recruitment/enrollment schematic. Study was coordinated at East
7
8 Carolina University, Greenville, NC, from June 2011-June 2012.
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13 415 **Figure 2.** Images of intervention features: A. Portable pedal machine, B. Pedal machine activity
14 tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot
15 416 of the website homepage.
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1
2 1 **Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial**
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5
6 3 **Corresponding Author:**
7

8 4 Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House
9
10 5 E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu
11
12 6

13
14
15 7 **Co-Authors:**
16

17 8 Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay,
18
19 9 Ontario, Canada
20

21 10 Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA
22

23 11 Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
24

25 12 Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
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32 15 **Keywords:** sedentary, multicomponent, cardiometabolic
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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/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. 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.

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2 54 • We hypothesized that the intervention group would significantly reduce daily sedentary time
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4 55 and select cardiometabolic disease risk factors compared to the wait-list control group after 12
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6 56 weeks.
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9 57 • As an exploratory aim, we conducted a process evaluation to explore intervention compliance
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11 58 and identify helpful components of the intervention.
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13 59 **Key messages**

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15 60 • This multicomponent intervention resulted in significant reductions in time spent sedentary
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17 61 and waist circumference when comparing the intervention group to the wait list control
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20 62 group.
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22 63 • The present study builds upon past studies as our study was among the first to demonstrate
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24 64 significant reductions in objectively measured sedentary time when compared to a control
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26 65 group.
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29 66 • The findings of this study are important given the paucity of research in this area and
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31 67 growing evidence demonstrating the importance of limiting daily sedentary time for
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33 68 reducing risk of chronic diseases.
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35 69 **Strengths**

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38 70 • Primary strengths of this study include: 1) among the first RCT's to target sedentary time as a
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40 71 primary outcome; 2) among the first RCT's to use an objective measure of sedentary time; 3)
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42 72 conducted a 12 week trial which extends previous sedentary interventions that have typically
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44 73 been of brief durations; 4) measured cardiometabolic risk factors; and 5) conducted a process
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46 74 evaluation to identify features of the intervention that worked particularly well.
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48 75 **Limitations**

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51 76 • Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of
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53 77 middle-aged females working at a single institution which limits generalizability; and 2)
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55 78 differential drop out, although follow-up analyses indicate no differences between those that
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2 79 | dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time
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4 80 | (P=0.32).
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10 83 INTRODUCTION

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13 84 | Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic
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15 85 | health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic
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17 86 | syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting
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19 87 | and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day
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21 88 | may be effective for improving various cardiometabolic disease risk factors.[7 8]
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24 89 | The modern workplace has been identified as a setting in which individuals engage in
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26 90 | prolonged bouts of sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk
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28 91 | for being sedentary as they often spend more than 75% of work time sitting[9-11].Currently, more
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30 92 | than 27% of the U.S. labor force works in low-activity occupations.[12] The observed decline in
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32 93 | occupational energy expenditure (~100 kcals/day) over the past 50 years has been identified as a key
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34 94 | contributor to the observed increase in mean body mass amongst U.S. adults over the same time
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36 95 | period.[13] Traditional behaviorally focused worksite interventions have focused primarily on
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38 96 | increasing physical activity and have resulted in modest effect sizes (Cohen's $d = 0.21-0.22$).[14 15]
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40 97 | In a shift away from behaviorally focused approaches, studies grounded in social ecological
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42 98 | theory[16] have begun testing the effect of modifying the work environment to reduce occupational
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47 100 | To date, only a handful of sedentary interventions have been conducted in the worksite. While
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49 101 | many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials
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51 102 | have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies
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53 103 | conducted in the worksite have been limited by the use of self-report measures of sedentary time
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55 104 | and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted
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57 105 | reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and
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2 106 the possible desire/need of many employers and employees to remain seated while completing their
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4 107 work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a
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6 108 means for reducing sedentary time.

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9 109 In a previous study testing the feasibility of modifying the work environment as a means of
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11 110 reducing occupational sedentary time through promoting active sitting, our team provided portable
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13 111 pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10].
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15 112 Importantly, participants rated the pedal machines as feasible and acceptable for use while
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17 113 completing their work. Further, despite a lack of any accompanying behavioral intervention,
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19 114 participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per
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21 115 day. Although these results are promising, it is possible the addition of a motivational behavioral
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23 116 intervention could result in increased pedaling compliance and reduced sedentary time.

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26 117 The primary aim of the present study was to test the effectiveness of a multicomponent
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28 118 intervention for reducing daily sedentary time and improving cardiometabolic risk factors amongst a
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30 119 sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We
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32 120 hypothesized that the intervention group would significantly reduce daily sedentary time and select
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34 121 cardiometabolic disease risk factors compared to the wait-list control group after 12 weeks. As an
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36 122 exploratory aim, we conducted a process evaluation to explore intervention compliance and identify
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38 123 helpful components of the intervention.

43 125 **METHODS**

45 126 **Subjects and Design**

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50 128 Many sedentary interventions to date have been limited by short durations. Therefore, we
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52 129 conducted a 12 week randomized controlled trial design comparing a treatment group to a no
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54 130 treatment wait-list control group. We recruited apparently healthy but sedentary (self-reporting less
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56 131 than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body mass
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58 132 index (BMI) ≥ 25.0 kg/m²) adults working in full-time (reporting minimum of 35.0+ hours/week)

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2 133 sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting).
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4 134 Participants were required to gain permission from their supervisor prior to enrollment. Research staff
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6 135 members screened participants for eligibility by telephone. Exclusionary criteria included: 1)
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8 136 limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive
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10 137 impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and
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12 138 anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart
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14 139 failure or cancer. Participants were not compensated for participation in the study. Experimental
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16 140 protocols were approved by the University and Medical Center Institutional Review Board and
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18 141 voluntary written informed consent was obtained from each participant.
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22 142 Participants of all races and ethnic backgrounds working at a large southern university were
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24 143 passively recruited through email advertisements placed on an electronic mailing list serve that
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26 144 served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were
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28 145 excluded from participation due to: not meeting eligibility criteria which primarily consisted of not
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30 146 meeting BMI and/or physical activity requirements -(N=120); declined to participate (N=19); or other
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32 147 reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using
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34 148 an online random sequence generator.[21] Participants were assigned to one of two groups by a
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36 149 research staff member not involved in data collection based on the order in which they enrolled into
37
38 150 the study. A total of 49 participants deemed interested and eligible for participation were randomized
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40 151 to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40
41
42 152 participants completed all baseline and post-intervention assessments. Nine participants were lost to
43
44 153 follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention
45
46 154 participants and 17 control participants (see Table 1). More than half of all participants were college
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48 155 educated, reported an annual income greater than \$40,000 and reported being non-Hispanic/White.
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50 156 Participants were enrolled and completed all testing sessions between June 2011 and June 2012.
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56 158 [Figure 1 here]
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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

1
2 187 research staff and participant's supervisors occurred during the course of the study. Participants were
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4 188 located in 18 different buildings across campus. No participants worked within visible proximity of
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6 189 each other.
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8
9 190 Intervention participants were also provided access to a motivational website that was
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11 191 individually customized to the local culture of the worksite of which participants were recruited (Figure
12
13 192 2). Examples of customization included posting local images and messages specific to the local
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15 193 institution. The content of the intervention focused primarily on reducing time spent sedentary (both
16
17 194 increasing active sitting via pedaling and taking breaks from sitting). Example messages included
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19 195 "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up
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21 196 burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at
22
23 197 work although some messages broadly targeted sedentary time in general and could have impacted
24
25 198 sedentary time outside of work. Messages were theory based targeting constructs of the Social
26
27 199 Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived
28
29 200 environment. For example, participants were prompted via daily email messages to self-monitor their
30
31 201 daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on
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33 202 the website was used to fuel a virtual competition (aimed at building social support) in which small
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35 203 groups of intervention participants (4-5 per group) collectively traveled across America. Participants
36
37 204 were also emailed three theory-based motivational messages each week targeting goal setting, self-
38
39 205 efficacy, and perceived environment. Specific goals were not set for intervention participants, rather
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41 206 participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try
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43 207 fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook,
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45 208 participants were able to post profile photos and status updates on a newsfeed and send messages
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47 209 to members of their small groups further fostering social support.
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54 211 [Figure 2 here]
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58 213 **Measures**
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2 214 All measures were collected at baseline and post-intervention (12 weeks) in a controlled
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4 215 laboratory setting by two staff members blinded to participant's group assignment. The two staff
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6 216 members were provided specific measurement duties to ensure each measure was collected by the
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8 217 same staff member at both baseline and post-intervention. The primary outcome was daily sedentary
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10 218 time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations,
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12 219 Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn
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14 220 on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the
15
16 221 StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for
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18 222 steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both
19
20 223 sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The
21
22 224 StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when
23
24 225 compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the
25
26 226 monitor during all wakeful hours for seven consecutive days and keep track of wear time using an
27
28 227 activity log. Days in which participants wore the monitors for less than 10 hours were excluded from
29
30 228 final analysis. Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%)
31
32 229 days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for
33
34 230 13.8 hours/day. The threshold for sedentary (0 steps/min) was based on the recommendation
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36 231 provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75
37
38 232 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work
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40 233 which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute
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42 234 depending on height and stride length[26].

