Health and productivity at work: which active workstation for which benefits: a systematic review

Francois Dupont, Pierre-Majorique Léger, Mickael Begon, François Lecot, Sylvain Sénécal, Elise Labonté-Lemoyne, Marie-Eve Mathieu

Abstract

In order to reduce sedentary behaviour at work, research has examined the effectiveness of active workstations. However, despite their relevance in replacing conventional desks, the comparison between types of active workstations and their respective benefits remains unclear. The purpose of this review article is thus to compare the benefits between standing, treadmill and cycling workstations. Search criteria explored Embase, PubMed and Web of Science databases. The review included studies concerning adults using at least two types of active workstations, evaluating biomechanical, physiological work performance and/or psychobiological outcomes. Twelve original articles were included. Treadmill workstations induced greater movement/activity and greater muscular activity in the upper limbs compared with standing workstations. Treadmill and cycling workstations resulted in elevated heart rate, decreased ambulatory blood pressure and increased energy expenditure during the workday compared with standing workstations. Treadmill workstations reduced fine motor skill function (ie, typing, mouse pointing and combined keyboard/mouse tasks) compared with cycling and standing workstations. Cycling workstations resulted in improved simple processing task speeds compared with standing and treadmill workstations. Treadmill and cycling workstations increased arousal and decreased boredom compared with standing workstations. The benefits associated with each type of active workstation (eg, standing, treadmill, cycling) may not be equivalent. Overall, cycling and treadmill workstations appear to provide greater short-term physiological changes than standing workstations that could potentially lead to better health. Cycling, treadmill and standing workstations appear to show short-term productivity benefits, while treadmill workstations reduce the performance of computer tasks.

Introduction

In 2013, costs associated with sedentary behaviour were estimated at $65.5 billion worldwide. Moreover, a shift from manual labour jobs to highly sedentary service industry and office-based professions has been observed over the last decades. Recently, researchers have begun to study interventions designed to break up and reduce sedentary time throughout the workday by replacing the sitting workstation, which promotes sedentary behaviour, with active workstations.

Standing, treadmill or cycling workstations change the ergonomic paradigm of the 09:00–17:00 workday, allowing a change in posture (ie, sitting vs standing) and improved muscle activation (ie, none vs muscular contractions) during work activities (figure 1). Many studies suggest that active workstations could reduce sedentary time at work, maintain work productivity, increase energy expenditure, regulate high blood pressure, relieve back pain, enhance positive affect and increase cognitive abilities compared with conventional seated workstations.

Considering the growing body of evidence that suggests that standing, treadmill and cycling workstations may improve health and productivity at work compared with seated workstations, it would be relevant to have a better understanding of what benefits are specific to each of these active workstations. The purpose of this review article is thus...
METHODS

Eligibility and exclusion criteria
To be included in this review, studies were required to be published in peer-reviewed academic journals, written in English and respect Participants, Interventions, Comparators, Outcomes, Study criteria (table 1). Participant criteria included adult population, healthy or with cardiometabolic disorders and free of musculoskeletal complaints. Studies were required to include at least two types of active workstations. Both laboratory and free-living environment intervention protocols were included. Studies also needed to evaluate biomechanical, physiological, psychobiological and/or cognitive outcomes. Studies were excluded if active workstations were not standing, treadmill or cycling based, and included ‘interest of use’ or ‘social acceptance’ outcomes.

Literature search and study selection
A computer-assisted systematic search of Central, Embase, PubMed and Web of Science databases was conducted on 13 March 2018 and included all studies prior to that date. The following keywords were used: ‘desks’, ‘workstation’, *work station, *works station and the following Boolean phrase: active OR bik* OR cycling OR ‘height adjustable’ OR stepping OR ‘stand up’ OR standing OR treadmill* OR walk* OR elliptical OR bicycl* OR pedaling OR ‘stability ball’ OR ‘stability balls’ OR ‘exercise ball’ OR ‘exercise balls’ OR ‘swiss ball’ OR ‘swiss balls’ OR ‘sit-to-stand’ OR ‘sit stand’.

