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# Feasibility of using a compact elliptical device to increase energy expenditure during sedentary activities

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## Abstract

**Objectives—**This study aimed to evaluate the feasibility of using a compact elliptical device to increase energy expenditure during sedentary activities. A secondary aim was to evaluate if two accelerometers attached to the elliptical device could provide reliable and valid assessments of participants' frequency and duration of elliptical device use.

**Design—**Physically inactive adults (n = 32, age range = 25–65) were recruited through local advertisements and selected using stratified random sampling based on sex, body mass index (BMI), and age.

**Methods—**Indirect calorimetry was used to assess participants' energy expenditure while seated and while using the elliptical device at a self-selected intensity level. Participants also self-reported their interest in using the elliptical device during sedentary activities. Two Actigraph GT3X accelerometers were attached to the elliptical device to record time-use patterns.

**Results—**Participants expended a median of 179.1 kilocalories per hour while using the elliptical device (range = 108.2–269.0), or a median of 87.9 more kilocalories (range = 19.7–178.6) than they would expend per hour of sedentary sitting. Participants reported high interest in using the



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elliptical device during TV watching and computer work, but relatively low interest in using the device during office meetings. Women reported greater interest in using the elliptical device than men. The two accelerometers recorded identical time-use patterns on the elliptical device and demonstrated concurrent validity with time-stamped computer records.

**Conclusions—**Compact elliptical devices could increase energy expenditure during sedentary activities, and may provide proximal environmental cues for increasing energy expenditure across multiple life domains.

**Keywords**

Physical activity; Exercise; Sedentary lifestyle; Obesity; Environment design; Environment and public health

## 1. Introduction

Developing population-level strategies to increase energy expenditure may be critical for addressing the obesity epidemic and reducing cardiometabolic risk factors, as most US adults spend over 11 hours per day engaged in sedentary behaviors (e.g., computer work, TV watching).[1] Evidence suggests that sedentary lifestyles have contributed to average weight gains of 1–2 pounds per year among US adults over the last 20 years.[2,3] Increasing energy expenditure by about 50–100 kilocalories per day might help prevent this annual weight gain.[3,4] Increased energy expenditure, and breaks in sedentary time, might also help improve blood glucose and lipid profiles associated with premature mortality.[5–7]

Although efforts to increase energy expenditure have traditionally emphasized structured moderate and vigorous physical activity (PA) such as fitness walking or aerobics, even low intensity PA performed during daily living activities may contribute to weight control and improved cardiometabolic biomarkers.[8,9] Results from studies using treadmill desks,[10–12] and compact stepping devices/stationary stepping[13–15] suggest that combining simultaneous, low intensity PA with sedentary activities could increase daily caloric expenditure and reduce cardiometabolic risk factors. Furthermore, combining PA with sedentary activities could reduce time-related costs of PA—a frequent barrier to regular PA.[16,17] Reducing time-related costs could help sustain PA participation.

To further sustain participation in low intensity PA, ecological models suggest that opportunities to combine low intensity PA with sedentary activities should be implemented across multiple life settings.[18,19] Providing multiple PA opportunities can build cultural support for active living, and reduce the likelihood that competing sedentary activities will interfere with PA. Disseminating low intensity PA opportunities across multiple settings will require developing PA options compatible with diverse sedentary activities. However, only a limited range of options (e.g., treadmill desks, stepping-in-place, cycling) have been tested for facilitating low-intensity PA *concurrent* with sedentary activities.[12,15,20] As these options may not be scalable across all settings, evaluating an expanded range of options for integrating PA with sedentary activities could be beneficial.

To our knowledge, no prior studies have evaluated the feasibility of using a compact, low-cost elliptical device to increase energy expenditure during sedentary activities. In contrast to energy expenditure strategies such as treadmill workstations and stepping-in-place, compact elliptical devices can be used in a seated position, which may help increase energy expenditure among those with difficulty standing or walking for extended periods. Furthermore, the elliptical device we selected for evaluation (Stamina 55–1610 InMotion E-1000) is lower in cost (~$100) than treadmill workstations and some other compact exercise devices, quiet in operation, requires only 12×20 inches of floor space, and does not require an electrical outlet, which increases its potential to be disseminated across diverse life settings. Therefore, the primary aims of this study were to measure: (1) the energy expenditure of using a compact elliptical device at a self-selected intensity level among physically inactive adults; and (2) participants' interest in performing specific types of sedentary activities *concurrent* with elliptical device use. As precise measures of participants' elliptical device use could facilitate future intervention research,[21] a secondary aim was to explore if accelerometers attached to the elliptical device could detect frequency and duration of use.

