Increased sedentary behavior (SB) has been shown to raise the risk of obesity and chronic diseases due to extended period of time spent sitting. This study aimed to investigate the effect of a portable device, “Desk Jockey” (DJ), on increasing non-exercise activity thermogenesis (NEAT) and reducing sedentary behavior in a simulated office environment. Thirteen participants whose daily work required long hours sitting were recruited and completed the study (seven males and six females). Metabolic rates (METs), energy expenditure (EE), respiratory quotient (RQ) and heart rates (HRs) were measured using an indirect calorimeter during five sessions. These included one sedentary and four sessions with different pedaling frequencies and resistances. Each session included a 10 min baseline, 20 min pedaling and 20 min post-pedaling/recovery periods. Ratings of DJ’s usefulness were also obtained from each participants. Data revealed that METs, EE and HRs increased significantly (p’s < 0.0001) during pedaling period compared to the baseline period even though METs were still low (2.5 ± 0.6 MET) in each session. Total EE was significantly higher in sessions with pedaling (p’s < 0.0001) as compared with total sedentary session. RQ was not affected by pedaling. In high frequency sessions the METs during the 10 minutes recovery period were still higher (p’s < 0.05) than those at baseline. Thus pedaling frequency was a more important factor to METs and EE than resistance. DJ was tolerated well and no adverse effects was reported. It can be used by office workers to increase METs and EE during and post pedaling periods without interfering with work.

**Keywords:** sedentary behavior (SB); portable device; metabolic rates; energy expenditure; office workers

**Introduction**

The benefits of physical activity (PA) on health and body mass regulation are clearly defined (Chodzko-Zajko et al., 2009; Garber et al., 2011; Haskell et al., 2007). It was recommended that individuals should engage in at least 150 minutes per week of moderate or vigorous activity. However, it was estimated that in the US, adults in fulltime employment spend approximately 7.6 working hours (hrs) a day at work, and majority of this time sitting (U.S. Department of Labor, 2012). In addition, US adults spend an average of 2.8 hrs/day watching television, which usually involves sitting as well. Current research showed that long periods of non-exercise, or sedentary behavior (SB), independent of the PA levels, is a risk factor for chronic diseases such as diabetes, cardiovascular diseases, obesity, etc. (Matthews et al., 2014; de Rezende et al., 2014; Hamilton et al., 2007; Katzmarzyk et al., 2009; Booth et al., 2011; van Uffelen et al., 2010; Pandey et al., 2016). Hamilton et al (2004) reported that SB has independent and qualitatively different effects on health and should be treated as an independent construct. Physical inactivity has been shown, globally, as the fourth leading cause of non-communicable diseases (Kohl et al., 2012). Church et al (2011) reported that from 1960 to 1962 and from 2003 to 2006, there has been, on average, a drop of 142 kcal in energy expenditure (EE) due to reduced occupational physical activity. This reduction in EE translates to a weight gain of approximately 13 kg over the same period, paralleling the trend of obesity incidence (Smith et al., 2016). The 2008 Physical Activity
Guidelines for Americans stated that all adults should avoid inactivity and that any amount of activity was better than none (U.S. Department of Health and Human Services, 2008). The American College of Sports Medicine (ACSM) recommended that, in addition to regular exercise, reducing sedentary behavior should be concurrently pursued (Garber et al., 2011). It was further recommended that short bouts of standing or PA should be frequently engaged even in healthy adults (Garber et al., 2011). Therefore, this emphasis on reducing sedentary lifestyle represents a significant paradigm shift and has the potential of reducing chronic diseases including obesity, diabetes and health care cost in general public (Henson et al., 2013).

PA with intensity as low as 1.5 metabolic equivalent (MET) has been demonstrated to have significant health benefit (Levine et al., 1999). Levine et al (1999) termed this low level of activity (<1.5 MET) as “non-exercise activity thermogenesis” (NEAT). They have demonstrated that obese individuals spent 2.5 hrs/day more sitting than their lean counterparts. Levine et al (2007) also reported that leaner participants living and working in a similar environments to obese individuals expended an extra 350 kcal/day by not sitting, thus SB has contributed to the increased weight gain observed in the obese participants.