A first study selection was completed independently by two reviewers (FD, FL) based on the ‘inclusion of at least two active workstations’ by screening titles and abstracts. A final selection was made according to eligibility criteria by one reviewer (FD) using full texts.

Data extraction and results presentation
Data extraction process was completed by FD. Relevant outcomes were collected, analysed and summarised. Only significant differences (ie, mean values, z-scores, percentile, and so on) were reported in the review. Effect size (Cohen’s $d$) has been calculated for all significant differences.

Quality assessment
Two authors (FD, FL) used the modified Downs and Black checklist based on 27 ‘yes’-or-’no’ items across five sections of quality assessments to determine risk of bias: (1) study quality; (2) external validity; (3) study bias; (4) confounding and selection bias; and (5) power of the study.

RESULTS
Out of the 1352 studies identified through computer search, 274 examined the effects of active workstations (figure 2). Twelve studies met eligibility criteria (table 2) and their quality was assessed (table 3). Studies were diverse in terms of outcomes, measures and study design. Selected studies used different taxonomies to define ‘active workstation’, and we regrouped them as follows: (1) standing workstations, (2) walking workstations, and (3) cycling workstations.
(speed expressed in km/hour), and (3) pedalling/elliptical workstations (power expressed in watts (W) and in maximum aerobic power (MAP)). Conventional seated workstations were present in selected studies, but are beyond the scope of the present review.

Musculoskeletal activity

One study\textsuperscript{13} examined the biomechanics of three active workstations using electromyography of the trapezius and erector spinae, trunk and head 3D kinematics and physical activity quantified by accelerometers on the legs, trunk and arms. Twelve participants were asked to complete general office tasks (ie, typing, reading, correction, telephone use, mouse dexterity and cognitive tasks) while using active workstations. An increase in right trapezius activity was observed from standing to treadmill\textsuperscript{2.5} km/hour workstations: 3.8\% vs 8.1\% of maximum voluntary contraction (median values), respectively. Also, all variables concerning the intensity of movement (median and 95th percentile) increased in treadmill\textsuperscript{2.5} km/hour and treadmill\textsuperscript{0.6} km/hour conditions compared with standing, except for the physical activity intensity of the head at the 95th percentile for treadmill\textsuperscript{0.6} km/hour which remained similar to the standing condition.

Physiological activity

Six studies\textsuperscript{8, 13–17} reported physiological outcomes. Four\textsuperscript{13–16} included adults with no health issues (n=109) and two studies\textsuperscript{8, 17} included adults with overweight or class 1 obesity who also had prehypertension or impaired fasting glucose (n=22). From those four studies, mean heart rate (HR), blood pressure, energy expenditure, perceived exertion and pressure pain thresholds were assessed. All studies except one\textsuperscript{17} showed no difference between workstations.