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44 235 Blood pressure was measured with a stethoscope and sphygmomanometer using standard
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46 236 techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass
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48 237 was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade
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50 238 digital medical scale and height rod (Seca 769, Hanover, MD). Waist circumference was measured in
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52 239 duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood
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54 240 lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger
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2 241 stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been
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4 242 demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively),
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6 243 HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%
7
8
9 244 respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill
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11 245 walking test which had been previously demonstrated as a valid estimate of total aerobic fitness
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13 246 amongst middle-aged adults.[29]

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15 247 Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was
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17 248 assessed objectively via the activity tracking software. Pedal compliance data was downloaded
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19 249 directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g.,
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21 250 number of website logins, number of steps logged on the website) was assessed objectively at the
22
23 251 end of 12 weeks via a backend tracking database made available by the website administrators. In
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26 252 order to assess which components of the intervention participants 'perceived' as helpful for reducing
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28 253 their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention
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30 254 completers. Participants rated each intervention component using a five point Likert scale.
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35 256 **Design/Statistical Analysis**

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37 257 A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80%
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39 258 power, at $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference
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41 259 was identified as a reasonable estimate based on our previous study in which participants used the
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43 260 same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means
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45 261 (SD) were used to describe data where appropriate.

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47 262 The paired samples t-test was used to determine any within group differences at baseline and
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49 263 post-intervention. Analysis of covariance (ANCOVA) was used to test for differences between groups
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51 264 at post-intervention. Baseline values of interest were included as covariates in the model for all
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53 265 continuous variables consistent with recommended statistical procedures [30]. The underlying
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55 266 assumption no between group differences at baseline was confirmed for all measures by one way
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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 \pm 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).

	<u>Baseline</u>	<u>Post-Intervention</u>	<u>Mean Difference^a (95% CI)</u>	<u>Within Group P value</u>	<u>Between Group P value (Post)</u>
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).

	<u>Baseline</u>	<u>Post- Intervention</u>	<u>Mean Difference^a (95% CI)</u>	<u>Within Group P value</u>	<u>Between Group P value (Post)</u>
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 V_{O2} (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	<u>35.7</u>
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	<u>29.3</u>
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

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2 331 | behavior whereas many previous interventions have relied upon self-report measures of sedentary
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4 332 | time[17]. The present study builds upon past studies as our study was among the first to demonstrate
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6 333 | significant reductions in objectively measured sedentary time when compared to a control group. This
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8 334 | is important, as it has been suggested that decreasing sedentary time can result in improved health
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10 335 | benefits independent of physical activity.[2 32-34]

13 336 | Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day
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15 337 | or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle
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17 338 | et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention
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19 339 | that included educational materials on sedentary health risks and tips to reduce sedentary time.[31]
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21 340 | However, this study did not include a control group. In a study that did include a control group, Evans
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23 341 | et al. found no between group differences in objectively measured sitting time after five days of point-
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25 342 | of-choice software reminders to stand up every 30 minutes while at work.[19]

28 343 | We also observed ~~a group x time interaction~~ a significant intervention effect for waist
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30 344 | circumference. This finding is important as waist circumference has been shown to predict mortality
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32 345 | amongst adults with coronary artery disease.[35] Confidence in this finding is strengthened by past
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34 346 | studies that have found waist circumference to be sensitive to change in the absence of changes in
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36 347 | other measures of adiposity[36] as well as studies reporting interruptions from sedentary time to be
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38 348 | associated with waist circumference. [37] Furthermore, this finding is consistent with findings of a
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40 349 | previous 16-week internet-delivered physical activity program which demonstrated modest
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42 350 | improvements in daily steps and waist circumference. [36] The lack of changes in other
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44 351 | cardiometabolic risk factors may be due to the low intensity of the intervention as well as the limited
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46 352 | duration of 12 weeks. Studies of longer duration are needed to determine whether long-term
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48 353 | reduction in sedentary time results in cardiometabolic risk reduction.

52 354 | Participant compliance to the website overall was high with participants logging into the
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54 355 | website an average of 71% of all intervention days. This is important as past internet-delivered
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56 356 | intervention studies have identified engagement to be a challenge [38 39] and a predictor of
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58 357 | intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical
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2 358 activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high
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4 359 website compliance in the present study may be due to the tailoring of the website to include locally
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6 360 relevant images and messages and/or the regular email messages.

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9 361 Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day)
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11 362 was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These
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13 363 findings suggest the added motivational intervention, which included suggestions for setting goals and
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15 364 finding time to pedal each day, resulted in improved daily compliance that was sustained over a
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17 365 longer duration. Despite the logistical limitation of the portable pedal machine when paired with
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19 366 standard height desks (i.e., many participants reported their knees hit the underside of their desk
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21 367 while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize
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23 368 compliance with such portable pedal machines in future studies, it is recommended these devices be
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25 369 paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

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28 370 Intervention participants reported features that provided feedback including the pedal machine
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30 371 tracking software, pedometers and self-monitoring daily activity on the website (which was
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32 372 immediately followed by a graph illustrating the individual's daily progress) as the most helpful
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34 373 features for reducing their daily sedentary time. This information is important and could be used to
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36 374 inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past
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38 375 studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

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40
41 376 The main limitation of the study was the limited generalizability due to a small sample size that
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43 377 comprised primarily of middle-aged females working at a single institution. We also experienced
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45 378 differential drop out, although follow-up analyses indicate no differences between those that dropped
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47 379 and those that completed for age, BMI, or daily sedentary time.

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49
50 380 The present study is among the first interventions conducted within the worksite aimed
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52 381 specifically at reducing daily sedentary time to demonstrate between group differences in objectively
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54 382 measured sedentary time. Compliance with the motivational website was high while compliance with
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56 383 the pedal machine was moderate. These findings are promising considering the relatively low cost of
57
58 384 the intervention which cost a total of \$180 (pedal machine and software, pedometer, access to

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2 385 | [website\) per participant.](#) While an intervention effect was observed for waist circumference, no
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4 386 between group differences were observed for any other cardiometabolic risk factors. More sedentary
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6 387 focused interventions are needed to examine whether reducing sedentary time can be sustained
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8 388 long-term and whether long-term changes result in significant reductions in risk for chronic diseases.
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17 392

18
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22
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24
25 396 might have an interest in the submitted work in the previous three years, and no other relationships or
26
27 397 activities that could appear to have influenced the submitted work.
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31 398 **Contributorship Statement:**
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- 35 399 • Dr. Lucas Carr was responsible for the design of the study and lead the manuscript
36 400 preparation.
- 37 401 • Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript
38 402 preparation.
- 39 403 • Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for
40 404 leading the intervention which included duties of interacting with participants on a daily basis.
- 41 405 • Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation
42 406 and were responsible for collecting data at the baseline and post-intervention time points.
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53 407 **Data Sharing**
54 408