Due to prevalence of obesity and the vast number of daily hours spent sitting, designing a work environment that encourages employees to engage in NEAT activities should be a priority. One solution could be the instillation of a device at work that enhances the engagement of NEAT activities, while not impeding on the working day. Several such strategies have been tested, such as “walk-and-work” desk (Levine and Miller, 2007), and the “Take-a-Stand” project (Pronk et al., 2012). But these devices/strategies have their limitations and may not be easily adopted to an office or home environment. In the current study, a new portable and easily adaptable device, the “Desk Jockey” (DJ, Desk Jockey LLC, Detroit, MI, described below) was employed to test its effectiveness in increasing METs, EE, and ratings of its usefulness, and to identify whether it was frequency or resistance that determined the METs and EE. The relationships between BMI and METs, EE were also examined. We hypothesized that DJ would be able to increase METs and EE during the pedaling periods. We also expected that DJ would be tolerated by the participants without adverse effects.

Methods

Participants

This research received ethical approval from the Institutional Review Board (IRB). Based on the research reported by Horswill et al (2017) that a sample size of 16 produced significant results, and this study used a repeated measure design with each participant had his/her own baseline measures, a convenient sample of 18 participants (8 males and 10 females) were recruited from university staff and students. Pregnant or nursing women and individuals with joint/hip problems, diabetes, cardiovascular disease and hypertension were excluded. Two participants (2 females) withdrew immediately after the first session. Three more participants (1 male and 2 females) withdrew in the middle of research due to different expectations and limited available time. The demographic and anthropometric data of the 13 participants (7 males and 6 females) who completed all five sessions are presented in Table 1. For analysis purpose, all participants were dichotomized into lean/healthy weight (BMI < 24.9 kg/m²) or overweight/obese group (BMI > 25.0 kg/m²). The DJ was tolerated well by participants: no falls, slips or injuries reported.

Table 1: Demographic and anthropometric data of the 13 participants who completed the study.

| Measurement                  | Mean ± SD  | Range     |
|------------------------------|------------|-----------|
| Age, Years                   | 24.7 ± 7.5 | 18–47     |
| Body Weight, Kg              | 73.1 ± 19.2| 47.1–108.9|
| Height, Cm                   | 169 ± 0.1  | 155–183   |
| BMI, Kg/M²                   | 25.53 ± 6.0| 19.1–37.7 |
| Normal Weight (N = 8)        | 21.8 ± 1.8 | 19.1–24.2 |
| Overweight (N = 3)           | 27.8 ± 1.0 | 26.6–28.6 |
| Obese (N = 2)                | 37.3 ± 0.5 | 37.0–37.7 |
| Sitting At Work, Hours       | 4.3 ± 2.6  | 0–8.0     |
| Sitting At Home, Hours       | 4.2 ± 2.2  | 0–8.0     |
Procedure
This study was conducted in the Exercise Physiology laboratory, one participant at a time to ensure privacy and confidentiality. Informed consent form was obtained from each participant. Height (portable stadiometer, Model 242, Seca Corp, Hanover, MD) and body mass (Model 644, Seca Corp.) of each participant were measured three times and the average values reported. Before data collection started, participants would first sit comfortably on an office chair, put their feet on the pedals and familiarize/acclimatize with the laboratory environment for about 10 min. After this period, an indirect calorimeter mask and nose clip (TrueMax 2400 computerized metabolic systems, described below) were then placed on the participant’s face to collect oxygen consumption and carbon dioxide production data continuously during each of the five sessions (described below) for the entire 50 min/session. A fingertip Pulse Oximeter (described below) was also attached to participant’s index finger to measure pulse rate as an estimation of heart rate (HR).