Mean HR

Increased HR was observed in all four studies\textsuperscript{8, 13–15} when using treadmill or cycling compared with standing workstations. Specifically, Botter et al\textsuperscript{13} reported an increase of 12 beats per minute (bpm) using a treadmill\textsuperscript{2.5} km/hour (91 bpm) compared with standing (79 bpm), which was corroborated by Cox et al.\textsuperscript{14} Moreover, Straker et al\textsuperscript{15} reported an increase of 5 bpm for the treadmill\textsuperscript{3.2} km/hour and an increase of 7 bpm for cycling\textsuperscript{50} W compared with standing workstations. All other conditions with lower power or speed (eg, treadmill\textsuperscript{1.6} km/hour; cycling\textsuperscript{5} W) did not result in an increase in bpm. Zeigler et al\textsuperscript{8} monitored HR during a 12-hour period (08:00–20:00) and were specifically interested in two periods (ie, work hours (08:00–16:00) and postwork...
### Table 2: Overview of studies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study Design</th>
<th>Intervention Duration</th>
<th>Sample Size</th>
<th>Population Characteristics</th>
<th>Experimental Conditions</th>
<th>Measures</th>
<th>Results</th>
<th>Effect Size (Cohen's $d$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dupont et al.</td>
<td>21 Counterbalanced randomised experiment</td>
<td>2019-2020</td>
<td>Males=14; Females=12</td>
<td>Healthy undergraduate students</td>
<td>Sitting, Standing</td>
<td>Pain, Mood, Cardiovascular Function</td>
<td>All results were non-significant</td>
<td>NA</td>
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<tr>
<td>Botter et al.</td>
<td>Randomised repeated measures</td>
<td>2019-2020</td>
<td>Males=6; Females=6</td>
<td>Healthy undergraduate students</td>
<td>Sitting, Standing</td>
<td>Pain, Mood, Cardiovascular Function</td>
<td>Heart rate, Energy expenditure</td>
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</tbody>
</table>
### Table 2 continued