- 55 409 • Extra data is available by emailing Dr. Lucas Carr at lucas-carr@uiowa.edu.
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2 411 **Figure Legend**
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6 413 **Figure 1.** Sequence of events and recruitment/enrollment schematic. Study was coordinated at East
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9 414 Carolina University, Greenville, NC, from June 2011-June 2012.
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13 416 **Figure 2.** Images of intervention features: A. Portable pedal machine, B. Pedal machine activity
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15 417 tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot
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17 418 of the website homepage.
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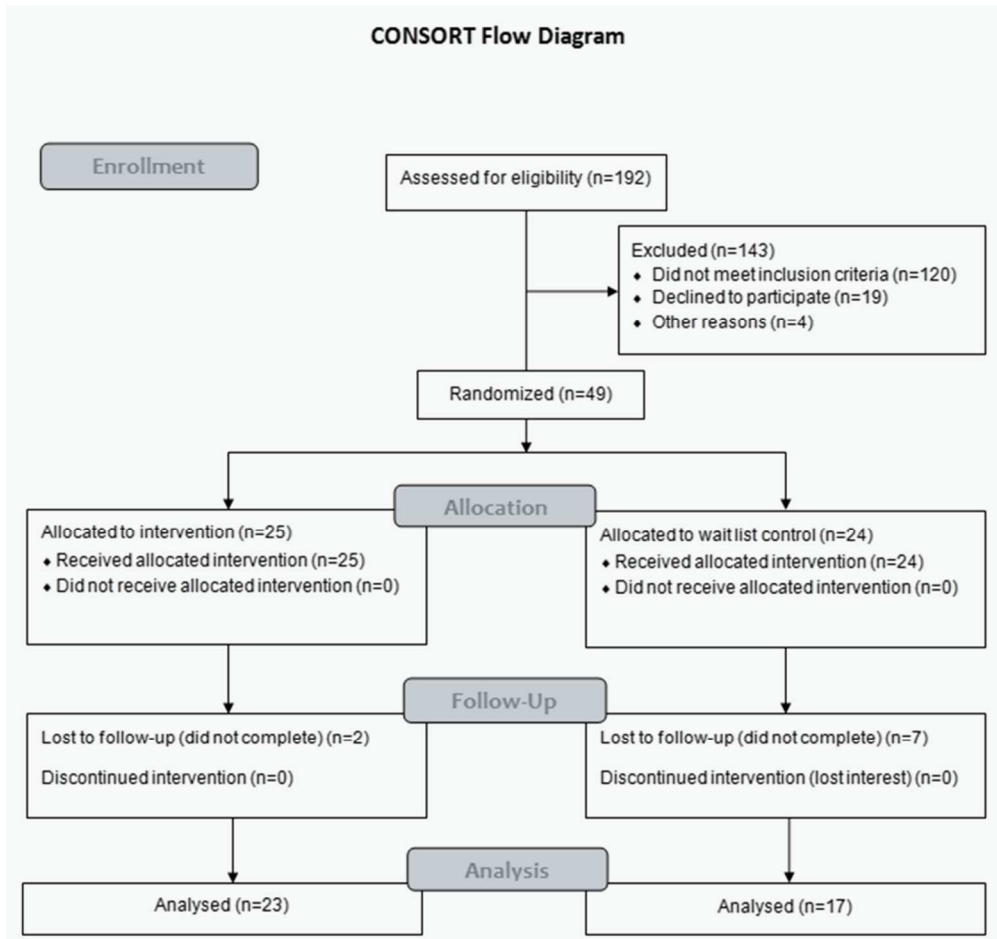
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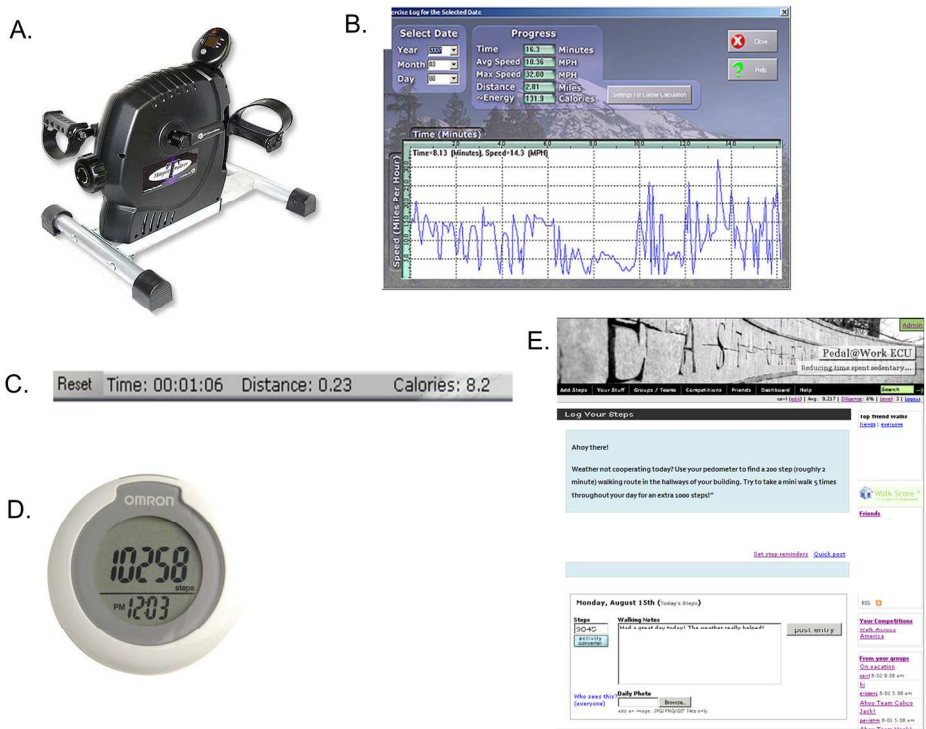


Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.
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CONSORT 2010 checklist of information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

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2	Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how
3			5&7
4		11b	If relevant, description of the similarity of interventions
5			NA
6	Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes
7		12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses
8			NA
9	Results		
10	Participant flow (a	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and
11	diagram is strongly		were analysed for the primary outcome
12	recommended)	13b	For each group, losses and exclusions after randomisation, together with reasons
13			5
14	Recruitment	14a	Dates defining the periods of recruitment and follow-up
15		14b	Why the trial ended or was stopped
16			5
17	Baseline data	15	A table showing baseline demographic and clinical characteristics for each group
18	Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was
19			by original assigned groups
20			5
20	Outcomes and	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its
21	estimation		precision (such as 95% confidence interval)
22		17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended
23			NA
24	Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing
25			pre-specified from exploratory
26			8-13
26	Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)
27			NA
28	Discussion		
29	Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses
30	Generalisability	21	Generalisability (external validity, applicability) of the trial findings
31	Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence
32			13-16
33	Other information		
34	Registration	23	Registration number and name of trial registry
35			ClinicalTrials.
36			gov
37			(NCT0137108
38			4)
39	Protocol	24	Where the full trial protocol can be accessed, if available
40			Oak Ridge
41			Associated
42			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}

¹Centers for Behavioral and Preventive Medicine, The Miriam Hospital, Providence, Rhode Island, USA

²Department of Exercise and Sport Science, East Carolina University, Greenville, North Carolina, USA

³Program 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; carrlj@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

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Original article

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/m²; 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 were 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/m²) 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 protocol²⁹ 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

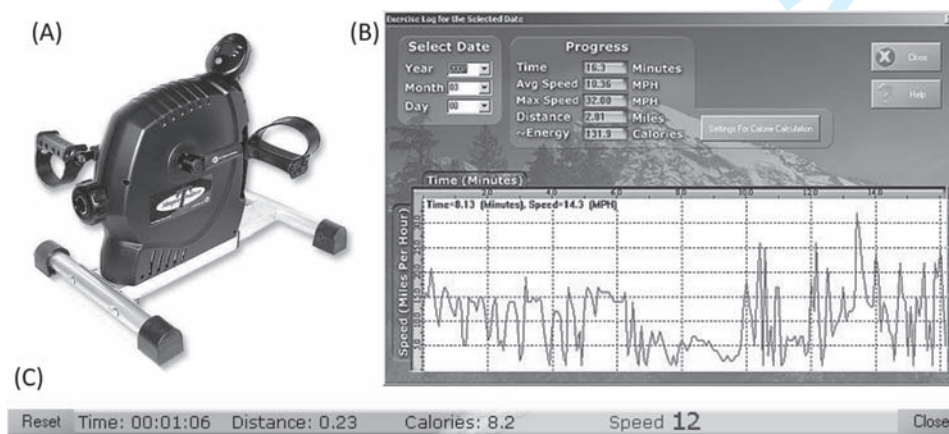


Figure 1 (A) The portable pedal exercise machine. (B) A screenshot of the exercise log, which provides feedback on pedal use activity per day. (C) A screenshot of the real-time monitor, which provides real-time feedback to the user.

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(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 pedalling 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/m²) 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 \pm SD and ranges of pedal time, pedal speed, distance pedalled and caloric expenditure

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

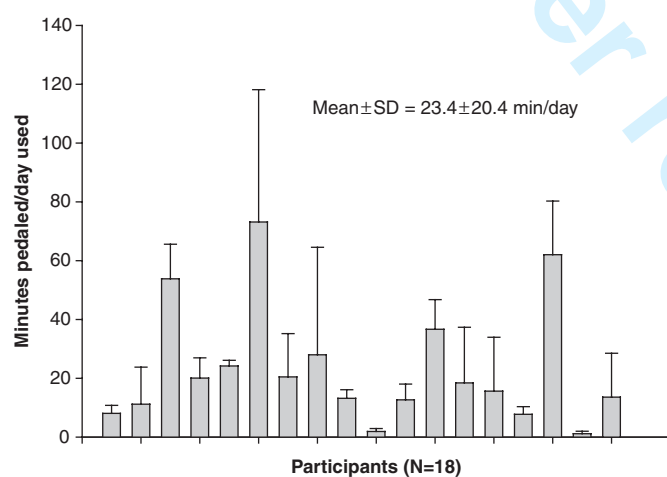
Data were downloaded using the FitXF exercise tracking software.

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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

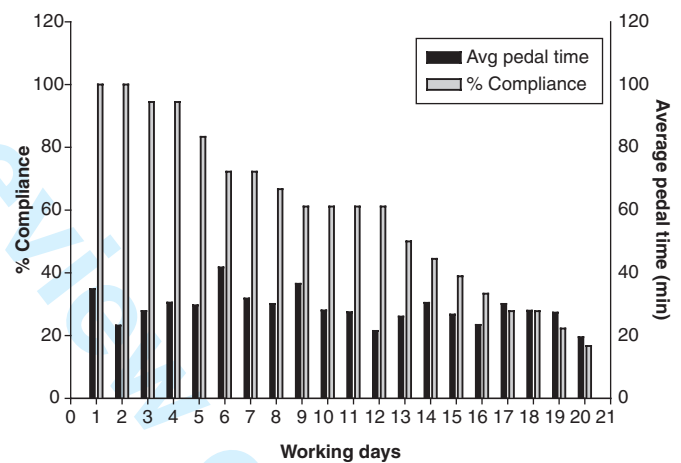
Do you agree or disagree with the following statement?	Q1	Median	Q3
If offered to me by my employer, I would use the machine while at work	4.3	5.0	5.0
My physical activity increased while at work as a result of the machine	3.0	4.0	5.0
My physical activity increased outside of work as a result of the 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).

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

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

serve as a means to monitor employee participation in work-site 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.

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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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Competing interests None.

Patient consent Obtained.

