Dynamic sitting: An under-the-table leg-movement device and energy expenditure

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ABSTRACT

Introduction. Work contributes significantly to sedentariness. Here, we evaluated an under-the-table device that was designed to promote leg movement whilst seated. Our hypothesis was the under-the-table device would increase energy expenditure.

Methods. We measured energy expenditure and heart rate in 26 people whilst they sat and worked using a standard chair, and used an under-the-desk device that encourages leg movement.

Results. Energy expenditure increased significantly while using the under-the-table device, when compared to the standard office chair (standard chair, 81 ± 18 kcal/hr; under-the-table device, 96 ± 23 kcal/hr (P < 0.001). The changes in energy expenditure were not as great as walking (1 mph, 168 ± 46 kcal/hour, P<0.001; 2 mph, 205 ± 51 kcal/hour).

Conclusions. An under-the-table device that promoted leg fidgeting can increase energy expenditure by about 20%. Dynamic sitting may be among a lexicon of options to help people move more whilst at work.

INTRODUCTION

Sedentariness is associated with a myriad of chronic diseases, impaired cognition (1) and obesity (2-5). The mechanism by which sitting excessively causes disease is not well understood but it is known that breaking up sitting improves insulin sensitivity and lipids (6). Several studies have examined the effectiveness of programs to displace sitting with standing or walking whilst working (7, 8). These measures can effectively decrease sitting time and improve productivity (6, 9, 10) although their long-term health benefits have not been proven.

When a person walks at even 1 mph, energy expenditure doubles when compared to basal metabolic rate (11, 12). Sitting, however even while fidgeting, is not substantially exothermic (5-10% increase above basal metabolic rate)(13-15). We wanted to assess whether a device that promotes, 'dynamic sitting' (16, 17) can increase energy expenditure significantly above resting values. To this end, we examined the thermogenic impact of under-the-table device designed specifically to encourage leg movement whilst sitting. We measured the changes in energy expenditure and heart rate that accompanied its use compared to using a standard office chair without the device. We compared these conditions to 1 and 2 mph walks since walking is known to improve health (18). Our hypothesis was that the under-the-table device was associated with increased in energy expenditure compared to using a standard office chair without the device. The null hypothesis was that the under-the-table device does not increase energy expenditure above resting values. The secondary hypothesis examined how 'dynamic sitting' and walking influenced heart rate.

SUBJECTS AND METHODS

Subjects

Subjects provided informed written consent and the Mayo Clinic IRB approved the protocol. Twenty-six participants (14 women and 12 men) were included with a mean (±SD) age, 23 ± 5 years; Body Mass Index (BMI), 26 ± 5.5 kg/m^2.

Standard Office Chair

Standard Office Chair (Control Chair). The Criterion model chair is a standard office chair (Steelcase, Grand Rapids, Michigan, USA).

Under-the-table leg-movement device (Figure 1).

HOVR® (Active Ideas Inc., Chicago IL) is a device designed to promote leg and lower body motion while in a seated position. It is made of molded plastic with aluminum footplates that rotate freely. HOVR allows unrestricted 270-degree motion of a user's legs. It weighs approximately one and a half pounds, has a length of 21 to 25 inches, with footplates that have diameters of seven inches.

Protocol

Participants were tested in thermal comfort, two hours after eating and after 30 minutes of rest. Prior to testing, subjects were shown the equipment and the experimental protocol was explained. Body composition was assessed.

Subjects were asked to sit on a Standard Office Chair (Steelcase Criterion) for 20 minutes while working, checking email, or using the Internet. During this time energy expenditure and heart rate were monitored. Subjects then continued their work-like activities and were provided with the under-the-table leg-movement device. Energy expenditure and heart rate were then measured for 20 minutes. Finally, subjects walked at 1 and 2 mph each for 20 minutes on a calibrated treadmill (4front, Woodway, Waukesha, WI); these speeds are comparable to those of people walking whilst at work (19).

Methods

Body composition

Participants body composition and weight were measured using a calibrated Seca Medical Body Composition Analyzer 514 (20)(Seca, Hamburg, Germany) in light clothing (athletic shorts and t-shirt) and height was measured using a Seca 219 stadiometer without shoes (Seca, Hamburg, Germany).2

Energy expenditure

Energy expenditure was measured using indirect calorimetry (14)(Metamax 3B; Cortex. Leipzig, Germany). The calorimeter was calibrated using 5.0% CO_2 15.0% O_2 balance nitrogen (Praxair, Danbury, CT, USA) and ambient air according to the manufacturer's specifications. In addition, it was volume calibrated before each participant using a 3L syringe. The calorimeter collects breath-by-breath CO_2 and O_2 production and consumption, respectively and energy expenditure is calculated using standard formulae (21).