<table>
<thead>
<tr>
<th>Authors/study</th>
<th>Design</th>
<th>Intervention duration</th>
<th>Sample (n)</th>
<th>Population characteristics</th>
<th>Experimental conditions</th>
<th>Measures</th>
<th>Results</th>
<th>Effect size (Gail &amp; al)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commisaris et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Randomised repeated measures</td>
<td>1 workday</td>
<td>Males=7 Females=8</td>
<td>29.8 years old BMI=22.3 kg/m²</td>
<td>Sitting Standing Treadmill (2.5 km/hour)</td>
<td>Typing task (number of characters typed/min); Reading and correcting task (number of characters read/min); Reaction time test; Mouse task; Multi-directional cognitive task; Telephone task</td>
<td>No statistical analyses have been done between active workstations.</td>
<td>NA</td>
</tr>
<tr>
<td>Cox et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Randomised repeated measures</td>
<td>60 min</td>
<td>Males=9 Females=22</td>
<td>37 years old</td>
<td>Sitting Standing Treadmill (1.6 km/hour)</td>
<td>Aerobic capacity (ml/min/kg); Heart rate; Blood pressure; Perceived effort; Dyspnoea perception; Speech assessment</td>
<td>Treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (2.8±0.3) increased VO&lt;sub&gt;2&lt;/sub&gt; demands compared with standing (2.6±0.3). Treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; increased heart rate compared with standing. SBP values were greater in standing (126±6) and treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (127±6). Treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; lowered blood pressure compared with standing. Ratings of perceived effort values: standing (5.3); treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (3.1±0.6). Treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; increased perceived effort compared with standing. Dyspnoea perception scores showed that treadmill perception of breathing effort was higher compared with standing. All other results were non-significant.</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt; treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; vs standing (1.80); Heart rate treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; vs standing (3.02); SBP treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; vs standing (11.29); Ratings of perceived effort treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; vs standing (4.53); Dyspnoea treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; vs standing (5.9)</td>
</tr>
<tr>
<td>Gilson et al&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Pilot study</td>
<td>1.5-hour work period/day experimental condition</td>
<td>Males=10 Females=3</td>
<td>35–50 years old</td>
<td>Sitting Standing Cycling</td>
<td>Arousal treadmill vs standing=0.77; Arousal cycling vs standing=0.95; Boredom treadmill vs standing=−1.84; Boredom cycling vs standing=−0.68; Task satisfaction treadmill vs standing=0.58; Performance-level cycling vs standing=−0.68</td>
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<tr>
<td>Kruse et al&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Pilot study</td>
<td>(1) 4-hours of uninterrupted sitting (2) 4-hours of sitting interrupted with four 10-min bouts of light-intensity desk cycling</td>
<td>Males=10 Females=3</td>
<td>35–50 years old BMI=29.7 kg/m² Sedentary, overweight and obese adults</td>
<td>Sitting Standing Treadmill (self-determined speed range between 1.6 and 4 km/hour)</td>
<td>Arousal treadmill vs standing=0.77; Arousal cycling vs standing=0.95; Boredom treadmill vs standing=−1.84; Boredom cycling vs standing=−0.68; Task satisfaction treadmill vs standing=0.58; Performance-level cycling vs standing=−0.68</td>
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<tr>
<td>Ohlinger et al&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Within-participants experimental</td>
<td>75 min for all assessments</td>
<td>Males=10 Females=7</td>
<td>30–50 years old BMI=25.3 kg/m² Sedentary/overweight</td>
<td>Sitting Standing Treadmill (1.3 km/hour)</td>
<td>Short-term auditory verbal memory; Heart rate; Blood pressure; Calf circumference</td>
<td>Treadmill&lt;sub&gt;1.3 km/hour&lt;/sub&gt; showed lower performance speed than cycling20 W. Detection test reaction time values: standing (2.72±0.13 log&lt;sub&gt;10&lt;/sub&gt; ms), treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (2.71±0.13 log&lt;sub&gt;10&lt;/sub&gt; ms) and cycling20 W (2.66±0.14 log&lt;sub&gt;10&lt;/sub&gt; ms). Reaction time was faster for cycling20 W compared with standing. All other results were non-significant.</td>
<td>Detection test processing speed cycling20 W vs standing (1.37); Simple motor task satisfaction treadmill vs standing=0.15</td>
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<tr>
<td>Mullane et al&lt;sup&gt;18&lt;/sup&gt;</td>
<td>Randomised crossover</td>
<td>6-hour experimental condition with bouts of 10, 15, 20 and 30 min on active workstation</td>
<td>Males=2 Females=7</td>
<td>30–60 years old BMI=23.7 kg/m² Physically active (n=7)</td>
<td>Sitting Standing Treadmill (1.6 km/hour)</td>
<td>Detection test (speed expressed in a z-score and mean log&lt;sub&gt;10&lt;/sub&gt; transformed reaction times for correct responses). Detection test reaction time values: standing (2.72±0.13 log&lt;sub&gt;10&lt;/sub&gt; ms); treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (2.71±0.13 log&lt;sub&gt;10&lt;/sub&gt; ms) and cycling20 W (2.66±0.14 log&lt;sub&gt;10&lt;/sub&gt; ms). Reaction time was faster for cycling20 W compared with standing. All other results were non-significant.</td>
<td>Detection test processing speed cycling20 W vs treadmill&lt;sub&gt;1.6 km/hour&lt;/sub&gt; (0.63); Detection test processing speed cycling20 W vs standing (0.61); Reaction time cycling20 W vs standing=0.44</td>
<td></td>
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<tr>
<td>Sliper and Hua&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Pilot study</td>
<td>35 min</td>
<td>Males=80 Females=21</td>
<td>21.2 years old BMI=23.9 kg/m² Undergraduate students</td>
<td>Sitting Standing Treadmill Cycling</td>
<td>Stress; Arousal; Boredom; Task satisfaction; Performance (number of correct tasks; number of errors in task)</td>
<td>Treadmill&lt;sub&gt;5.8 km/hour&lt;/sub&gt; (2.85±0.3) increased stress compared with standing (2.55±0.4). Cycling increased arousal compared with standing. Treadmill decreased boredom compared with standing. Treadmill increased task satisfaction compared with standing. Treadmill decreased stress compared with standing. Treadmill provided more task satisfaction than standing. Performance-level (number of items completed correctly) showed a decrease in performance between cycling and standing. All other results were non-significant.</td>
<td>Arousal treadmill vs standing=0.77; Arousal cycling vs standing=0.99; Boredom treadmill vs standing=1.84; Boredom cycling vs standing=1.32; Stress treadmill vs standing=0.77; Task satisfaction treadmill vs standing=0.58; Performance-level cycling vs standing=0.68</td>
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## Table 2 - continued