## 2. Methods

Participants were recruited through a Penn State Hershey Medical Center employee newsletter, flyers, a Craigslist advertisement, and an ad posted on the Penn State Hershey Facebook research site. Inclusion criteria were: aged 25–65 years, physically inactive (less than 150 minutes/week of moderate intensity PA, or less than 60 minutes/week of vigorous PA),[22,23] able to perform moderate intensity PA, non-smoker, and BMI between 18.5–34.9. Exclusion criteria were: systolic blood pressure > 160mmHg, diastolic blood pressure > 100mmHg, cardiovascular disease, uncontrolled hyperlipidemia, lung disease, diabetes, chest pain upon exertion, joint problems, and current pregnancy.

Of the 102 people requesting study information, 88 completed screening forms, and 72 met inclusion criteria. Women accounted for 82% of eligible participants. Among participants not meeting inclusion criteria, 63% exceeded BMI limits, 12% exceeded age requirements, 12% had diabetes, 6% had lung disease, and 6% were smokers. From the remaining eligible sample, we selected 32 participants who best matched stratified random sampling criteria based on sex, BMI (18.5–24.9 vs. 25–34.9), and age (25–44 vs. 45–65) to balance the sample on characteristics associated with PA.[24] The study followed the American Medical Association ethical guidelines, and was approved by the Penn State College of Medicine Institutional Review Board (approval #39298EP). Participants provided informed written consent.

The compact elliptical device (Figure 1) contains a knob to adjust the resistance level (resistance range=0–119 clicks); however, it does not indicate the power output corresponding to each "click." The elliptical device also includes a screen displaying the number of strides (revolutions), elapsed time, and calories expended (with generic formula).

To confirm the test-retest reliability of the resistance settings, three different resistance settings (at a rate of 60 revolutions/minute) were each tested three times using a dynamometer. Results indicated strong consistency between each of the three recorded wattages at each resistance level (ICC=1.0, 95% CI=.997–1.0). To confirm the test-retest reliability of elliptical-display data for number of revolutions, data were recorded from 3 consecutive trials in which the elliptical device was in motion for 15 revolutions. The total revolutions recorded on the elliptical device corresponded 100% to manual counts of the revolutions by two independent observers.

Because the elliptical device display of "elapsed time" can be reset by participants and cannot be monitored remotely (e.g., in interventions), we attached two Actigraph GT3X accelerometers to the rear of each elliptical device foot pod (Figure 1) to evaluate if accelerometers could detect elliptical device activity. We used two accelerometers to verify that accelerometers placed on both sides of the elliptical device would provide identical activity estimates. The Actigraph epoch period was set to record physical motion as activity counts per minute.[25,26] Current Actigraph software enables remote, real-time monitoring of activity counts.

Participant assessments were conducted in a temperature and humidity-controlled research laboratory. Participants were asked to wear comfortable clothing and shoes, to avoid exercising on the day of the assessment, and to refrain from consuming food, alcohol, or caffeine for at least 3 hours before the assessment.

Upon arriving at the laboratory, participants' blood pressure and resting pulse were measured with an automatic cuff using a calibrated hospital-grade device, after sitting quietly for 5 minutes. Height was measured with a wall-mounted stadiometer, and weight was measured with a calibrated digital scale, with participants in light clothing with shoes removed.

Next, participants were asked to use the elliptical device while seated in a standard office chair, and to select an intensity level that would be "comfortable" to use while watching television for one hour. Because no prior research has explored elliptical device intensity levels that participants would voluntarily select for concurrent use with sedentary activities, we asked participants to select the intensity level. Participants were fitted with a Polar heart rate monitor, and connected to the TrueMax 2400 Metabolic Measurement System (Parvo Medics, Salt Lake City, UT) to measure energy expenditure.[27] Gas exchange was measured and calibrated before each test with standard gases of known oxygen and carbon dioxide. A face mask was fitted to each participant for indirect calorimetry metabolic measurements, and nose clips were placed to ensure breathing occurred through the mouth. A neutral television episode was started and the television screen-height was individually adjusted. After sitting still for three minutes, resting energy expenditure was calculated using the oxygen uptake and gas exchange ratios during two minutes of sitting immediately prior to elliptical device use. Participants were asked to use the elliptical device at a consistent rate for five minutes as their expired air was analyzed and their resting metabolic rate was measured. Data were averaged every 10 seconds. Oxygen uptake and the gas exchange ratios from the last two minutes of the 5-minute elliptical device use interval were used to calculate energy expenditure during elliptical device use. Metabolic equivalents of kilocalorie expenditure were calculated using the average rate of oxygen consumption recorded during the last two minutes of elliptical device use. Steady state heart rate was averaged over the last minute of elliptical device use. Immediately following completion of the 5-minute interval, participants were asked to rate their perceived exertion during elliptical device use with the 15-category Borg Scale (6=very, very light exercise, 20=very, very hard exercise).[28] Research staff also counted the number of clicks (intensity level) each participant selected, and the number of revolutions recorded during elliptical device use.