Heart Rate Monitoring

Participants were also fitted with a Polar Heart Rate Monitor H7 (Polar Inc, Lake Success, NY, USA). Heart rate samples were recorded synchronized for each breath.

Statistical analysis

To address the primary hypothesis that the under-the-table leg-movement device was associated with increased energy expenditure and/or heart rate over resting values, ANOVA and post-hoc paired t-tests were used.

RESULTS

Subjects tolerated the protocol without complaint. Anthropometric and body composition data are shown in Table 1. Four additional subjects were studied (3 women, 1 man) but their data are not included in the analysis because their data sets were incomplete because of technical failures. Omitting these four subjects did not have influence the principal conclusion because in all four cases, energy expenditure increased using the under-the-table leg-movement device.

Energy expenditure for the two seated conditions (the standard chair, the under-the-table leg-movement device and slow walking (1 and 2 mph) are shown in Figure 2. While sitting in the standard office chair resting energy expenditure (sitting in a standard chair) showed a positive correlation with body weight (r=0.55, P=0.003). The relationship was described by the equation: Resting energy expenditure (Kcal/hr) = 0.544 * Weight (kg) + 39.7.

Energy expenditure increased significantly while using the under-the-table leg-movement device when compared to the standard office chair. Energy expenditure increased in 25/26 subjects from a mean of, 81 $\pm$ 18 kcal/hr to 96 $\pm$ 23 kcal/hr (P< 0.001); representing a mean increase of 18.4 $\pm$ 16.2 %. As expected energy expenditure for sitting on the standard chair correlated positively with energy expenditure using the under-the-table leg-movement device (r^2=0.76; P<0.001). Heart rate did not increase significantly when using the under-the-table leg-movement device compared to sitting on a standard office chair without the device (73 $\pm$ 12 cf 75 $\pm$14 beats/min).

Changes in energy expenditure using the under-the-table leg-movement device were not as great as for walking at 1 or 2 mph (Figure 2). The change in energy expenditure over the standard office chair were for the under-the-table leg-movement device, 15 ± 11 kcal/hr, for walking at 1 mph 86 ± 24 kcal/hr and walking at 2 mph 124 ± 39 kcal/hr. Slow walking was associated with significant increases in heart rate (rest, 73 ± 12 bpm, 1 mph 90 ± 36 bpm (<P<0.001) and 2 mph 111 ± 51 bpm (P<0.001) compared to sitting in a standard office chair.

Overall, an under-the-table leg-movement device that encourages movement while working was associated with an increase in energy expenditure by about 20% but was not associated with increased heart rate.

DISCUSSION

The importance of sedentariness in obesity and chronic disease has been established (2, 7, 22-26). Although sedentary behaviors occur both during work and whilst at home (27), many people spend the majority of their weekly waking hours at work and so solutions to reverse work time sedentariness and promote physical activity are necessary (28).

High levels of work place sitting (29, 30) can be attributed to the computer-based nature of modern work and to standard office design, both of which encourage employees to remain seated throughout the workday. Although standing and/or walking whilst working are attractive solutions for breaking up sitting time (31), they are not practical for many employees (32). The incorporation of structured walk breaks throughout the workday is attractive (32, 33); however, many companies cannot encourage this because it interferes with workflow (34). Innovative approaches are therefore needed to help sedentary office workers move more.

One approach to reversing chair-based sedentariness could be to transform the act of sitting into an active behavior, 'dynamic sitting'. People who fidget whilst sitting can increase energy expenditure by 5-10% above resting values (14). In order to exploit this effect, several manufacturers have designed specific pieces of furniture that directly encourage an office worker to incorporate fidgeting movements whilst working seated at their usual business tasks. One example is to replace office chairs with large rubber balls (Swiss Balls) (35) whereby an employee continuously adjusts their balance and trunk and back musculature to maintain their posture. Other 'dynamic sitting' (36-38) solutions are being examined whereby furniture design is used to encourage chair-based fidgeting and/or leg movements. In this paper, we critically evaluated an under-the-table device to encourage leg movements.