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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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2 1 **Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial**
3
4 2

5
6 3 **Corresponding Author:**
7

8 4 Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House
9
10 5 E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu
11
12 6

13
14
15 7 **Co-Authors:**
16

17 8 Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay,
18
19 9 Ontario, Canada
20

21 10 Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA
22

23 11 Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
24

25 12 Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
26
27 13

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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](https://clinicaltrials.gov/ct2/show/study/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

- 1
2 82 • Primary limitations of this study include: 1) small sample size (N=40) comprised primarily of
3
4 83 middle-aged females working at a single institution which limits generalizability; and 2)
5
6 84 differential drop out, although follow-up analyses indicate no differences between those that
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8 85 dropped and those that completed for age (P=0.48), BMI (P=0.63), or daily sedentary time
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10 86 (P=0.32).
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17 89 INTRODUCTION

19 90 Excessive time spent in sedentary behavior is an independent risk factor for multiple chronic
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21 91 health outcomes including cardiovascular disease,[1 2] type 2 diabetes,[3] hypertension,[4] metabolic
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23 92 syndrome[5] and obesity.[6] Conversely, recent acute experimental studies suggest interrupting
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25 93 and/or replacing excessive sedentary behavior with light intensity physical activity throughout the day
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27 94 may be effective for improving various cardiometabolic disease risk factors .[7 8]The modern
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29 95 workplace has been identified as a setting in which individuals engage in prolonged bouts of
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31 96 sedentary time [9]. Adults working in full-time sedentary jobs are at particular risk for being sedentary
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33 97 as they often spend more than 75% of work time sitting[9-11].Currently, more than 27% of the U.S.
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35 98 labor force works in low-activity occupations.[12] The observed decline in occupational energy
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37 99 expenditure (~100 kcals/day) over the past 50 years has been identified as a key contributor to the
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39 100 observed increase in mean body mass amongst U.S. adults over the same time period.[13]
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41 101 Traditional behaviorally focused worksite interventions have focused primarily on increasing physical
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43 102 activity and have resulted in modest effect sizes (Cohen's $d = 0.21-0.22$).[14 15] In a shift away from
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45 103 behaviorally focused approaches, studies grounded in social ecological theory[16] have begun testing
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47 104 the effect of modifying the work environment to reduce occupational sedentary time.
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51
52 105 To date, only a handful of sedentary interventions have been conducted in the worksite. While
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54 106 many early worksite sedentary interventions did not demonstrate effectiveness [17], more recent trials
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56 107 have shown promise for reducing sitting time [18-20]. Overall, many sedentary interventions studies
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58 108 conducted in the worksite have been limited by the use of self-report measures of sedentary time
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1
2 109 and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted
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4 110 reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and
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6 111 the possible desire/need of many employers and employees to remain seated while completing their
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8 112 work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a
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10 113 means for reducing sedentary time.

13 114 In a previous study testing the feasibility of modifying the work environment as a means of
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15 115 reducing occupational sedentary time through promoting active sitting, our team provided portable
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17 116 pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10].
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19 117 Importantly, participants rated the pedal machines as feasible and acceptable for use while
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21 118 completing their work. Further, despite a lack of any accompanying behavioral intervention,
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23 119 participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per
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25 120 day. Although these results are promising, it is possible the addition of a motivational behavioral
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27 121 intervention could result in increased pedaling compliance and reduced sedentary time.

30 122 The primary aim of the present study was to test the effectiveness of a multicomponent
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32 123 intervention for reducing daily sedentary time amongst a sample of sedentary, overweight, full-time
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34 124 working adults compared to a wait-list control group. We hypothesized that the intervention group
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36 125 would significantly reduce daily sedentary time compared to the wait-list control group after 12 weeks.
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38 126 As a secondary aim, we tested the effectiveness of intervention on cardiometabolic risk factors
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40 127 including measures of adiposity, blood pressure, estimated aerobic fitness and blood lipids. We
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42 128 hypothesized the intervention group would reduce their overall cardiometabolic disease risk
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44 129 compared to the wait-list control group. Finally, as an exploratory aim, we conducted a process
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46 130 evaluation to explore intervention compliance and identify helpful components of the intervention.
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48 131

52 132 **METHODS**

54 133 **Subjects and Design**

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2 135 Many sedentary interventions to date have been limited by short durations. Therefore, we
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4 136 conducted a 12 week randomized controlled trial design comparing a treatment group to a no
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6 137 treatment wait-list control group. We recruited apparently healthy but physically inactive (self-reporting
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8 138 less than 60 minutes of moderate-to-vigorous intensity physical activity per week), overweight (body
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10 139 mass index (BMI) ≥ 25.0 kg/m²) adults working in full-time (reporting minimum of 35.0+ hours/week)
11
12 140 sedentary/desk-dependent occupations (reporting minimum of 75% of working time spent sitting).
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14 141 Participants were required to gain permission from their supervisor prior to enrollment. Research staff
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16 142 members screened participants for eligibility by telephone. Exclusionary criteria included: 1)
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18 143 limitations with or contraindications to ambulatory exercise; 2) acute illness or injury; 3) cognitive
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20 144 impairment, psychosis, or other diagnosed psychological illness (with the exception of depression and
21
22 145 anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic condition such as heart
23
24 146 failure or cancer. Participants were not compensated for participation in the study. Experimental
25
26 147 protocols were approved by the University and Medical Center Institutional Review Board and
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28 148 voluntary written informed consent was obtained from each participant.

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32 149 Participants of all races and ethnic backgrounds working at a large southern university were
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34 150 passively recruited through email advertisements placed on an electronic mailing list serve that
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36 151 served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were
37
38 152 excluded from participation due to: not meeting eligibility criteria which primarily consisted of not
39
40 153 meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other
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42 154 reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using
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44 155 an online random sequence generator.[21] Participants were assigned to one of two groups by a
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46 156 research staff member not involved in data collection based on the order in which they enrolled into
47
48 157 the study. A total of 49 participants deemed interested and eligible for participation were randomized
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50 158 to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40
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52 159 participants completed all baseline and post-intervention assessments. Nine participants were lost to
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54 160 follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention
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56 161 participants and 17 control participants (see Table 1). More than half of all participants were college
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2 162 educated, reported an annual income greater than \$40,000 and reported being non-Hispanic/White.

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4 163 Participants were enrolled and completed all testing sessions between June 2011 and June 2012.

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9 165 [Figure 1 here]

10 166 11 12 13 167 **Group Descriptions**

14 15 168 16 17 169 *Wait List Control Group*

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19 170 Participants randomized to the wait-list control group were asked to maintain their current
20 171 behaviors for 12 weeks at which time they were given the option to receive the intervention treatment
21 172 materials.
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26 173 27 28 174 *Intervention Group*

29
30 175 The primary intent of the intervention was to encourage participants to reduce their time spent
31 176 sedentary. The name used to promote the study on advertisements and study materials was
32 177 "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three
33 178 primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley,
34 179 CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive
35 180 tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer
36 181 to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height,
37 182 20" length) device that has been demonstrated as acceptable for use during sedentary office work
38 183 [10]. Because participants were sedentary employees working in professional environments, the
39 184 rationale for providing them pedal machines at work was to allow them to engage in light intensity
40 185 activity (i.e. active sitting) that they could perform for long periods throughout the day without causing
41 186 them to perspire. The pedal machine is accompanied by a PC interface and software package that
42 187 allows for objective monitoring of individual pedal activity. This software also provides the user with
43 188 real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The
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1
2 189 research team delivered the pedal machine to each participant's worksite, downloaded the pedal
3
4 190 tracking software to the participant's work computer, and worked with the participant to identify the
5
6 191 most feasible set up. Intervention participants were asked to keep the pedal machine connected to
7
8 192 their PC during all working hours. Intervention participants were required to gain clearance to use the
9
10 193 pedal machines and software at their work prior to participation. No additional interaction between the
11
12 194 research staff and participant's supervisors occurred during the course of the study. Participants were
13
14 195 located in 18 different buildings across campus. No participants worked within visible proximity of
15
16 196 each other.
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18

19 197 Intervention participants were also provided access to a motivational website that was
20
21 198 individually customized to the local culture of the worksite of which participants were recruited (Figure
22
23 199 2). Examples of customization included posting local images and messages specific to the local
24
25 200 institution. The content of the intervention focused primarily on reducing time spent sedentary (both
26
27 201 increasing active sitting via pedaling and taking breaks from sitting). Example messages included
28
29 202 "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up
30
31 203 burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at
32
33 204 work although some messages broadly targeted sedentary time in general and could have impacted
34
35 205 sedentary time outside of work. Messages were theory based targeting constructs of the Social
36
37 206 Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived
38
39 207 environment. For example, participants were prompted via daily email messages to self-monitor their
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41 208 daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on
42
43 209 the website was used to fuel a virtual competition (aimed at building social support) in which small
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45 210 groups of intervention participants (4-5 per group) collectively traveled across America. Participants
46
47 211 were also emailed three theory-based motivational messages each week targeting goal setting, self-
48
49 212 efficacy, and perceived environment. Specific goals were not set for intervention participants, rather
50
51 213 participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try
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53 214 fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook,
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1
2 215 participants were able to post profile photos and status updates on a newsfeed and send messages
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4 216 to members of their small groups further fostering social support.
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11 219 12 13 220 **Measures**

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15 221 All measures were collected at baseline and post-intervention (12 weeks) in a controlled
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17 222 laboratory setting by two staff members blinded to participant's group assignment. The two staff
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19 223 members were provided specific measurement duties to ensure each measure was collected by the
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21 224 same staff member at both baseline and post-intervention. The primary outcome was daily sedentary
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24 225 time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations,
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26 226 Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn
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28 227 on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the
29
30 228 StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for
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32 229 steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both
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34
35 230 sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The
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37 231 StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when
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39 232 compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the
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41 233 monitor during all wakeful hours for seven consecutive days and keep track of wear time using an
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43 234 activity log. Days in which participants wore the monitors for less than 10 hours were excluded from
44
45 235 final analysis.. The threshold for sedentary (0 steps/min) was based on the recommendation provided
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47 236 by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75 steps/min)
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50 237 and vigorous (76+ steps/min) intensity physical activities were based on previous work which
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52 238 demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute depending
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54 239 on height and stride length[26].
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56 240 Blood pressure was measured with a stethoscope and sphygmomanometer using standard
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58 241 techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass
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2 242 was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade
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4 243 digital medical scale and height rod (Seca 769, Hanover,MD). Waist circumference was measured in
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6 244 duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood
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8 245 lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger
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10 246 stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been
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12 247 demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively),
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14 248 HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%
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16 249 respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill
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18 250 walking test which had been previously demonstrated as a valid estimate of total aerobic fitness
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20 251 amongst middle-aged adults.[29]