Subsequently, participants self-reported demographic characteristics (age, sex, race/ethnicity, highest education, marital status) and hours per week of working, TV-watching, and computer-use. Self-rated overall health was assessed on a 5-point scale (1=poor, 5=excellent) with a question from the SF-36 short form.[29] Five questions designed by the investigators assessed participants' interest in using the elliptical device during TV watching, computer work, reading, office meetings, and "in general" on a 7-point scale (1=not interested, 7=very interested). Participants were asked how much they would be willing to pay for a similar elliptical device. An open-ended question asked if participants had suggestions for improving the elliptical device.

Descriptive statistics were computed to describe sample characteristics, and are presented as mean±SD or % for demographic variables, and median, interquartile range (IQR) for energy expenditure and interest in elliptical device use variables. The Wilcoxon Rank-Sum Test was used to evaluate the influence of sex, BMI [18.5–24.9 vs. 25–34.9], and age [25–44 vs. 45–65]) on participants' energy expenditure, and interest in elliptical device use. Because males had a higher BMI than females (mean = 31.9±3.15 vs. 24.3±4.59), we used the Cochran-Mantel-Haenszel test to adjust for BMI [18.5–24.9 vs. 25–34.9] and sex in analyses of the effects of sex, and BMI, respectively, on all outcome variables. The Wilcoxon Signed-Rank Test was used to compare energy expenditure and heart rate during sedentary sitting vs. using the elliptical device. Accelerometer data on elliptical device usage time were compared with time-stamped computer records from participants' energy expenditure assessments to determine concurrent validity. Statistical significance was set at a two-sided $P < 0.05$. Analyses were conducted with SAS, version 9.3 (SAS, Cary, NC).

## 3. Results

The 32 participants were aged 43.3±11.8 years, 65.6% female, 78.1% Caucasian, and 75% married. Participants' educational levels ranged: 34.4% reported graduating from high school/vocational program; 40.6% reported a Bachelor's degree, and 25% reported a graduate degree. Among health characteristics, participants exhibited a BMI of 26.9±4.6, systolic blood pressure of 128.8±13.7, diastolic blood pressure of 77.0±9.9, and reported moderate self-rated health of 3.6±0.8. In response to questions about daily time use, participants reported engaging in moderate-intensity PA 34.5±46.6 minutes/week during baseline screening, working 40.0±19.7 hours/week, using a computer 29.3±22.7 hours/week, and watching TV 11.7±8.7 hours/week.

Table 1 presents results for participants' self-selected workload and energy expenditure on the elliptical device. Participants expended a median of 87.9 more kilocalories using the elliptical device (range=19.7–178.6) than they would expend per hour of sedentary sitting.

The kilocalories expended while using the elliptical device were equivalent to a median MET value of 2.2 (range=1.3–3.9), which is similar to the energy expended by treadmill walking at 1–2 mph.[11,30] Eighty-six percent of participants using the elliptical device expended 50 or more kilocalories/hour above what they would expend during sedentary sitting. Participants expending fewer than 50 extra kilocalories/hour (range=20–47 kilocalories/hour) exhibited a median of 61.5 revolutions/minute on the elliptical device which was significantly less than other participants' median of 80.2 revolutions/minute ($p < .05$). Compared to women, men completed more revolutions/minute on the elliptical device, expended more kilocalories while sitting, and showed a trend toward expending more kilocalories while using the elliptical device, after adjusting for BMI. There were no significant differences on workload or energy expenditure variables on the elliptical device by age or by BMI, after adjusting for sex.

Table 2 presents participants' reported interest in using the elliptical device during sedentary activities. Participants reported high interest in using the elliptical device during TV watching and computer work, but relatively low interest in using the device during office meetings. Participants reported willingness to spend a range of $0–$200 to purchase the device. Men reported less interest than women in using the elliptical device, but there were no significant differences in interest by age. After adjusting for sex, there were no significant differences in interest by BMI, with the exception of greater interest in using the elliptical device during reading among those with BMI's of 25–34.9 vs. 18.5–24.9 (median=6 vs. 4, $p<.05$).

