Energy expenditure of deskwork when sitting, standing or alternating positions

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Background
Recent guidelines recommend accruing 2–4 h of standing or light activity during the working day. Use of sit–stand desks could achieve this goal, but whether standing can meaningfully increase energy expenditure (EE) is unclear.

Aims
To study EE, heart rate, feelings and productivity during deskwork while sitting, standing or alternating positions.

Methods
We measured EE by indirect calorimetry in working adults over three randomly ordered 60-min conditions while performing deskwork: continuous sitting (SIT), 30 min of each standing and sitting (STAND–SIT) and continuous standing (STAND). We also assessed heart rate, productivity and self-reported energy, fatigue and pain. Linear mixed models compared minute-by-minute EE and heart rate across conditions. Non-parametric tests compared remaining outcomes across conditions.

Results
The study group comprised 18 working adults. Compared with SIT, STAND–SIT engendered an additional 5.5 ± 12.4 kcal/h (7.8% increase) and STAND engendered an additional 8.2 ± 15.9 kcal/h (11.5% increase) (both p < 0.001). Alternating positions to achieve the recommended 4 h/day of standing could result in an additional 56.9 kcal/day for an 88.9 kg man and 48.3 kcal/day for a 75.5 kg woman. STAND–SIT and STAND also increased heart rate over SIT by 7.5 ± 6.8 and 13.7 ± 8.8 bpm, respectively (both p < 0.001). We observed no meaningful differences in feelings or productivity.

Conclusions
Desk-based workers could increase EE without added discomfort by using a sit–stand desk. These findings inform future research on sit–stand desks as a part of workplace interventions to increase EE and potentially improve health.

Key words
Breaks; energy expenditure; heart rate; sedentary behaviour.

Introduction
Overweight and obesity affect 39% of adults worldwide [1] with even higher prevalence rates in some industrialized nations such as the USA (69%) [2]. Scientists have identified sedentary behaviour, typically defined as sitting or reclining at very low intensities (≤1.5 metabolic equivalents) [3], as a novel risk factor for adverse health outcomes including obesity, metabolic disease and mortality [4–9]. Importantly, these associations occur independently from moderate-to-vigorous intensity physical activity, highlighting that sedentary behaviour is distinct from inactivity or the failure to engage in moderate-to-vigorous intensity physical activity. One specific mechanism through which sedentary behaviour could increase health risks is through decreased caloric expenditure which could lead to energy imbalance and obesity. Standing engages stability muscles and should result in greater energy expenditure (EE) than sitting, although this difference would probably be small [10]. However, experts have concluded that expending an extra 100 kcal/day could be enough to prevent weight gain [11]. Thus, accumulating time spent with slightly increased EE by standing rather than sitting over the entire day may close the energy gap between energy intake and EE. This could play a role in the prevention of weight gain within the population.

Prolonged sitting is common in the workplace [12]. Over the past 50 years in the USA, occupational EE has decreased by ~100 kcal/day due to more service-providing occupations and less employment in agricultural or goods-producing occupations [13]. A recent expert statement recommended that workers with desk jobs should progress to 4 h/day of light activity (e.g. standing...
or walking) during working hours [14]. Sit–stand desks offer a solution to the problem of too much sitting. Specifically, these height-adjustable workstations provide an option to reduce sitting during normal deskwork that otherwise would have to occur in a seated position at a traditional desk. Yet, despite growing commercial availability, debate remains about whether using sit–stand desks can produce clinically meaningful increases in EE [14,15]. Wide discrepancies among reports of EE comparing standing to sitting, which range from differences of −0.01 to 0.83 kcal/min, contribute to the uncertainty [16–21]. Also, although varying standing and sitting positions are implicit when using sit–stand desks, and are commonly recommended, whether alternating positions elicit the expected additive or additional EE is unclear. We, therefore, aimed to compare EE while performing deskwork in seated, standing or alternating (standing and sitting) positions in working adults who would be interested in using a sit–stand desk. Secondary objectives were to compare heart rate, productivity and self-reported fatigue, pain and energy across conditions.