<table>
<thead>
<tr>
<th>Author/study</th>
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<th>Measures</th>
<th>Results</th>
<th>Effect size (Odds ratio)</th>
</tr>
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<tbody>
<tr>
<td>Straker et al</td>
<td>Experimental mixed model</td>
<td>1 workday</td>
<td>22–64 years old</td>
<td>Body mass (BMI): standing (25.1) vs treadmill (23.5)</td>
<td>Sitting, Standing, Treadmill (0.64 km/h), Treadmill (0.72 km/h), Cycling (5.6 km/h), Cycling (30 W)</td>
<td>Typing speed (words/min), Typing accuracy (% typing errors), Typing perceived speed, Typing perceived accuracy Mouse pointing speed, Mouse task accuracy, Mouse perceived speed, Combined keyboard and mouse task perceived speed and error</td>
<td>Heart rate mean values: standing (82), treadmill (82), treadmill (87), cycling (79), cycling (89). Results showed an increase in the mean heart rate for treadmill (87) vs standing (82), treadmill (82) vs standing (82), treadmill (79) vs cycling (80), cycling (51) vs cycling (55), cycling (55) vs standing (82).</td>
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Combined keyboard-mouse perceived speed treadmill 3.2 km/hour vs standing 0.55
Combined keyboard-mouse perceived speed treadmill 1.6 km/hour vs standing 0.55
Combined keyboard-mouse perceived speed treadmill 3.2 km/hour vs bicycle 5 W = 0.51
Combined keyboard-mouse perceived speed treadmill 1.6 km/hour vs bicycle 5 W = 0.15
Combined keyboard-mouse perceived accuracy treadmill 3.2 km/hour vs standing 0.99
Combined keyboard-mouse perceived accuracy treadmill 1.6 km/hour vs standing 0.99
Heart rate treadmill 3.2 km/hour vs bicycle 5 W = 0.37
Heart rate bicycle 5 W vs bicycle 30 W = 0.47
Perceived exertion treadmill 3.2 km/hour vs bicycle 5 W = 0.25
Perceived exertion bicycle 30 W vs bicycle 5 W = 0.34

continued
Table 2 continued

<table>
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<th>Authors/study</th>
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<th>Experimental conditions</th>
<th>Measures</th>
<th>Results</th>
<th>Effect size (Cohen's (d))</th>
</tr>
</thead>
</table>
| **Leniger et al**⁹ | Randomised crossover | Monitoring for 12 hours (08:00–20:00) | Males=21 Females=7 | 30-years-old healthy adults | Siting Standing | Heart rate Blood pressure | 12-hour period (08:00–20:00) mean heart rate values: standing (74±12), treadmill (91±12), cycling (86±13). | **Heart rate:** 0.33 | Heart rate (08:00–20:00) treadmill vs standing=0.33 | 0.33 | **SBP:** 0.00–20:00 treadmill vs standing=0.33 | 0.33 | **DBP:** 0.00–20:00 treadmill vs standing=0.12 | 0.12 | **Heart rate (work hours):** treadmill vs standing=0.4 | 0.4 | "All other results were non-significant."

Values presented as means, unless otherwise specified. 
⁹: age group (firstline); % MVC, maximum voluntary contractions; BMI, body mass index; BHP, blood pressure; EEG, electroencephalography; EMG, electromyography; MAP, % of maximum aerobic power; MET, metabolic equivalent; NA, not applicable; RPM, revolutions per minute; SBP, systolic blood pressure; W, watts.
### Table 3  Study quality assessed by the modified Downs and Black checklist