In response to an open-ended question about how to improve the elliptical device, participants suggested making the height and angle of the foot pods adjustable (n=4), adding a gauge for intensity level (n=3), adding foot straps (n=3), making the device foldable/less bulky (n=3), and harnessing elliptical device activity to provide electric power for other electronic devices (n=1).

There was 100% agreement between the two accelerometers placed on the left and right side of the elliptical device regarding the duration of each participant's activity session, and frequency (number of separate sessions) of elliptical device use. Accelerometer data corresponded 100% with computer-generated time-stamped records of elliptical device use for each participant.

## 4. Discussion

Relatively few studies have explored strategies to increase low intensity PA done *concurrently* with sedentary activities,[12,14,20] despite growing recognition that sedentary behavior may be an independent risk factor for multiple cardiometabolic risk factors.[5,9] The present study explored the feasibility of using a compact elliptical device to increase daily energy expenditure. Results suggested that 86% of the sample could expend at least 50 extra kilocalories per day—an amount associated with weight gain prevention,[3,4] if they used the elliptical device for one hour at their initial self-selected intensity. Among the remaining 14% of participants, results suggested that slightly increasing the number of revolutions/minute on the elliptical device could increase kilocalorie expenditure. Assuming participants held other components of energy balance constant, daily use of the elliptical device for one hour might result in a weight loss of 5.2 pounds per year, and help prevent the 1–2 pound annual weight gain epidemic among US adults.[2,3] The average energy expenditure of using the elliptical device at a self-selected intensity was comparable to the energy expended while using a treadmill workstation at 1–2 mph,[11] but less than the energy expended by stepping-in-place.[13,14]

Most participants reported high interest in using the elliptical device during TV watching and computer work, but less interest in using the device during office meetings. As TV watching and computer work are among the most common contributors to adults' sedentary time,[5,19] the elliptical device might hold potential to increase daily energy expenditure. The elliptical device's compact design may facilitate its placement in people's immediate environments, where it could provide proximal cues for PA. As a result, unlike traveling to "relatively proximal" neighborhood fitness facilities, it may be possible to use the elliptical device without first taking intermediate steps such as stopping one's current activity, signaling to others that one will be taking a break, and changing physical locations. Each of these intermediate steps can present opportunities to delay or cancel PA plans. Placing an elliptical device in people's immediate environment, in contrast, may minimize potential disruptions and reduce time-related costs associated with transitioning from sedentary activities to more active ones. However, there is a need to further explore ergonomic, social and built environment, and individual factors that may promote or impede use of compact elliptical devices and other energy expenditure strategies across multiple life domains.

Among individual-level factors measured, only sex appeared to substantially influence interest in elliptical device use. Consistent with other similar studies,[6,12,15] few males responded to the study's recruitment materials, and women reported more interest than men in using the elliptical device. Participants' BMI and age were generally unrelated to their interest in using the elliptical device, suggesting that such devices might be marketed to diverse groups. Marketing efforts may benefit from educating the public about health-related correlates of sedentary behavior and from promoting opportunities for cost-savings, given that the median price participants were willing to spend on the elliptical device was about $50 less than its actual cost.

Perhaps in part to retain competitive pricing, the elliptical device, and other similar energy expenditure devices have not been well-designed to meet the measurement needs of researchers. For instance, it would be beneficial if the elliptical device provided reliable measurements of power output; however, adding this feature might increase its cost beyond what most consumers would pay. The elliptical device also lacks the capacity to remotely track participants' activity patterns. Therefore, we tested the feasibility of attaching Actigraph accelerometers to the elliptical device to objectively record time-use patterns. Although one study reported integrating an accelerometer with a stepping device,[13] to our knowledge, this is the first study to demonstrate the concurrent validity of elliptical device-attached accelerometers with time-stamped computer records. The accelerometers provided reliable and valid data on the frequency and duration of elliptical device use. Validation studies comparable to those conducted for ambulatory activity are needed to determine cut-points for light, moderate, and vigorous activity on the elliptical device.

Limitations of the current study included the short duration of energy expenditure testing, use of a self-selected sample, and the possibility that the presence of research staff may have elevated participants' self-selected intensity on the elliptical device, although participants reported "fairly light" exertion. Future studies should explore the extent to which larger samples of sedentary adults would consistently use the elliptical device in non-laboratory settings. A larger sample size may also have enabled more complete detection of differences related to sex, BMI, and age. Therefore, study results should be interpreted with caution.