The findings from our studies were clear. When a person sat on a chair and used an under-the-table device, energy expenditure increased significantly by about 20%. This degree of activity however was insufficient to increase heart rate in contrast to walking. We concluded that the under-the-table device that promoted leg fidgeting whilst sitting at work was exothermic but unlikely to contribution to aerobic fitness. However a person can use such an under-table device for many hours each day, which might impart health benefit. Future studies will need to examine this.

There are few studies to compare this one with. What is known is that office furniture can be manipulated to promote daily activity e.g.; standing or treadmill desks (19, 39). These systems have been widely deployed and direct, albeit limited, data show both improved healthcare outcomes and productivity (40, 41)). Dynamic sitting will need to go through a rigorous validation process in order to understand whether such devices benefit productivity and improve health in the long term.

There are several limitations to our studies, which we recognize. First, our studies were conducted in a laboratory environment, although we ensured that people partook of usual work tasks whilst measurements were gathered. Whether the under-the-table device would sustain the responses we documented in the ‘real world’ will require field-based study. Second, we did not directly assess true productivity, which our prior work has shown to be important for successfully deploying this types of equipment in the workplace (19, 39). Third, the changes in energy expenditure we measured are sufficiently encouraging that we would want to conduct future studies to assess health impact (e.g. benefits in glucose and lipids) although these data failed to examine this. Despite these limitations, the results of these straightforward experiments are encouraging. They suggest that it may be worthwhile examining ‘dynamic sitting’ interventions in real-world workplaces.

In conclusion, here we demonstrate that an under-the-table device can improve energy expenditure whilst a person sits. The value of such approaches in real-world offices remains to be determined. Innovative approaches are necessary to help reverse sedentary behavior and the ill-health associated with it.

Tables

	Age	**Height (cm)**	**Weight (Kg)**	**Body Mass Index (kg/m²)**	**Body fat (%)**	**Systolic BP**	**Diastolic BP**
14 women; 12 men	33 ± 15	171 ± 8	76 ± 19	26 ± 6.5	30 ± 18	116 ± 17	76 ± 11

Table 1: Demographic and body composition information for 26 volunteers engaged in study. Body fat was measured using was measured using Bioelectrical Impedance (20).

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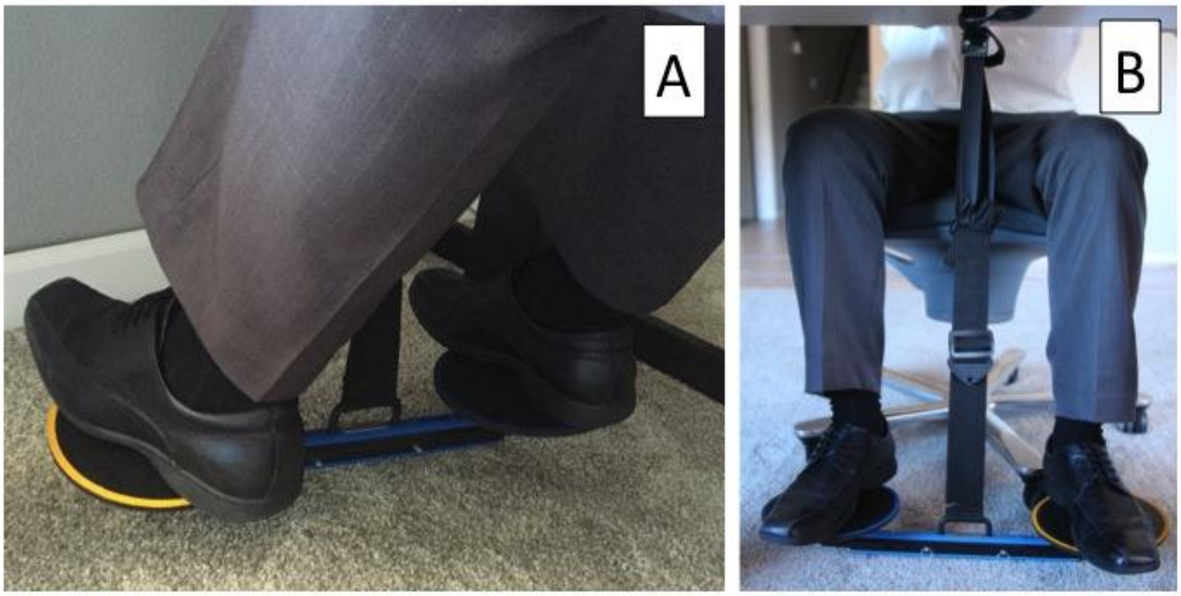

Figure 1. Under-the-table leg-movement device (HOVR ® Active Ideas Inc., Chicago IL). Panel A, angled view. Panel B, front view.