Each session was divided into: (1) period 1: 10 minutes of sitting in a chair without any leg movement to achieve a resting state (baseline); (2) period 2: 10–20 minutes of pedaling on the DJ; (3) period: 3 20–30 minutes of pedaling; (4) period 4: 30–40 min post-pedaling recovery period and (5) period 5: 40–50 min recovery period. Data were collected continuously during the entire 50 minutes in each session (Figure 1). Based on the pedaling resistance and frequency, five sessions were administered to each participant in randomized order:

- Total sedentary (TS): The participant was required to put both feet on DJ pedals for the first 30 min without movement. After that, the participant put both feet on the ground for the last 20 min. During the 50 min testing session, all the participants were asked to engage in activities such as reading, typing or working on the computer.
- Low frequency, low resistance (LFLR): The participant started to put both feet on the pedals without pedaling for the first 10 min to collect the baseline data. Then the participant was instructed to pedal the DJ for 20 min at low resistance (77.3 ounces) at the frequency of 112 beats per min following the motion of a metronome. The participant then kept both feet on the ground for the remaining 20 min. The indirect calorimeter was stopped once the participant finished the entire 50 min session.
- Low frequency, high resistance (LFHR): The participant followed the same procedure as the session “LFLR” except that the resistance was raised by attaching higher weight to the pedals (high resistance: 114.3 ounces).
- High frequency, low resistance (HFLR): The participant followed the same procedure as the session “LFLR” except for the frequency was increased to 152 beats per min.
- High frequency, high resistance (HFHR): The participant followed the same procedure as the session “LFLR” except for the frequency was 152 beats per min and the resistance was the high level of 114.3 ounces.

Equipment
The Desk Jockey (DJ)
The DJ is a simple, portable and convenient device designed by Desk Jockey LLC (Detroit, MI. Figure 2). It contains 2 pedals spaced with a 15° angle rather than parallel to be ergonomic and simulating the natural feet angle while walking. The resistance level of this device was determined by the weight added under the pedals. The appropriate resistance level was modified first according to the session order of each participant. The heavier the weight added, the higher the resistance. The DJ was placed on the floor directly in front of the participant’s chair. It was adjusted close to the participant for a safe and comfortable use. The participant then placed their feet firmly over the center of the foot pedals and both feet were secured with a fasten band. The participant cycled the foot pedals forward and backward, so that the right and left pedals were

![Figure 1](image-url): Experimental protocol for each session.
moved in the opposite direction from each other, as in the walking motion. This walking motion covered the entire span of track from the front to the back. The speed of pedaling was determined by the session order of the participant. Each participant was instructed to pedal according to the speed of a metronome that was placed adjacent to the DJ so the participant could easily follow its motion.

**Indirect calorimeter**

TrueMax 2400 computerized metabolic systems (ParvoMedics, Salt Lake City, UT) was used to collect MET, RQ and EE data. This equipment calculates the heat produced by measuring the production of carbon dioxide and the consumption of oxygen. After the calibration, each participant was fitted with a mask with a mouthpiece and nose clip. Through this mask and nose clip, the volume of oxygen consumed and carbon dioxide exhaled by the participant would all be measured through the collecting tube connected to the calorimeter. Then the system would calculate and save the results of METs, RQ and EE. The indirect calorimeter was calibrated according to manufacturer’s instruction every morning and afternoon before data collection. The calibration procedure took about 15 min to complete, with the standard room air concentration of 20.94% oxygen and 0.03% carbon dioxide. Data were collected in the environment with temperature 22.0 ± 0.5°C and barometric pressure 746.0 ± 2.1 mmHg.

**Pulse Oximeter**

A fingertip Pulse Oximeter CMS50E (FaceLake, Lake Bluff, IL) was used to measure the pulse rate (beats per minute, BPM) during the entire data collection periods. It was a non-invasive device with the attachment to the index finger. Pulse oximeters have been shown to be correlated significantly with heart rate at low exercise intensity (Iyriboz et al., 1991).