## 5. Conclusion

This feasibility study suggested that a compact elliptical device could contribute to increased energy expenditure, and that participants were interested in using the device. Future research should evaluate if elliptical devices can sustain increases in energy expenditure and improve health outcomes. By continuing to explore how best to integrate elliptical devices and other energy expenditure strategies across diverse settings, it may ultimately be possible to reach enough people to alter rates of chronic diseases associated with sedentary lifestyles.

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**Practical implications**

- Compact elliptical devices could help increase daily caloric expenditure.
- Sedentary adults may be interested in using compact elliptical devices during sedentary activities such as TV watching and computer work.
- Elliptical device use can be objectively tracked with accelerometers, which could facilitate real-time activity monitoring and feedback.

**Figure 1.**
Compact elliptical device with accelerometers attached at rear of each foot pod.

## Table 1

Self-Selected Workload and Energy Expenditure on Elliptical device for Total Sample, and by Sex

| | Total Sample | | Male (n ≥ 10)[a] | | Female (n ≥ 18)[a] | | |
|---|---|---|---|---|---|---|---|
| | Median | IQR | Median | IQR | Median | IQR | p |
| Revolutions per minute: elliptical device | 76.4 | 30.3 | 84.6 | 33.6 | 74.6 | 20.6 | **0.032** |
| Resistance setting: elliptical device[b] | 81.0 | 43.8 | 79.0 | 18.0 | 82.0 | 50.0 | 0.508 |
| Energy expenditure (kcal/hr): sedentary sitting[c] | 83.7 | 30.7 | 107.3 | 22.4 | 71.4 | 22.0 | **0.037** |
| Energy expenditure (kcal/hr): elliptical device[c] | 179.1 | 89.4 | 215.6 | 33.0 | 144.0 | 75.9 | 0.086 |
| Heart rate (bpm): sedentary sitting[c] | 76.0 | 15.0 | 77.0 | 6.0 | 74.0 | 19.0 | 0.200 |
| Heart rate (bpm): elliptical device[c] | 92.5 | 15.3 | 94.0 | 8.1 | 91.4 | 16.0 | 0.099 |
| Rating of perceived exertion: elliptical device[d] | 11.0 | 2.0 | 11.0 | 2.0 | 11.0 | 2.0 | 0.539 |

[a]Due to missing data, n-sizes ranged: Male = 10–11, Female = 18–21.

[b]Resistance settings ranged from 0–119 clicks.

[c]The Wilcoxon Signed-Rank Test indicated that energy expenditure (kcal/hour) and heart rate (bpm) while using the elliptical device were both significantly greater than energy expenditure and heart rate, respectively, during sedentary sitting for the total sample (p's < 0.0001), males (p's < 0.01), and females (p's < 0.0001).

[d]Borg's Rating of Perceived Exertion scale: 11 = "fairly light."[28]

IQR, interquartile range.

p, adjusted p-values controlling for BMI (18.5–24.9 vs. 25–34.9) from Cochran-Mantel-Haenszel mean score test. Results from Wilcoxon rank-sum tests (unadjusted for BMI) showed a similar pattern of results to the adjusted analyses.

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## Table 2

Interest in Using Elliptical device During Sedentary Activities for Total Sample, and by Sex

| | Total Sample | | Male (n = 11) | | Female (n ≥ 20)[a] | | |
|---|---|---|---|---|---|---|---|
| | **Median** | **IQR** | **Median** | **IQR** | **Median** | **IQR** | **p** |
| Interest in using elliptical device during:[b] | | | | | | | |
| TV watching | 7.0 | 2.0 | 5.0 | 4.0 | 7.0 | 1.0 | 0.098 |
| Reading | 5.0 | 3.8 | 5.0 | 3.0 | 6.0 | 4.0 | **0.047** |
| Computer work | 6.5 | 2.0 | 5.0 | 5.0 | 7.0 | 1.0 | **0.008** |
| Office meeting | 2.0 | 5.0 | 2.0 | 5.0 | 3.5 | 4.5 | 0.267 |
| In general | 6.0 | 2.0 | 5.0 | 3.0 | 7.0 | 1.0 | **0.025** |
| Amount ($) would pay for elliptical device | 50.0 | 55.0 | 50.0 | 100.0 | 45.0 | 42.5 | 0.466 |

[a]Due to missing data, n-sizes ranged: Female = 20–21.

[b]Interest in using elliptical device: 1 = not interested; 7 = very interested.

IQR, interquartile range.

p, adjusted p-values controlling for BMI (18.5–24.9 vs. 25–34.9) from Cochran-Mantel-Haenszel mean score test. Results from Wilcoxon rank-sum tests (unadjusted for BMI) showed a similar pattern of results to the adjusted analyses.