<table>
<thead>
<tr>
<th>Item</th>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is the hypothesis/aim/objective of the study clearly described?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>2</td>
<td>Are the main outcomes to be measured clearly described in the introduction or Methods section?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>3</td>
<td>Are the characteristics of the patients included in the study clearly described?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>4</td>
<td>Are the interventions of interest clearly described?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>5</td>
<td>Are the distributions of principal confounders in each group of subjects to be compared clearly described?</td>
<td>2 0 2 0 1 2 2 2 0 1 1 2</td>
</tr>
<tr>
<td>6</td>
<td>Are the main findings of the study clearly described?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>7</td>
<td>Does the study provide estimates of the random variability in the data for the main outcomes?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>8</td>
<td>Have all important adverse events that may be a consequence of the intervention been reported?</td>
<td>1 0 1 0 0 1 1 1 1 1 0 0 0 0</td>
</tr>
<tr>
<td>9</td>
<td>Have the characteristics of patients lost to follow-up been described?</td>
<td>0 0 0 0 0 1 0 0 1 1 1</td>
</tr>
<tr>
<td>10</td>
<td>Have actual probability values been reported (eg, 0.035 rather than &lt;0.05) for the main outcomes except where probability value is &lt;0.001?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>11</td>
<td>Were the subjects asked to participate in the study representative of the entire population from which they were recruited?</td>
<td>1 1 0 0 0 0 0 1 1 1 1 1</td>
</tr>
<tr>
<td>12</td>
<td>Were those subjects who were prepared to participate representative of the entire population from which they were recruited?</td>
<td>1 1 0 0 0 0 0 1 1 1 1 1</td>
</tr>
<tr>
<td>13</td>
<td>Were the staff, places and facilities where the patients were treated representative of the treatment the majority of patients receive?</td>
<td>0 0 1 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>14</td>
<td>Was an attempt made to blind study subjects to the intervention they have received?</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>15</td>
<td>Was an attempt made to blind those measuring the main outcomes of the intervention?</td>
<td>0 0 0 0 0 1 0 0 0 1 1</td>
</tr>
<tr>
<td>16</td>
<td>If any of the results of the study were based on &quot;data dredging&quot;, was this made clear?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>17</td>
<td>In trials and cohort studies, do the analyses adjust for differences in length of follow-up of patients, or in case-control studies, is the time period between the intervention and outcomes the same for cases and controls?</td>
<td>1 0 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>18</td>
<td>Were the statistical tests used to assess the main outcomes appropriate?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>19</td>
<td>Was randomisation used?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
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<tr>
<td>20</td>
<td>Were the main outcome measures used accurate and reliable?</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1</td>
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<table>
<thead>
<tr>
<th>Item</th>
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<tr>
<td>Internal validity—confounding (selection bias)</td>
<td></td>
<td></td>
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<tr>
<td>21</td>
<td>Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case–control studies) recruited from the same population?</td>
<td>1 1 0 0 0 0 0 0 1 0 1 1 1 1 0</td>
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<tr>
<td>22</td>
<td>Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case–control studies) recruited over the same period of time?</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
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<tr>
<td>23</td>
<td>Were study subjects randomised to intervention groups?</td>
<td>1 1 1 1 1 0 1 1 0 0 0 1 1 1 1</td>
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<tr>
<td>24</td>
<td>Was the randomised intervention assignment concealed from both patients and healthcare staff until recruitment was complete and irreversable?</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>25</td>
<td>Were there adequate adjustment for confounding in the analyses from which the main findings were drawn?</td>
<td>1 0 1 0 0 0 1 0 1 0 0 0 1 0 0</td>
</tr>
<tr>
<td>26</td>
<td>Were losses of patients to follow-up taken into account?</td>
<td>1 0 0 0 0 1 0 0 0 1 1 0 1 1 1</td>
</tr>
<tr>
<td>Power</td>
<td></td>
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<td>27*</td>
<td>Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.</td>
<td>0 0 0 0 0 0 0 1 0 1 0 1 0 1 0</td>
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<tr>
<td>Total score</td>
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<td>1928 1428 1728 1428 1628 1628 2028 1928 1728 1528 2128 1928</td>
</tr>
</tbody>
</table>

*Item has been modified: yes = 1; no = 0.
hours (16:00–20:00)). Results from the 12-hour period showed an increase of 4 bpm for both treadmill1.6 km/hour and cycling20 W conditions compared with standing. Results from the working hour-specific period showed an increase of 5 bpm for treadmill1.6 km/hour and 6 bpm for cycling20 W compared with standing. Results from postwork period showed no difference in HR between conditions.