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22 252 Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was
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24 253 assessed objectively via the activity tracking software. Pedal compliance data was downloaded
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26 254 directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g.,
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28 255 number of website logins, number of steps logged on the website) was assessed objectively at the
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30 256 end of 12 weeks via a backend tracking database made available by the website administrators. In
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32 257 order to assess which components of the intervention participants 'perceived' as helpful for reducing
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34 258 their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention
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36 259 completers. Participants rated each intervention component using a five point Likert scale.
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43 261 **Design/Statistical Analysis**

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45 262 A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80%
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47 263 power, at $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference
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49 264 was identified as a reasonable estimate based on our previous study in which participants used the
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51 265 same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means
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53 266 (SD) were used to describe data where appropriate. This study was not powered to detect differences
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55 267 in the measured cardiometabolic risk factors. These measures were collected as secondary outcomes
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57 268 and to inform future trials.
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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 \pm 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 ± 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

1				
2	Access to pedal exercise machine at work	4.0	4.0	5.0
3				
4	'Walk Across America' Group Challenge on website	3.0	3.0	5.0
5				
6	Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
7				
8	Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8
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DISCUSSION

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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 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]

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2 353 However, this study did not include a control group. In a study that did include a control group, Evans
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4 354 et al. found no between group differences in objectively measured sitting time after five days of point-
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6 355 of-choice software reminders to stand up every 30 minutes while at work.[19]
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9 356 We also observed a significant intervention effect for waist circumference. This finding is
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11 357 important as waist circumference has been shown to predict mortality amongst adults with coronary
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13 358 artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist
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15 359 circumference to be sensitive to change in the absence of changes in other measures of adiposity[36]
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17 360 as well as studies reporting interruptions from sedentary time to be associated with waist
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19 361 circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-
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21 362 delivered physical activity program which demonstrated modest improvements in daily steps and
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23 363 waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the
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26 364 low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration
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28 365 are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk
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30 366 reduction.
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32 367 Participant compliance to the website overall was high with participants logging into the
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34 368 website an average of 71% of all intervention days. This is important as past internet-delivered
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36 369 intervention studies have identified engagement to be a challenge [38 39] and a predictor of
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38 370 intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical
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40 371 activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high
41
42 372 website compliance in the present study may be due to the tailoring of the website to include locally
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44 373 relevant images and messages and/or the regular email messages.
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47 374 Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day)
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49 375 was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These
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51 376 findings suggest the added motivational intervention, which included suggestions for setting goals and
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53 377 finding time to pedal each day, resulted in improved daily compliance that was sustained over a
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55 378 longer duration. Despite the logistical limitation of the portable pedal machine when paired with
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57 379 standard height desks (i.e., many participants reported their knees hit the underside of their desk
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1
2 380 while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize
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4 381 compliance with such portable pedal machines in future studies, it is recommended these devices be
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6 382 paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.
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9 383 Intervention participants reported features that provided feedback including the pedal machine
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11 384 tracking software, pedometers and self-monitoring daily activity on the website (which was
12
13 385 immediately followed by a graph illustrating the individual's daily progress) as the most helpful
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15 386 features for reducing their daily sedentary time. This information is important and could be used to
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17 387 inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past
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19 388 studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

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21 389 The main limitation of the study was the limited generalizability due to a small sample size that
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23 390 comprised primarily of middle-aged females working at a single institution. We also experienced
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25 391 differential drop out, although follow-up analyses indicate no differences between those that dropped
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27 392 and those that completed for age, BMI, or daily sedentary time.
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30 393 The present study is among the first interventions conducted within the worksite aimed
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32 394 specifically at reducing daily sedentary time to demonstrate between group differences in objectively
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34 395 measured sedentary time. Compliance with the motivational website was high while compliance with
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36 396 the pedal machine was moderate. These findings are promising considering the relatively low cost of
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38 397 the intervention which cost a total of \$180 (pedal machine and software, pedometer, access to
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40 398 website) per participant. While an intervention effect was observed for waist circumference, no
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42 399 between group differences were observed for any other cardiometabolic risk factors. More sedentary
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44 400 focused interventions are needed to examine whether reducing sedentary time can be sustained
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46 401 long-term and whether long-term changes result in significant reductions in risk for chronic diseases.
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1
2 406 **Competing Interests:** All authors have completed the ICMJE uniform disclosure form at
3
4 407 www.icmje.org/coi_disclosure.pdf and declare: no financial support from the funder Oak Ridge
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6 408 Associated Universities for the submitted work, no financial relationships with any organizations that
7
8 409 might have an interest in the submitted work in the previous three years, and no other relationships or
9
10 410 activities that could appear to have influenced the submitted work.
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14 411 **Contributorship Statement:**

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17
18 412 • Dr. Lucas Carr was responsible for the design of the study and led the manuscript preparation.
- 19
20 413 • Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript
21
22 414 preparation.
- 23
24 415 • Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for
25
26 416 leading the intervention which included duties of interacting with participants on a daily basis.
- 27
28 417 • Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation
29
30 418 and were responsible for collecting data at the baseline and post-intervention time points.
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34 419 **Data Sharing**

- 35 420
36 421 • No additional data available.
37 422
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39 423 **Figure Legend**

40 424
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42 425 **Figure 1.** Sequence of events and recruitment/enrollment schematic. Study was coordinated at East
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44 426 Carolina University, Greenville, NC, from June 2011-June 2012.
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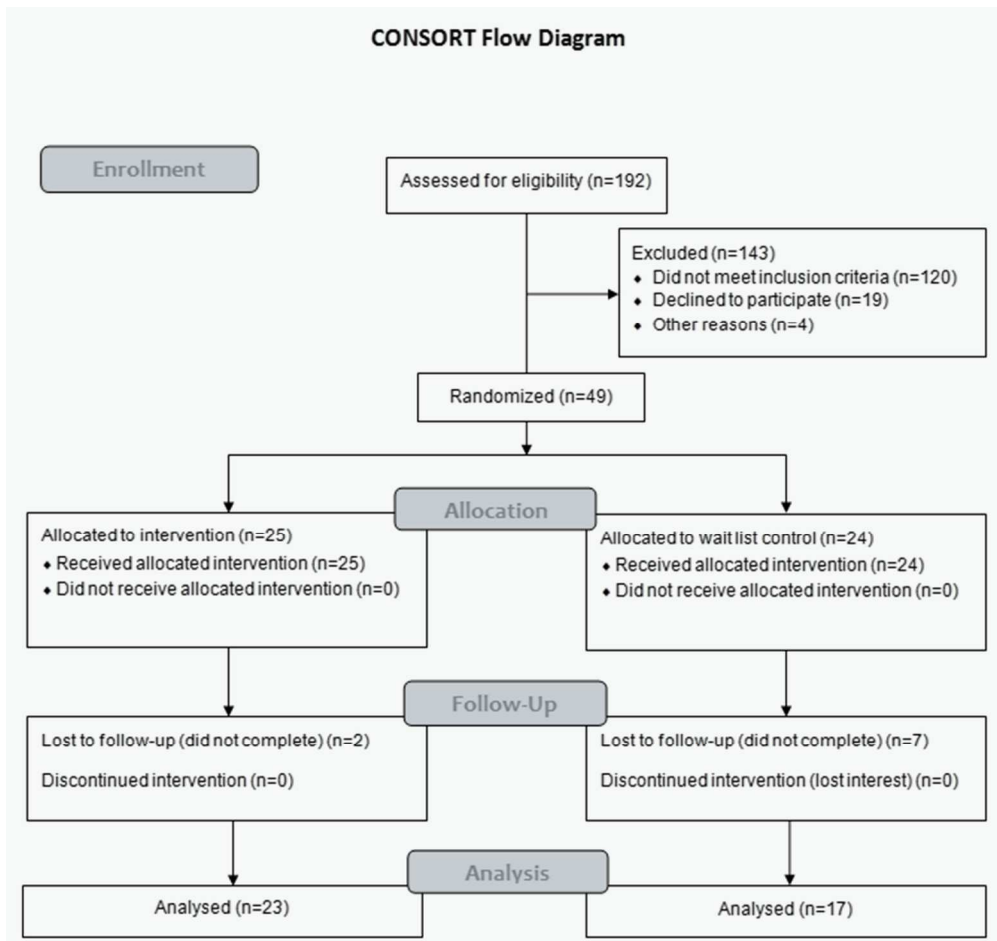
50 428 **Figure 2.** Images of intervention features: A. Portable pedal machine, B. Pedal machine activity
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52 429 tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot
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54 430 of the website homepage.
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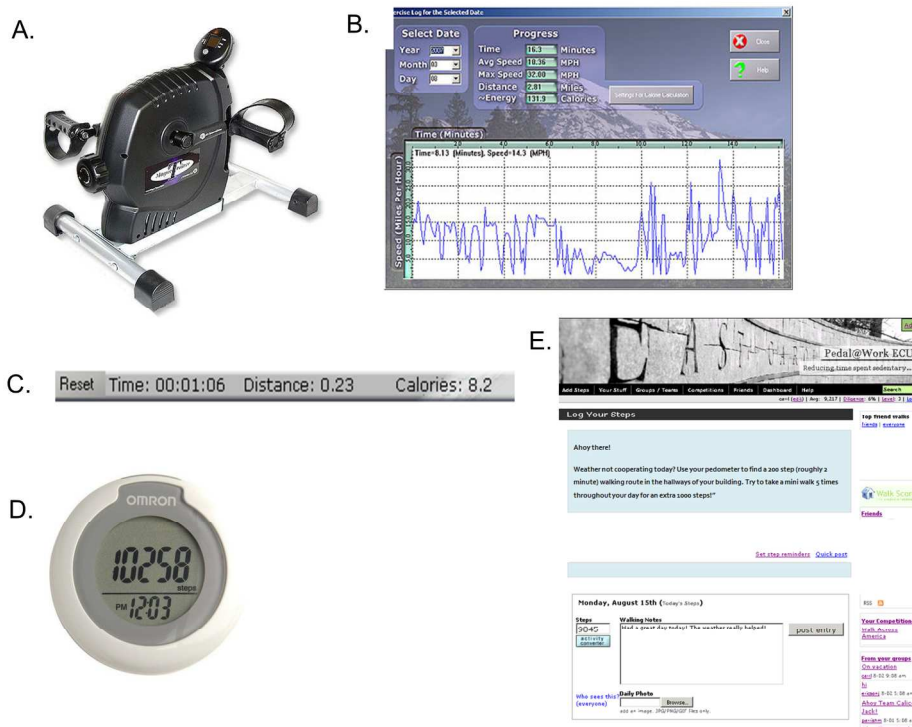