![Figure 2: The DJ used in the current study.](image)
Statistical analysis
Data from the five sessions were analyzed by SPSS 25.0 statistics software (IBM Corp, Armonk, NY). All data collected were tested for normality using the Shapiro-Wilk test in SPSS and determined that all data were normally distributed hence parametric statistical analyses were performed. METs, RQ, EE and HRs during the baseline (0–10 min), pedaling (10–20, 20–30 min) and post-pedaling recovery periods (30–40, 40–50 min) were compared among the 5 sessions, regardless of BMI status, with two factor repeated measures (periods and sessions), and pair-wise comparisons were performed using general linear model statistic. Effect size was estimated by the partial eta squared. Participants were classified into two groups according to BMI (lean/healthy vs overweight/obese) to analyze if METs, RQ, HRs and EE were different with different weight categories. Sex differences were also examined for these parameters. Post-hoc pair-wise comparisons were conducted to determine if frequency or resistance affected METs or EES differently. Pearson’s correlations were calculated to identify whether METs and EE would be influenced by BMI or age. Significance was considered at p < 0.05.

Results
Effects of DJ pedaling irrespective of BMI
The METs during the pedaling periods were low (2.5 ± 0.6 METs) and therefore were considered to be in the NEAT range. The METs were affected by both sessions (p < 0.0001, effective size: 0.72), periods (p < 0.0001, effective size: 0.95) and their interaction (p < 0.0001, effect size: 0.56). The METs increased significantly during pedaling periods when compared to first 10 min baseline period (Figure 3), regardless of whether the frequency and resistance were high or low. The METs increased by 32%, 36%, 48% and 48% in sessions of LFLR, LFHR, HFLR and HFHR respectively as compared to TS session (p < 0.0001, effect size = 0.90). Post-

![Figure 3: METs and HRs over the 50 min data collection period during five sessions. METs increased significantly during pedaling periods when compared to the resting periods in each session. Data are expressed as mean ± SD. TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.](image-url)
hoc paired comparisons showed that all pedaling sessions (LFLR, LFHR, HFLR, HFHR) had higher METs than that of the TS session (p’s < 0.0001). HFLR session had higher METs than the LFLR session (p < 0.05). No other difference between sessions was identified.

When comparing the effects of periods with all the pedaling sessions combined, there were significant increases of METs of 62% (period 2, 10–20 min, p < 0.0001), 68% (period 3, 20–30 min, p < 0.0001), and 9% (period 4, 30–40 min, p < 0.05) as compared to the first 10 min baseline period. Period five had similar METs (~4%) as that of the period one. Second and third periods had similar METs and both were significantly higher than periods four and five (p’s < 0.0001). Period four also had higher METs than period five (p < 0.001).

HRs were affected by sessions (p < 0.0001, effect size: 0.40), periods (p < 0.0001, effect size: 0.90) and their interaction (p < 0.0001, effect size: 0.42) (Figure 3). The increase in HRs were 13%, 12%, 16% and 19% for LFLR, LFHR, HFLR and HFHR respectively, above the TS session. The HFLR and HFHR sessions had significantly higher HRs than that of the TS (p’s < 0.001). No other difference in HRs was observed among the sessions.

HRs were significantly higher during the pedaling periods than that of the baseline and post-pedaling recovery period (p’s < 0.0001). There was no difference in HRs between baseline and periods four and five, the post-pedaling periods.

RQs were not different among baseline, pedaling and recovery periods.

Post-hoc pairwise comparisons revealed that high frequency significantly increased METs and HRs regardless resistance levels (p’s < 0.01). On the other hand, different resistance levels (high or low) did not affect METs or HRs (p’s > 0.05). These results showed that frequency was a more important factor than resistance in affecting METs and HRs.

As shown in Figure 4, EE during the pedaling periods were significantly higher than that of the baseline period (p’s < 0.0001, effect size = 0.72). During period 4 (recovery period 30–40 min) the EE was still

![Energy Expenditure](image)

**Figure 4:** Top: Mean energy expenditure (EE) during each period among all participants in all five sessions (mean ± SD). Bottom: Mean energy expenditure during the entire 50 min sessions; Bars with different letters are significantly different from each other at p < 0.05 or 0.01 (mean ± SD). TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.
significantly higher than baseline (p < 0.05) but the difference disappeared during the 40–50 min recovery period. The EE for LFLR, LFHR, HFLR and HFHR sessions were significantly higher than that of the TS session (p < 0.0001, effect size = 0.78). Raising frequency level increased EE significantly (p < 0.01) during pedaling periods while no difference was found in raising resistance levels.