Methods

We recruited subjects via printed advertisements placed around the University of Pittsburgh campus. Inclusion criteria targeted employed adults who would be likely to use a sit–stand desk as follows: 20–65 years old, employed full-time in a job that required sitting at a desk ≥20 h/week and self-reported interest in using a sit–stand desk. We stratified recruitment by gender and age group (<40 and ≥40 years old) to obtain a diverse sample of working adults. Exclusion criteria included any health condition that would limit standing, actively trying to lose weight, current treatment for cancer, heart disease, diabetes or polycystic ovarian syndrome, use of medications that could affect metabolism, current or recent pregnancy or lactation and inability to attend all study sessions. All subjects provided informed written consent prior to study participation. The Institutional Review Board at the University of Pittsburgh approved all study procedures.

This study utilized a randomized crossover design. After screening, subjects performed standardized deskwork for 60 min during three experimental sessions: sitting for 60 min (SIT), standing for 60 min (STAND) and standing for 30 min followed by sitting for 30 min (STAND–SIT). Subjects completed experimental sessions in a random order, at least 48 h apart, and within 4 weeks. Before each experimental session, we confirmed that subjects followed instructions to abstain from moderate-to-vigorous physical activity, alcohol consumption and tobacco use for 24 h and any food for 8 h.

We fitted subjects with a metabolic mask and heart rate monitor. Then, we instructed them to sit at a sit–stand desk (Float; Humanscale, New York, NY, USA) with a computer monitor attached to a monitor arm at eye level, keyboard and writing utensils. We monitored continuous metabolic and heart rate for 70 min during each session. After subjects rested quietly for 10 min, research staff asked subjects to begin deskwork in a seated (SIT) or standing position (STAND and STAND–SIT) (Figure 1). Subjects remained in the same position for the 60-min session during SIT and STAND. During STAND–SIT, research staff lowered the desk after 30 min to ensure proper position and to isolate EE from the sit–stand transition (preventing any EE due to lowering the desk). Standardized deskwork included typing articles from a magazine on a computer (0–15 and 31–45 min) and completing worksheets consisting of copying definitions from a dictionary, reading comprehension and mathematical problems (16–30 and 46–60 min).

We measured body weight using a digital scale to the nearest 0.1 kg in light clothing with shoes removed at each visit. We measured height at baseline to the nearest 0.1 cm using a wall-mounted stadiometer. An automated blood pressure machine assessed blood pressure at baseline with subjects in a seated position after 5 min of rest. Patient characteristics measured at baseline by questionnaire included physical activity participation [22], demographics and time spent sitting at work. We measured attitudes toward a sit–stand desk using a questionnaire developed by our team (see ‘Attitudes about a Sit–Stand
Desk Questionnaire’, available as Supplementary data at Occupational Medicine Online).

We used indirect calorimetry to measure metabolic parameters (Vmax Encore metabolic cart; CareFusion, San Diego, CA, USA). Prior to each experimental session, we performed both gas and flow meter calibration according to manufacturers’ instructions. We carefully checked mask fit throughout the protocol. To calculate EE, we multiplied oxygen consumption by the caloric equivalent corresponding to the simultaneous respiratory quotient for each minute. We measured heart rate during each minute using a Polar heart rate watch and monitor (Polar USA, New York, USA). We recorded the number of characters typed and the number of worksheets completed at the end of each session. Every 15 min, we asked subjects to point to separate visual analogue scales ranging from 0 to 10 to indicate feelings of fatigue, pain and energy. Averaging previous indirect calorimetry studies reporting caloric differences of 0.34 kcal/min [17] and 0 kcal/min [18] and a SD of 0.21 kcal/min [17], we estimated a need for 16 subjects to detect a 0.17 kcal/min difference in EE with 90% power, considering multiple comparisons and a within-individual correlation of $r = 0.05$. With further allowance for missing data, this procedure yielded a sample size of 18 subjects.