Figure 2. Images of intervention features: A. Portable pedal machine, B. Pedal machine activity tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot of the website homepage.

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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

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2	Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how
3			5&7
4		11b	If relevant, description of the similarity of interventions
5			NA
6	Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes
7		12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses
8			NA
9	Results		
10	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
11		13b	For each group, losses and exclusions after randomisation, together with reasons
12			5
13	Recruitment	14a	Dates defining the periods of recruitment and follow-up
14		14b	Why the trial ended or was stopped
15			5
16	Baseline data	15	A table showing baseline demographic and clinical characteristics for each group
17	Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups
18			Table 1 (p.9)
19			5
20	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)
21		17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended
22			8-13
23	Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory
24			NA
25			8-13
26	Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)
27			NA
28	Discussion		
29	Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses
30	Generalisability	21	Generalisability (external validity, applicability) of the trial findings
31	Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence
32			15
33			15
34			13-16
35	Other information		
36	Registration	23	Registration number and name of trial registry
37			ClinicalTrials.gov (NCT01371084)
38			4)
39	Protocol	24	Where the full trial protocol can be accessed, if available
40			Oak Ridge Associated Universities
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44	CONSORT 2010 checklist		
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Grant
(#212112)

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5 Funding 25 Sources of funding and other support (such as supply of drugs), role of funders
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7 *We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the
8 items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological
9 treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist,
10 see www.consort-statement.org.
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2 1 **Multicomponent Intervention to Reduce Daily Sedentary Time: A Randomized Controlled Trial**
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6 3 **Corresponding Author:**
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8 4 Lucas J. Carr, Ph.D.; University of Iowa; Department of Health and Human Physiology; Field House
9 5 E118; Iowa City, IA 52242; Phone: (319)353-5432; Email: Lucas-Carr@uiowa.edu
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14
15 7 **Co-Authors:**
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17 8 Kristina Karvinen, Ph.D.; School of Physical and Health Education; Nipissing University; North Bay,
18 9 Ontario, Canada
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21 10 Mallory Peavler, M.S., Department of Kinesiology; East Carolina University; Greenville, NC, USA
22

23 11 Rebecca Smith, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
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26 12 Kayla Cangelosi, M.S.; Department of Kinesiology; East Carolina University; Greenville, NC, USA
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30 14 **Word Count:**
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32 15 **Keywords:** sedentary, multicomponent, cardiometabolic
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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](https://clinicaltrials.gov/ct2/show/study/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

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2 109 conducted in the worksite have been limited by the use of self-report measures of sedentary time
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4 110 and/or short duration interventions (1-4 weeks). Further, most studies in this area have promoted
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6 111 reduced 'sitting time'. Given the recent availability of seated activity permissive workstations [10] and
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8 112 the possible desire/need of many employers and employees to remain seated while completing their
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10 113 work, there is a need for interventions that promote 'active sitting' as opposed to 'reduced sitting' as a
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12 114 means for reducing sedentary time.

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15 115 In a previous study testing the feasibility of modifying the work environment as a means of
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17 116 reducing occupational sedentary time through promoting active sitting, our team provided portable
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19 117 pedal machines (MagneTrainer, 3D Innovations) to 18 sedentary desk workers for four weeks [10].
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21 118 Importantly, participants rated the pedal machines as feasible and acceptable for use while
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23 119 completing their work. Further, despite a lack of any accompanying behavioral intervention,
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25 120 participants used the pedal machines on 61% of all work days for an average of 23.4 minutes per
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27 121 day. Although these results are promising, it is possible the addition of a motivational behavioral
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29 122 intervention could result in increased pedaling compliance and reduced sedentary time.
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32 123 The primary aim of the present study was to test the effectiveness of a multicomponent
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34 124 intervention for reducing daily sedentary time ~~and improving cardiometabolic risk factors~~ amongst a
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36 125 sample of sedentary, overweight, full-time working adults compared to a wait-list control group. We
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38 126 hypothesized that the intervention group would significantly reduce daily sedentary time ~~and select~~
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40 127 ~~cardiometabolic disease risk factors~~ compared to the wait-list control group after 12 weeks. As a
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42 128 secondary aim, we tested the effectiveness of intervention on cardiometabolic risk factors including
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44 129 measures of adiposity, blood pressure, estimated aerobic fitness and blood lipids. We hypothesized
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46 130 the intervention group would reduce their overall cardiometabolic disease risk compared to the wait-
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48 131 list control group. Finally, as an exploratory aim, we conducted a process evaluation to explore
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50 132 intervention compliance and identify helpful components of the intervention.
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55 134 **METHODS**

56 135 **Subjects and Design**

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4 137 Many sedentary interventions to date have been limited by short durations. Therefore, we
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6 138 conducted a 12 week randomized controlled trial design comparing a treatment group to a no
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9 139 treatment wait-list control group. We recruited apparently healthy but [physically inactive sedentary](#)
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11 140 (self-reporting less than 60 minutes of moderate-to-vigorous intensity physical activity per week),
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13 141 overweight (body mass index (BMI) ≥ 25.0 kg/m²) adults working in full-time (reporting minimum of
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15 142 35.0+ hours/week) sedentary/desk-dependent occupations (reporting minimum of 75% of working
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17 143 time spent sitting). Participants were required to gain permission from their supervisor prior to
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19 144 enrollment. Research staff members screened participants for eligibility by telephone. Exclusionary
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21 145 criteria included: 1) limitations with or contraindications to ambulatory exercise; 2) acute illness or
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23 146 injury; 3) cognitive impairment, psychosis, or other diagnosed psychological illness (with the exception
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26 147 of depression and anxiety); 4) currently using psychotropic drugs; or 5) diagnosis of a chronic
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28 148 condition such as heart failure or cancer. Participants were not compensated for participation in the
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30 149 study. Experimental protocols were approved by the University and Medical Center Institutional
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32 150 Review Board and voluntary written informed consent was obtained from each participant.

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35 151 Participants of all races and ethnic backgrounds working at a large southern university were
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37 152 passively recruited through email advertisements placed on an electronic mailing list serve that
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39 153 served 5,392 employees. A total of 192 people responded to our advertisements of which 143 were
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41 154 excluded from participation due to: not meeting eligibility criteria which primarily consisted of not
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43 155 meeting BMI and/or physical activity requirements (N=120); declined to participate (N=19); or other
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45 156 reasons (N=4). A 1:1 random allocation sequence was generated by the principal investigator using
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47 157 an online random sequence generator.[21] Participants were assigned to one of two groups by a
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50 158 research staff member not involved in data collection based on the order in which they enrolled into
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52 159 the study. A total of 49 participants deemed interested and eligible for participation were randomized
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54 160 to one of two groups: 1) intervention (N=25); 2) wait-list control (N=24). Of the 49 enrolled, 40
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56 161 participants completed all baseline and post-intervention assessments. Nine participants were lost to
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58 162 follow-up (see Figure 1). Final analyses were completed on 40 participants with 23 intervention
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2 163 participants and 17 control participants (see Table 1). More than half of all participants were college
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4 164 educated, reported an annual income greater than \$40,000 and reported being non-Hispanic/White.
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6 165 Participants were enrolled and completed all testing sessions between June 2011 and June 2012.
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11 167 [Figure 1 here]
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14 15 169 **Group Descriptions**

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18 19 171 *Wait List Control Group*

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21 172 Participants randomized to the wait-list control group were asked to maintain their current
22 173 behaviors for 12 weeks at which time they were given the option to receive the intervention treatment
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24 174 materials.
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29 30 176 *Intervention Group*