**Effects of sex on METs, HR and EE**

Male participants had significantly higher METs and EE than females. There was no interaction between sex and pedaling sessions (**Figure 5**). No difference in HR was observed between male and female participants.

*Figure 5*: Mean METs, EE and HR over the 50 min data collection periods according to sex. Asterisk indicates significant difference between males and females at p < 0.05 or 0.01.

TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.
**Effects of body weight status on METs, HR and EE**

Overweight/obese participants had higher METs compared to participants with healthy BMI (p = 0.013, Figure 6) in TS, LFLR, LFHR and HFLR sessions. Overweight/obese group also had a significant higher EE when compared to the healthy weight group in all five sessions (p < 0.05). BMI categories did not affect the HR at each of the five sessions (Figure 6).

**Figure 6**: Comparison of METs, HR and EE between lean/healthy weight and overweight/obese groups among all the five sessions. Asterisk indicates significant difference between lean/healthy and overweight/obese at p < 0.05 or 0.01.

TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.
Relationships between BMI and METs and EE
There were significant positive correlations between BMI and METs during pedaling period in sessions of TS, LFLR, LFHR and HRLF (p's < 0.01, Figure 7). When both frequency and resistance were high (HFHR), this relationship between METs and BMI no longer existed. Similar findings were obtained when testing correlations between BMI and EE after pedaling for 20min (Figure 8). Significant positive correlations were found in sessions of TS, LFLR, LFHR and HRLF (p < 0.05) while no correlation was found in HFHR session. In addition, there were no correlations discovered between age and METs or age and EE. Results also showed that subjects with similar BMIs (19.6 vs. 19.1) could have quite different levels of EE at all study sessions (Figure 8).

Discussion
In the current study, it was observed that DJ was well-accepted by the participants. The participants were able to read or use computer while pedaling the DJ. The METs, EE and HRs were elevated significantly during the pedaling compared to the baseline period. During the first 10 min recovery period, METs and EE were still significantly higher than that of the baseline period. Pedaling frequency affected the METs, EE and HRs more than the resistance.

The DJ studied here was a portable, convenient and inexpensive device aimed at reducing SBS among office workers (OWs) and increasing NEAT. It is designed to be used in any office, home, gym, or rehabilitation settings. This is a simple, ergonomic, and portable device that can be placed under a typical office desk or in

Figure 7: The relationship between BMI and METs after 20min pedaling in five sessions. TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.
front of a couch in any room. When OWs sit at their desks, they can put their feet on the pedals and move their feet back and forth like they are walking. The radii that the two pedals are guided through imitate the natural gauge of walking. The angle between the pedals accounts for the legs' natural rotation about the hips to provide a very natural motion. The motion covers the entire span of travel from front to back so counters mounted at both ends of the pedals can register the number of strides a person makes. The resistance level in the DJ can be adjusted by using different weights attached to the pedals.

This device offers several advantages over others: (1) A person can use this device while sitting, thus eliminating the burden placed on the knees compared to other types of PA, especially for overweight or obese individuals; (2) Because the PA level is low, it can be performed for a prolonged period of time thus reducing the number of hours of being sedentary; (3) Its use can be incorporated into daily life without extra effort, such as driving to the gyms or changing into exercise clothes; (4) It is inexpensive and portable, does not require extra office space, and can be used anytime during working or waking hours and anywhere, such as a living room while watching TV or doing other housework; (5) It can be used without interrupting work flow; (6) There is no upward leg motion therefore there is no need to adjust the height of office desks; (7) It can also be used as a physical therapy device for individuals in need of strengthening leg muscles but having difficulty in standing, or in need of increasing blood flow to the legs; and (8) There is an increase in METs and EE during the pedaling and post-pedaling periods. Sit-stand desks may not have such benefits, and whether sit-stand desks can repair the damage done due to prolonged sitting is not yet clear.