We checked all data from enrolled subjects for normality and outliers. We summarized demographic data using frequencies, means and standard deviations. We plotted EE and heart rate for each condition averaged across 15-min intervals, during which subjects performed a single task, and across the full 60-min protocol. We converted minute-by-minute EE (kcal/min) to hourly rates by multiplying by 60 min/h and compared across conditions using linear mixed models. We analysed heart rate using similar methods. Post hoc testing considered differences across conditions for each 15-min task-specific interval and were adjusted for multiple comparisons using the Bonferroni method [23]. For clinical application, we calculated arithmetic and geometric means (medians) for the total and relative (per kilogram of body weight) additional EE and heart rate for each hour of STAND–SIT versus SIT and STAND versus SIT due to the small sample size and borderline normality tests. We compared feelings scales across conditions using Friedman’s non-parametric analysis of variance. Because productivity metrics did not meet parametric assumptions, we compared overall productivity for the two tasks (typing and worksheets) during the STAND–SIT and the STAND condition to the SIT condition using the Wilcoxon rank-sum test and adjusted for multiple comparisons using the Bonferroni method [23].

Results

Of 39 subjects screened, 18 (46%) were eligible, enrolled and completed the protocol. Reasons for exclusion were not employed full time ($n = 4$), exclusionary comorbid condition ($n = 6$), trying to lose weight ($n = 6$) and lack of interest or availability ($n = 5$). Subjects represented a wide range of working individuals who would be interested in using a sit–stand desk (Table 1). Our recruitment strategy resulted in age, gender and educational diversity but limited racial diversity. The mean age was 39 and ranged from 22 to 57 years. Body mass index category also varied, with a majority of subjects being overweight. Mean blood pressure was in the normal range. Two-thirds of subjects self-reported meeting physical activity recommendations; mean reported sitting time was 8.8 h/day. Subjects had positive attitudes about sit–stand desks: 78% would like a sit–stand desk ‘quite a bit’ or ‘very much’, 72% thought that a sit–stand desk would improve their health ‘quite a bit’ or ‘very much’ and 94% thought that they would stand at a sit–stand desk at least half of the day.

Figures 2A and B display EEs (kcal/min) during the experimental protocol overall (Figure 2B) and in 15-min increments (Figure 2A). Figure S1A, available as Supplementary data at Occupational Medicine Online, displays minute-by-minute data. Cumulative hourly EE was 70.8 ± 14.8 kcal/h for SIT, 76.3 kcal/h for STAND–SIT and 79.1 kcal/h for STAND. From the mixed models, STAND–SIT and STAND both significantly increased EE versus SIT (both $P < 0.001$; Table 2). In follow-up testing, during each 15-min interval, STAND

### Table 1. Subject characteristics ($n = 18$)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD or $n$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>9 (50)</td>
</tr>
<tr>
<td>Male</td>
<td>9 (50)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>16 (89)</td>
</tr>
<tr>
<td>Non-White or multiracial</td>
<td>2 (11)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>High school diploma or GED</td>
<td>2 (11)</td>
</tr>
<tr>
<td>Some college or associates degree</td>
<td>2 (11)</td>
</tr>
<tr>
<td>College graduate</td>
<td>7 (39)</td>
</tr>
<tr>
<td>Master’s or doctoral degree</td>
<td>7 (39)</td>
</tr>
<tr>
<td>Age, years</td>
<td>39 ± 13</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>75.6 ± 13.8</td>
</tr>
<tr>
<td>Body Mass Index category</td>
<td></td>
</tr>
<tr>
<td>Normal or underweight (BMI &lt; 25 kg/m$^2$)</td>
<td>7 (39)</td>
</tr>
<tr>
<td>Overweight (BMI 25 to &lt;30 kg/m$^2$)</td>
<td>10 (56)</td>
</tr>
<tr>
<td>Obese (BMI ≥ 30 kg/m$^2$)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td>117 ± 13/71 ± 10</td>
</tr>
<tr>
<td>Physical activity level</td>
<td></td>
</tr>
<tr>
<td>Inactive</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Insufficiently active</td>
<td>5 (28)</td>
</tr>
<tr>
<td>Meeting physical activity recommendations</td>
<td>12 (67)</td>
</tr>
<tr>
<td>Sitting time, h/day</td>
<td>8.8 ± 2.1</td>
</tr>
</tbody>
</table>

GED, General Educational Development exam.
had significantly greater EE for each 15-min interval (all \( P < 0.01 \)) and STAND–SIT had significantly greater EE for the first three 15-min intervals (all \( P < 0.01 \)) but not during the final 15 min (\( P = \) not significant). Notably, during the third 15-min interval, EE while standing during the STAND condition was 7.4 \[95\% \text{ confidence interval (CI)} \ 5.1–9.7\] kcal/h higher than SIT and while sitting during the STAND–SIT condition was 7.8 (95\% CI 5.5–10.1) kcal/h higher than SIT (Figure 2).