31
32 177 The primary intent of the intervention was to encourage participants to reduce their time spent
33
34 178 sedentary. The name used to promote the study on advertisements and study materials was
35
36 179 "*Pedal@Work: Reducing time spent sedentary...*". The intervention (Figure 2) comprised of three
37
38 180 primary components: 1) access to a portable pedal machine (MagneTrainer, 3D Innovations, Greeley,
39
40 181 CO) at their worksite; 2) access to a motivational website (Walker Tracker, Portland, OR) to receive
41
42 182 tips and reminders focused on reducing sedentary behaviors throughout the day; and 3) a pedometer
43
44 183 to use in conjunction with the website (Omron HJ-150). The pedal machine is a portable (18" height,
45
46 184 20" length) device that has been demonstrated as acceptable for use during sedentary office work
47
48 185 [10]. Because participants were sedentary employees working in professional environments, the
49
50 186 rationale for providing them pedal machines at work was to allow them to engage in light intensity
51
52 187 activity (i.e. active sitting) that they could perform for long periods throughout the day without causing
53
54 188 them to perspire. The pedal machine is accompanied by a PC interface and software package that
55
56 189 allows for objective monitoring of individual pedal activity. This software also provides the user with
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1
2 190 real-time feedback via a display monitor on pedal time, distance, speed and caloric expenditure. The
3
4 191 research team delivered the pedal machine to each participant's worksite, downloaded the pedal
5
6 192 tracking software to the participant's work computer, and worked with the participant to identify the
7
8 193 most feasible set up. Intervention participants were asked to keep the pedal machine connected to
9
10 194 their PC during all working hours. Intervention participants were required to gain clearance to use the
11
12 195 pedal machines and software at their work prior to participation. No additional interaction between the
13
14 196 research staff and participant's supervisors occurred during the course of the study. Participants were
15
16 197 located in 18 different buildings across campus. No participants worked within visible proximity of
17
18 198 each other.
19

20
21
22 199 Intervention participants were also provided access to a motivational website that was
23
24 200 individually customized to the local culture of the worksite of which participants were recruited (Figure
25
26 201 2). Examples of customization included posting local images and messages specific to the local
27
28 202 institution. The content of the intervention focused primarily on reducing time spent sedentary (both
29
30 203 increasing active sitting via pedaling and taking breaks from sitting). Example messages included
31
32 204 "Let's try to pedal an extra five minutes during your lunch break today" and "Did you know standing up
33
34 205 burns more calories than sitting? Maybe it's time for a break!?" Most messages targeted time spent at
35
36 206 work although some messages broadly targeted sedentary time in general and could have impacted
37
38 207 sedentary time outside of work. Messages were theory based targeting constructs of the Social
39
40 208 Cognitive Theory[22] including self-monitoring, social support, self-efficacy, and perceived
41
42 209 environment. For example, participants were prompted via daily email messages to self-monitor their
43
44 210 daily pedal time and daily steps (via pedometer) on the website. The activity participants logged on
45
46 211 the website was used to fuel a virtual competition (aimed at building social support) in which small
47
48 212 groups of intervention participants (4-5 per group) collectively traveled across America. Participants
49
50 213 were also emailed three theory-based motivational messages each week targeting goal setting, self-
51
52 214 efficacy, and perceived environment. Specific goals were not set for intervention participants, rather
53
54 215 participants received advice on how to set goals and suggestions for daily pedaling time (e.g. "Try
55
56 216 fitting in 10 minutes of pedaling during your lunch today.") Finally, using a forum similar to Facebook,
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1
2 217 participants were able to post profile photos and status updates on a newsfeed and send messages
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4 218 to members of their small groups further fostering social support.
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11 221 12 13 222 **Measures**

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15 223 All measures were collected at baseline and post-intervention (12 weeks) in a controlled
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17 224 laboratory setting by two staff members blinded to participant's group assignment. The two staff
18
19 225 members were provided specific measurement duties to ensure each measure was collected by the
20
21 226 same staff member at both baseline and post-intervention. The primary outcome was daily sedentary
22
23 227 time as measured objectively by the StepWatch physical activity monitor (Orthocare Innovations,
24
25 228 Mountlake Terrace, Wash, USA). The StepWatch was specifically chosen for this study as it is worn
26
27 229 on the ankle making it ideally suited to measure both pedaling and walking behavior. Further, the
28
29 230 StepWatch has been demonstrated as a reliable measure of walking behavior (3 day agreements for
30
31 231 steps per day (39.1%) and percent inactive time (9.52%)) [23] and an accurate measure of both
32
33 232 sedentary behaviors (89.8-99.5% accurate) and light intensity walking (86.1% accurate)[24]. The
34
35 233 StepWatch has demonstrated superior ability for detecting pedaling time (23.5-54.4% accurate) when
36
37 234 compared to hip worn accelerometers (8.1-47.1% correct).[25] Participants were asked to wear the
38
39 235 monitor during all wakeful hours for seven consecutive days and keep track of wear time using an
40
41 236 activity log. Days in which participants wore the monitors for less than 10 hours were excluded from
42
43 237 final analysis. ~~Intervention participants wore the StepWatch monitor an average of 5.7 of 7.0 (81.0%)~~
44
45 238 ~~days for 14.5 hours/day while control participants wore the monitor an average of 5.5 days (78.6%) for~~
46
47 239 ~~13.8 hours/day.~~ The threshold for sedentary (0 steps/min) was based on the recommendation
48
49 240 provided by the product manufacturer. The thresholds for light (1–45 steps/min), moderate- (46-75
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51 241 steps/min) and vigorous (76+ steps/min) intensity physical activities were based on previous work
52
53 242 which demonstrated moderate-intensity walking stride rate to range from 90–113 steps/minute
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55 243 depending on height and stride length[26].
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1
2 244 Blood pressure was measured with a stethoscope and sphygmomanometer using standard
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4 245 techniques. Heart rate was monitored with a Polar™ heart rate monitor and chest strap. Body mass
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6 246 was measured to the nearest 0.1 kg and height to the nearest 0.5 cm using a professional grade
7
8 247 digital medical scale and height rod (Seca 769, Hanover, MD). Waist circumference was measured in
9
10 248 duplicate with a standard Gulick measuring tape according to standard procedures.[27] Fasting blood
11
12 249 lipids (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides) were assessed via finger
13
14 250 stick and using a point-of-care analyzer (Cholestech LDX analyzer) that has previously been
15
16 251 demonstrated as an accurate and precise measure of total cholesterol (1.6% and 3.0% respectively),
17
18 252 HDL-cholesterol (-2.74% and 1.05% respectively) and triglycerides (2.11% and 2.65%
19
20 253 respectively).[28] Estimated aerobic fitness was assessed via a single-stage submaximal treadmill
21
22 254 walking test which had been previously demonstrated as a valid estimate of total aerobic fitness
23
24 255 amongst middle-aged adults.[29]

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26 256 Compliance with the pedal machine (i.e., minutes pedaled/day, total days pedaled) was
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28 257 assessed objectively via the activity tracking software. Pedal compliance data was downloaded
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30 258 directly from each individual's work computer at the end of 12 weeks. Website use compliance (e.g.,
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32 259 number of website logins, number of steps logged on the website) was assessed objectively at the
33
34 260 end of 12 weeks via a backend tracking database made available by the website administrators. In
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36 261 order to assess which components of the intervention participants 'perceived' as helpful for reducing
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38 262 their sedentary time, a process evaluation survey was conducted at 12 weeks amongst intervention
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40 263 completers. Participants rated each intervention component using a five point Likert scale.
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47 265 **Design/Statistical Analysis**

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49 266 A sample size of 40 (recruiting 49 assuming 20% attrition) was necessary to detect, with 80%
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51 267 power, at $\alpha=0.05$, a 30 minute/day difference in daily sedentary time. The 30 minute/day difference
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53 268 was identified as a reasonable estimate based on our previous study in which participants used the
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55 269 same pedal machines an average of 23 minutes/day without any motivational intervention.[10] Means
56
57 270 (SD) were used to describe data where appropriate. This study was not powered to detect differences
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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 \pm 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%
<u>Job Category (%)</u>			
<u>Professional/Executive</u>	<u>35.0%</u>	<u>52.0%</u>	<u>45.0%</u>
<u>Administrative</u>	<u>65.0%</u>	<u>48.0%</u>	<u>55.0%</u>

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)
<u>Monitor Wear Time (Min/day)</u>					
<u>Control</u>	<u>829.6(93.5)</u>	<u>869.5(94.1)</u>		<u>0.10</u>	<u>0.15</u>
<u>Intervention</u>	<u>867.1(142.8)</u>	<u>827.2(71.9)</u>		<u>0.42</u>	
<u>Minutes Sedentary (Min/day)</u>					
Control	544.2(76.9)	599.7(106.6)	+55.5 (2.8, 108.1)	0.04*	<0.01**
Intervention	584.9(136.1)	526.1(77.3)	-58.7 (-118.4, 0.99)	0.04*	
<u>% Time Sedentary</u>					
Control	65.7(7.5)	67.5(8.0)	-1.8% (-2.7%, 6.3%)	0.41	0.06
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	