Figure 8: The relationship between BMI and Energy Expenditure for the five sessions. TS: total sedentary; LFLR: low frequency/low resistance; LFHR: low frequency/high resistance; HFLR: high frequency/low resistance; HFHR: high frequency/high resistance.
The results demonstrate that pedaling on DJ for twenty minutes could increase EE up to 70 kcal, compared to 25 kcal, the EE while sitting for twenty minutes. More importantly, the METs and EE were still higher than baseline period after pedaling stopped. Future studies should lengthen the pedaling time and examine post-pedaling EE recovery pattern. When pedaling time is prolonged, the expected EE during recovery time should also increase. This may further increase EE and improve body weight status and other metabolic parameters.

There are several devices that encourage movement while working. For example, "walk-and-work" desk, designed by Levine and Miller (2007), is a vertical workstation, combining a movable desk and a computer station. This workstation easily slides over a standard treadmill. The worker has the choice to stand-and-work, walk-and-work, or sit-and-work. The authors reported that the energy expenditure while using walk-and-work was 119 kcal/hr above the sit-and-work condition. However, these workstations are expensive and require more office space than a typical desk alone. Therefore, it is not a setup that can be widely adopted in work places. There are other work stations designed to reduce sitting time in the office by designing a desk that can be easily elevated or lowered for standing or sitting without interrupting work flow (Prønk et al., 2012). Participants in the Take-a-Stand project reduced their sitting time by 66 min/day, reduced lower and neck pain by 54%, and improved their moods (Prønk et al., 2012). Interestingly, these health benefits were short-lived. After removing this device, the benefits disappeared within 2 weeks. Furthermore, there is no evidence that the EE was increased during the standing time (Shrestha et al., 2016).

Sit-stand desks are gaining popularity. MacEwen et al (2017) reported that by using Sit-Stand Desk, office worker’s sitting time has significantly reduced and standing time significantly increased. However, there was no changes in sitting or standing time outside office hours. In addition, there was no observed improvement in cardiometabolic parameters. Mantzari et al (2019) also reported that with sit-stand desks, office worker’s sitting time was reduced and standing time increased during working hours but not in non-working days. These desks’ impact on energy expenditure and cardiometabolic benefits are still not clear. Furthermore, whether workspaces permit the installation of such sit-stand desks should be considered. Nevertheless, using the sit-stand desks may have long-lasting effects. Dutta et al (2019) reported that at one-year follow-up, those who used sit stand desks still showed increased standing time and reduced sitting time. These findings stress the importance that any anti-physical inactivity programs/devices have to be portable, easily incorporated into daily life and adopted by sedentary workers without much adjustment in lifestyle or working environment. Such a device will significantly improve the PA levels and energy expenditure, and reduce SB. In the long run, such a device will improve the general health and reduce disease risks in the general public.

Although sit and stand type desks increased standing time and reduce sitting time, they do not involve dynamic contraction of leg muscles. The DJ, on the other hand, involved dynamic contractions of both legs, mimicking a true walking movement. This may explain the higher relative increase in METs (77%–92%) using DJ while Horwill et al (2017) reported an increase of ~17% using the HOVR device. The differences in increase in METs between DJ and HOVR may be attributed to the lack of muscle contraction and lack of resistance adjustment in HOVRs.