Table 2 displays additional EE for STAND–SIT versus SIT and STAND versus SIT as mean (SD) and median (25th, 75th percentile) absolute differences (kcal/h) and differences relative to body weight (kcal/kg·h). The additional EE associated with standing 50% of the time during the STAND–SIT condition was 67% of the extra EE observed in STAND.

Figures 2C and D display heart rates during the experimental protocols overall (Figure 2D) and in 15-min increments (Figure 2C). Figure S1B, available as Supplementary data at Occupational Medicine Online, displays minute-by-minute data. STAND–SIT and STAND each significantly increased heart rate versus SIT (both \( P < 0.001 \)) (Table 2). In follow-up testing, STAND and STAND–SIT each had significantly greater heart rate versus SIT for each 15-min interval (all \( P < 0.001 \); Table S1, available as Supplementary data at Occupational Medicine Online). Notably heart rate was 12–13 bpm higher during the first two 15-min intervals in both the STAND–SIT and STAND versus SIT conditions. During the third and fourth 15-min intervals, STAND–SIT was only 2–3 bpm higher than SIT while STAND was 14–15 bpm higher than SIT. Table 2 displays mean (SD) and median (25th, 75th percentile) additional heart rate for STAND–SIT versus SIT and STAND versus SIT. The extra heart rate associated with standing 50% of the time during the STAND–SIT condition was 55% of the extra heart rate observed in STAND.

Experimental conditions yielded similar trajectories of self-rated energy (Figure 3A), fatigue (Figure 3B) and pain (Figure 3C) over time. Non-parametric testing of feelings scores across conditions and within
individuals revealed no significant differences across conditions. During the typing task in the first and third 15-min intervals, the total number of characters typed was not statistically different across conditions [median (25th, 75th percentile): 4822 (2910, 6529) for SIT, 4761 (2678, 6511) for STAND–SIT and 4271 (2678, 6511) for STAND]. For worksheets completed during the second and fourth 15-min intervals, subjects completed a similar number in the SIT [2.0 (1.75, 4.0)] and STAND–SIT [1.75 (1.5, 2.25)] conditions (not significant). However, subjects completed significantly fewer worksheets in the STAND [1.75 (1.5, 2.25)] versus SIT conditions ($P < 0.05$).

**Discussion**

We found that performing deskwork in standing or alternating (standing then sitting) positions significantly increased EE as compared with sitting alone. Though statistically significant, the increases in EE were modest with a 7.8% increase for the combination of standing and sitting and an 11.5% increase for continuous standing. Interestingly, alternating equally between standing and sitting engendered more than half of the additional EE observed during standing alone, supporting a benefit of sit–stand transitions as recommended by ergonomists. Standing and alternating positions were accompanied by an increase in heart rate, similar productivity when typing (though not when completing worksheets) and similar feelings of energy, fatigue and pain.

**Strengths of this study** include the representative population, long assessment interval, carefully standardized testing procedures and assessment of EE by indirect calorimetry. However, there are limitations too: this study explored acute and not long-term effects of using sit–stand desks. Also, although we did our best to mimic an office setting, subjects performed standardized desk tasks while wearing metabolic equipment (including a mask) that could have reduced external validity.