1						
2	Intervention	31.8(5.0)	31.9(5.0)	-0.1 (-0.3, 0.5)	0.57	
3	Systolic BP (mmHg)					0.70
4	Control	117.1(13.0)	117.5(12.8)	-0.8 (-5.0, 3.6)	0.71	
5	Intervention	120.0(13.8)	115.7(10.8)	-4.3 (-8.0, -0.7)	0.02*	
6	Diastolic BP (mmHg)					0.51
7	Control	72.8(10.3)	73.2(10.6)	-0.1 (-5.0, 4.8)	0.96	
8	Intervention	78.2(10.3)	75.4(7.4)	-2.8 (-6.2, 0.7)	0.11	
9	Waist Circumference (cm)					0.03**
10	Control	92.9(11.1)	93.9(10.8)	+1.0 (-0.7, 2.7)	0.22	
11	Intervention	92.6(11.2)	91.6(11.3)	-1.0 (-2.1, 0.3)	0.06	
12	Estimated V02 (ml/kg/min)					0.10
13	Control	29.6(2.5)	30.0(2.6)	+0.3 (-0.1, 0.8)	0.14	
14	Intervention	30.8(5.1)	31.1(4.6)	+0.3 (-0.6, 1.1)	0.53	
15	Total Cholesterol (mg/dL)					0.83
16	Control	184.4(25.9)	185.0(18.9)	-0.8 (-15.1, 13.4)	0.91	
17	Intervention	191.4(26.3)	189.7(27.0)	+0.7 (-5.9, 7.2)	0.83	
18	HDL (mg/dL)					0.65
19	Control	47.6(18.4)	46.7(18.9)	-0.9 (-6.8, 5.1)	0.76	
20	Intervention	45.7(17.6)	43.7(16.4)	-2.1 (-8.1, 3.4)	0.46	
21	LDL (mg/dL)					0.96
22	Control	111.2(32.1)	120.2(25.3)	+5.4 (-11.3, 22.1)	0.50	
23	Intervention	119.4(23.2)	116.7(29.4)	-3.7 (-12.8, 5.4)	0.41	
24	Triglycerides					0.91
25	Control	130.6(65.4)	131.0(59.9)	+4.7 (-24.0, 33.3)	0.73	
26	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

1				
2	Email reminders to log physical activity on website	4.0	4.0	5.0
3				
4	Access to pedal exercise machine at work	4.0	4.0	5.0
5				
6	'Walk Across America' Group Challenge on website	3.0	3.0	5.0
7				
8	Social networking features on website (profile, newsfeed, messaging)	3.0	3.0	4.0
9				
10	Environmental features (Walkscore, information on facilities)	3.0	3.0	3.8
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13	334			
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18 336 DISCUSSION

19 337 The primary findings of this study suggest that this multicomponent intervention resulted in
20 338 significant time spent sedentary in a small sample of inactive, overweight employees. The decreased
21 339 sedentary time observed among the intervention group appears to have been at least partially
22 340 replaced by an increase in moderate intensity activity. Our findings are important as the present study
23 341 was among the first worksite interventions to promote 'active sitting' as a means of reducing
24 342 sedentary time. Further, the present study was conducted over a longer duration (12 weeks)
25 343 compared to similar trials [19 31] [which is necessary in order to determine whether the intervention](#)
26 344 [instills habitual behavior change and/or whether such behavior change results in changes in](#)
27 345 [cardiometabolic outcomes. While longer trials are necessary to confirm whether sedentary employees](#)
28 346 [will adhere to such an intervention, process evaluation data suggests](#) participants [engaged with the](#)
29 347 [intervention and maintained engagement through the 12 weeks. This study also](#) utilized an objective
30 348 measure of sedentary/physical activity behavior whereas many previous interventions have relied
31 349 upon self-report measures of sedentary time[17]. The present study builds upon past studies as our
32 350 study was among the first to demonstrate significant reductions in objectively measured sedentary
33 351 time when compared to a control group. This is important, as it has been suggested that decreasing
34 352 sedentary time can result in improved health benefits independent of physical activity.[2 32-34]

35 353 Sedentary time amongst the intervention group was reduced by an average of 58 minutes/day
36 354 or 3.7% of daily time. Our findings are within the range of similar studies. For example, Kozy-Keadle
37 355 et al. found daily sedentary time reduced from 67.0% to 62.7% after a simple, seven day intervention
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2 356 that included educational materials on sedentary health risks and tips to reduce sedentary time.[31]

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4 357 However, this study did not include a control group. In a study that did include a control group, Evans
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6 358 et al. found no between group differences in objectively measured sitting time after five days of point-
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9 359 of-choice software reminders to stand up every 30 minutes while at work.[19]

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11 360 We also observed a significant intervention effect for waist circumference. This finding is
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13 361 important as waist circumference has been shown to predict mortality amongst adults with coronary
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15 362 artery disease.[35] Confidence in this finding is strengthened by past studies that have found waist
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17 363 circumference to be sensitive to change in the absence of changes in other measures of adiposity[36]
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19 364 as well as studies reporting interruptions from sedentary time to be associated with waist
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21 365 circumference.[37] Furthermore, this finding is consistent with findings of a previous 16-week internet-
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23 366 delivered physical activity program which demonstrated modest improvements in daily steps and
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25 367 waist circumference.[36] The lack of changes in other cardiometabolic risk factors may be due to the
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27 368 low intensity of the intervention as well as the limited duration of 12 weeks. Studies of longer duration
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29 369 are needed to determine whether long-term reduction in sedentary time results in cardiometabolic risk
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31 370 reduction.
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35 371 Participant compliance to the website overall was high with participants logging into the
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37 372 website an average of 71% of all intervention days. This is important as past internet-delivered
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39 373 intervention studies have identified engagement to be a challenge [38 39] and a predictor of
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41 374 intervention success.[40] By comparison, Lewis et al. reported participants logged on to a physical
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43 375 activity website a median number of 50 times (13.7%) over 12 months.[41] Reasons for such high
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45 376 website compliance in the present study may be due to the tailoring of the website to include locally
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47 377 relevant images and messages and/or the regular email messages.
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50 378 Participant compliance with the pedal machines in the present 12 week trial (31 minutes/day)
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52 379 was higher when compared to compliance in our previous four week trial (23 minutes/day).[10] These
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54 380 findings suggest the added motivational intervention, which included suggestions for setting goals and
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56 381 finding time to pedal each day, resulted in improved daily compliance that was sustained over a
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58 382 longer duration. Despite the logistical limitation of the portable pedal machine when paired with
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2 383 standard height desks (i.e., many participants reported their knees hit the underside of their desk
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4 384 while pedaling), participants used the pedal machine on a fairly regular basis. In order to maximize
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6 385 compliance with such portable pedal machines in future studies, it is recommended these devices be
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8 386 paired with height adjustable desks that allow for comfortable pedaling during computer work tasks.

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11 387 Intervention participants reported features that provided feedback including the pedal machine
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13 388 tracking software, pedometers and self-monitoring daily activity on the website (which was
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15 389 immediately followed by a graph illustrating the individual's daily progress) as the most helpful
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17 390 features for reducing their daily sedentary time. This information is important and could be used to
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19 391 inform future interventions aimed at reducing sedentary behavior. This finding is consistent with past
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21 392 studies which have found biofeedback as a useful tool to improve health behaviors.[42 43]

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23
24 393 The main limitation of the study was the limited generalizability due to a small sample size that
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26 394 comprised primarily of middle-aged females working at a single institution. We also experienced
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28 395 differential drop out, although follow-up analyses indicate no differences between those that dropped
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30 396 and those that completed for age, BMI, or daily sedentary time.

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32 397 The present study is among the first interventions conducted within the worksite aimed
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34 398 specifically at reducing daily sedentary time to demonstrate between group differences in objectively
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36 399 measured sedentary time. Compliance with the motivational website was high while compliance with
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38 400 the pedal machine was moderate. These findings are promising considering the relatively low cost of
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40 401 the intervention which cost a total of \$180 (pedal machine and software, pedometer, access to
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42 402 website) per participant. While an intervention effect was observed for waist circumference, no
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44 403 between group differences were observed for any other cardiometabolic risk factors. More sedentary
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46 404 focused interventions are needed to examine whether reducing sedentary time can be sustained
47
48 405 long-term and whether long-term changes result in significant reductions in risk for chronic diseases.
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52 406
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58 409
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1
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3
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5
6 412 Associated Universities for the submitted work, no financial relationships with any organizations that
7
8 413 might have an interest in the submitted work in the previous three years, and no other relationships or
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10 414 activities that could appear to have influenced the submitted work.
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14 415 **Contributorship Statement:**

- 17
18 416 • Dr. Lucas Carr was responsible for the design of the study and led the manuscript preparation.
- 19
20 417 • Dr. Kristina Karvinen assisted in the design of the study and assisted in the manuscript
21
22 418 preparation.
- 23
24 419 • Ms. Mallory Peavler contributed to the manuscript preparation and was solely responsible for
25
26 420 leading the intervention which included duties of interacting with participants on a daily basis.
- 27
28 421 • Ms. Rebecca Smith and Ms. Kayla Cangelosi both contributed to the manuscript preparation
29
30 422 and were responsible for collecting data at the baseline and post-intervention time points.
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34 423 **Data Sharing**

- 35 424 • Extra data is available by emailing Dr. Lucas Carr at lucas-carr@uiowa.edu.
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39 427 **Figure Legend**

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42 429 **Figure 1.** Sequence of events and recruitment/enrollment schematic. Study was coordinated at East
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44 430 Carolina University, Greenville, NC, from June 2011-June 2012.
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50 432 **Figure 2.** Images of intervention features: A. Portable pedal machine, B. Pedal machine activity
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52 433 tracking software screenshot, C. Pedal machine monitor feedback; D. Pedometer; and E. Screenshot
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54 434 of the website homepage.
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