Most researchers have focused on moderate-to-vigorous PA (3 to 8 METs) to study the effects of PA on human health (Pate et al., 1995). However, regular desk jobs and limited office space make it unrealistic to perform PA during working time in office. In addition, increasing PA alone is not enough for achieving benefits. Long and continuous sitting/sleep time has significantly negative effects even when OWs have enough purposeful exercises (Healy et al., 2008; Henson et al., 2013). Instead, enhancing short and frequent bouts of PA during working hours is more beneficial for OWs as ACSM has recommended (Garber et al., 2011). Therefore, this research studied the impact of low-intensity PA on NEAT with the consideration of OWs’ working environment. Once a person starts walking, even at speed as low as 1 mile/hr, the METS could double. Increasing walking speed to 2 miles/hr could raise EEs to 150–200 kcal/hr while EE during recovery is only 20 kcal/hr (McCrady-Spitzer and Levine, 2012). This study of using DJ also provided supportive evidences that EE increased during the “walking” (pedaling) sessions. This low-intensity activity significantly raised METs and EE compared to sitting. Moreover, the EE increased not only during pedaling, but also after activity ceased. Results showed that the distances traveled would be approximately 1.54 mile/hr at low pedaling speed and 2.09 mile/hr at high speed. Therefore, if OWs use DJ for 1 hour, EE could increase significantly, which is similar to walking at the speed of 2 miles/hr; moreover, using DJ during sitting time won’t disturb deskwork when compared to walking. The design of this DJ has another benefit: it is used while sitting. Using DJ will not cause any hardship for individuals with difficulty in standing.
Previous research suggested that METs could be affected by various abiotic and biotic factors, including age, gender, body mass, activity level, reproductive and absorptive state and behaviors (McNab, 2008). Among all factors, body mass accounts for the most variation (90%) (McNab, 2008). Our study also showed that participants with higher BMI had significantly higher METs and EE when compared to participants with lean/healthy BMI, both during sedentary state and pedaling sessions. Recent studies have also demonstrated that METs of individuals of similar size could differ over magnitude order (Tompuri, 2015). It was supported in our study showing that even with similar BMIs, participants had different EEs. It is speculated even with similar BMI, different body composition may have contributed to the different EEs. It is apparent that using DJ in office could be an effective way for OWs to decrease sedentary time and increase NEAT; and it could help overweight and obese OWs expend more energy than lean OWs. But the EE expended during the pedaling could be varied significantly.

This study did not provide evidence indicating that age is correlated to METs. However, male participants had higher METs at all five sessions. More research, with a larger sample size and that measures body composition, should be performed to study the factors affecting METs and EEs. People with varied physical conditions or body compositions could use specific frequency/resistance to increase NEAT efficiently.

This study also tested effects of different frequencies (112 beats/min vs 152 beats/min) and resistances (77.3 oz. vs 114.3 oz.) on raising NEAT. As Figures 3 and 4 show, even though both frequency and resistance affect METs, HR and EE, raising frequency is more effective than raising resistance in elevating these parameters. Therefore, when using DJ to increase NEAT, choosing a higher pedaling speed would help OWs boost EE more than adding resistance to pedals.

This study found significant correlation between BMI and MET as well as BMI and EE in all four sessions except for session HFHR (Figures 7 and 8). The METs of the overweight/obese group in the HFHR session were unexpectedly low and were not significantly different from those of lean/healthy weight group (Figure 6). This could be because some participants, especially overweight and obese ones, were not able to follow high frequency with high resistance at the same time. They might not move pedals the entire length of the tracks. Various frequencies and resistances could be tested in the future to identify the optimal parameters for best effects and comfort.

Limitations
The limitations of this study include: (1) Participants of this study were employees or students of a university. Thus they tended to be younger and with lower BMI than the general population; (2) Sample size was based on a previous study (Horswill et al, 2017) using a device to increase NEAT. The attrition rate of the current study was higher than expected with 13 participants completed the study. However even with this small sample size, significant results were obtained, implying that the beneficial effects of DJ may be even higher than observed if a larger sample were used; (3) The university laboratory setting may not be the same as other settings, such as at home or in rehabilitation facilities; and (4) The duration of the pedaling period was 20 min/session, it may not be long enough to determine if users would continue to pedal for longer period of time in each session.

Conclusion
Using DJ in the office is an efficient way to increase NEAT and EEs among adults, not only during the pedaling process but also during the first 10 minutes after pedaling stops. This inexpensive, portable, and convenient device could reduce SB of OWs and consequently enhance EE through low-METs activities. More importantly, using DJ under the desk would not disturb OWs’ regular deskwork, which could contribute to the efficiency of working and expending energy at the same time. Sitting at desk and pedaling will not cause any difficulties associated with standing. Further research should investigate the long-term benefits of using DJ based on a larger sample size with various frequencies and longer time of using DJ, as well as the metabolic changes associated with using the DJ.

Competing Interests
There is no competing interests for Drs. Tang, Yeh, Jen and Mr. Scarchilli. Mr. Scarchilli designed and provided the Desk Jockey for this study but was not involved in the data collection, analysis and interpretation.

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