Existing studies of the EE associated with standing versus sitting report variable results [16–21]. Our data are comparable to studies in subjects with obesity [19] or overweight and obesity [21], which found increases in EE over sitting of 15 and 13%, respectively, using indirect calorimetry [19]. Studies reporting greater additional EE from standing versus sitting, as compared with the results of our study, had notable differences that could explain the disparate results, including different measurement methodology (e.g. additional 50 kcal/h reported when using heart rate monitors to estimate EE) [16] or different sample populations (e.g. 33% increase in EE among healthy young adults) [17]. Although the literature and the lay media have reported higher estimates, providing accurate, generalizable and realistic estimates of the additional EE that working adults can expect by standing more is an important public health responsibility.

A unique contribution of this research is the effect of alternating positions (30-min standing, 30-min sitting) on EE. The finding that standing for 50% of the time and then sitting can produce 67% of the additional EE observed with continuous standing supports an alternating sit–stand desk routine. These results dovetail nicely with ergonomic recommendations that frequent position changes are best for musculoskeletal health [24,25] and with physiological studies that have found such an alternating pattern can reduce postprandial glucose excursions [26]. These other benefits of more standing and position changes are also important and, combined with the results of this study, suggest that using sit–stand desks can improve multiple aspects of health in desk workers with sedentary occupations.

Subjects in this study had similar feelings of pain, energy and fatigue across conditions. These findings differ from other research reporting that self-reported

![Figure 3.](image-url)
pain improved with the use of a sit–stand or standing desk [24,25,27]. Though not entirely clear, we suspect that our global measure of pain, small sample size and the potentially uncomfortable mask and equipment required for indirect calorimetry may have limited the ability to detect the benefits observed in other studies. Also in another study, subjects reported increased feelings of energy after a short-term sit–stand desk intervention study [27], suggesting that prolonged rather than acute exposure to more standing at work may be necessary to increase energy levels. This study found that typing productivity was similar across conditions while worksheet completion was lower in a standing position. Other studies have found that productivity has not differed in a seated versus standing position [24,25,27] and, in a short-term sit–stand desk intervention study, self-rated productivity increased [27]. We suspect that the qualitatively different results in productivity we observed resulted from a limitation of the experimental setting and not a true detriment to productivity while standing. When subjects were able to gaze unobstructed at the monitor and type, productivity was similar when standing or sitting; when subjects had to look down onto the desk, over their mask and the mass flow sensor, this was more difficult in the standing position. Thus, we believe the typing results, which suggest similar productivity across conditions, are more valid and that our results are consistent with other reports of comparable productivity in a standing or seated position.

Our research could be helpful for recommending the use of a sit–stand desk at work. A recent expert statement commissioned by Public Health England and the Active Working Community Interest Company concluded that, for employees with sedentary occupations, at least 2 h/day and ideally 4 h/day should be spent in light activity (e.g. standing or walking) [14]. Using estimates from this study for the alternating condition, we would predict that accumulating 2–4 h/day of standing could result in an additional 21–48 kcal/day for an average-sized American woman (75.5 kg) and an additional 25–57 kcal/day for the averaged-sized American man (88.9 kg) [28]. Although modest, the additional EE would accumulate over time and could be a meaningful part of the solution to recovering the estimated deficit of 100 kcal/day that has occurred in occupational EE over the past five decades [28]. Considered specifically from an energy balance perspective, individuals able to achieve 4 h/day of standing could get about halfway to the 100 kcal/day ‘energy gap’ that experts believe could help prevent weight gain in 90% of people [11]. Moreover, individuals could achieve this benefit as part of the normal working day. Future research investigating whether sit–stand desks can affect long-term weight outcomes in real-world settings will help elucidate the potential role for sit–stand desks in weight control for desk-based workers.

Key points

- Use of a sit–stand desk to perform work in an alternating or standing position provides an opportunity to increase energy expenditure during the working day.
- Sitting, standing or alternating these postures resulted in similar feelings of fatigue, energy, pain and productivity while typing.
- Though modest, accumulation of this small benefit over time could be an important part of the public health strategy to prevent weight gain in deskbound workers.

Funding

This research was funded by the Humanscale Company (an office furnishings company that manufactures, among other things, sit–stand desks). Humanscale approved our investigator-initiated research proposal, but all research was conducted independently by the research team at the University of Pittsburgh and Humanscale was not involved in data collection, data analysis or manuscript preparation.

Conflicts of interest

None declared.

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