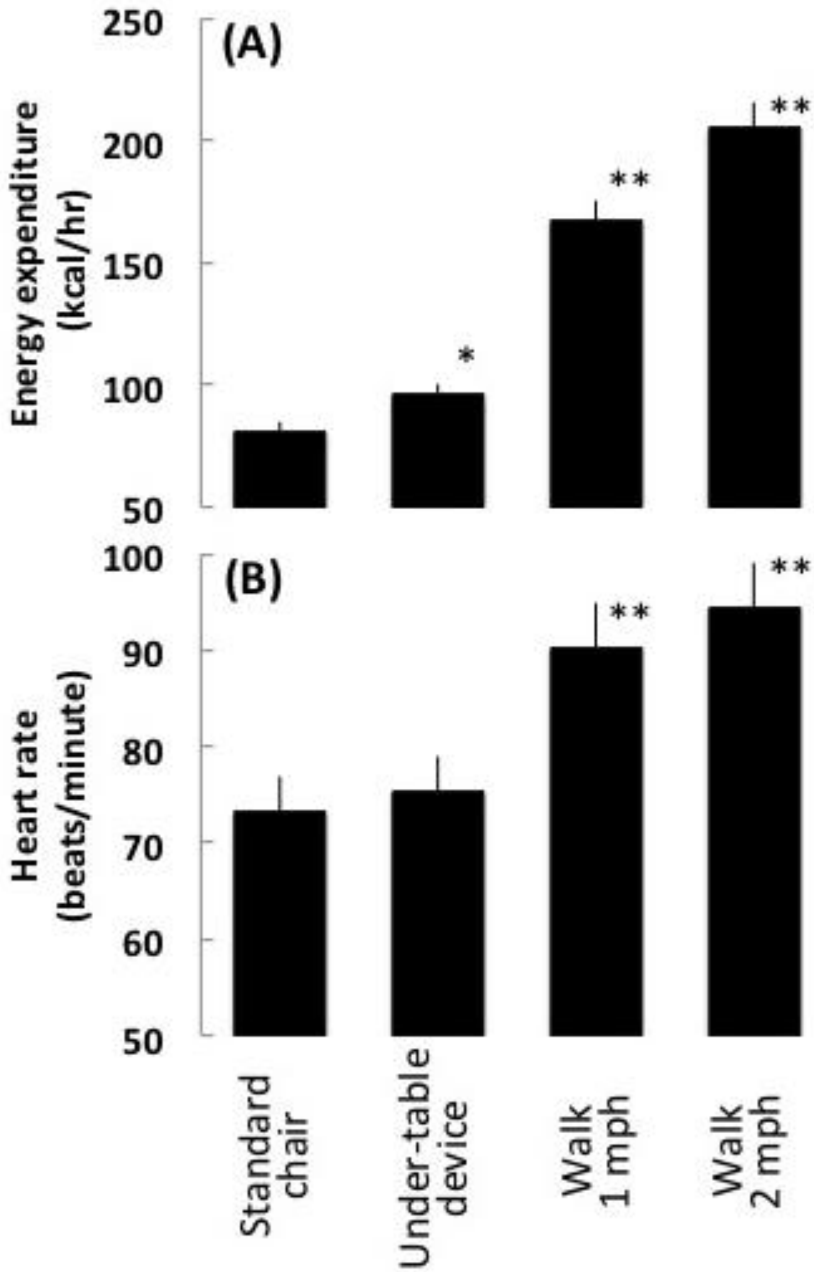

Figure 2. Energy expenditure (A) and Heart rate (B) is 26 subjects (14 women) while sitting in a standard office chair and working and then using an under-the-table device to encourage leg movement. Walking

measurements were conducted at 1 mph and 2 mph. Data are shown as mean ± SEM. Compared to standard office chair, *P=0.003, **P<0.001