Blood pressure
Two studies14 16 with different populations and active workstations examined mean systolic blood pressure (SBP) and mean diastolic blood pressure (DBP). Cox et al14 found no difference in SBP and DBP measured during an intervention comparing standing and treadmill workstations. The second study8 monitored ambulatory blood pressure on adults with overweight or class 1 obesity meeting prehypertensive or impaired fasting glucose criteria over a 12-hour period (08:00–20:00). During the 12-hour period, a reduction of 2 mm Hg for cycling20 W and 1 mm Hg for treadmill1.6 km/hour was reported in SBP compared with standing. For the work hour period (08:00–16:00), a decrease in SBP of 2 mm Hg was reported for cycling20 W compared for both treadmill1.6 km/hour and standing workstations. In the postwork period (16:00–20:00), there was a greater decrease in SBP compared with the two periods mentioned above. SBP for cycling20 W decreased by 8 mm Hg compared with treadmill1.6 km/hour and 9 mm Hg compared with the standing workstation. DBP was similar between standing and treadmill1.6 km/hour conditions for all three periods. However, cycling20 W decreased DBP by 3 mm Hg compared with standing, and 2 mm Hg compared with treadmill1.6 km/hour workstations for the 12-hour period as well as decreased DBP by 3 mm Hg compared with standing during working hours.

Energy expenditure
Energy expenditure and VO₂ were measured in three studies.13 14 16 Botter et al13 showed an increase in energy expenditure of 1.2 metabolic equivalent (MET) for treadmill1.6 km/hour workstations compared with standing. Cox et al14 measured a similar increase of 1 MET from standing to treadmill1.6 km/hour. Tronarp et al16 measured energy expenditure in kcal. In this study, energy expenditure increased between all three conditions: an increase of 2.9 kcal/min between cycling20%MAP and standing; an increase of 6.9 kcal/min between cycling50%MAP and standing.

Perceived exertion and pain tolerance
Two studies14 15 measured perceived exertion, both using the 10-point Borg Scale. In the first study, Cox et al14 reported an increase in perceived effort and perceived breathlessness (ie, dyspnoea) on the treadmill compared with standing for all tasks, namely warm-up, silent reading, reading aloud and speaking aloud spontaneously. The second study reported higher perceived exertion for treadmill1.6 km/hour (1.74/10), treadmill2 km/hour (2.39/10), cycling30 W (1.66/10) and cycling50 W (2.61/10) compared with standing (0.95/10). Furthermore, higher perceived exertion was reported for greater power and speed on treadmill and cycling workstations (eg, treadmill3.2 km/hour and cycling50 W compared with treadmill1.6 km/hour and cycling20 W).

Pressure pain threshold was measured in kilopascals (kPa) using a Somedic algometer on the right quadriceps, right ventral forearm and right trapezius.14 Only differences in the pressure pain threshold of the right trapezius between standing (16.8 kPa) and cycling20%MAP (39.3 kPa) were reported.

Work performance
Seven studies10 15 16 18–21 reported cognitive outcomes. The authors measured perceived and actual task performances (eg, typing, mouse, psychomotor performances), attention and short-term memory capacity as well as psychobiological (eg, arousal, boredom) outcomes.

Perceived work performance
One study15 reported perceived task performance. Studies observed perceived speed and accuracy of typing, mouse pointing and combined keyboard/mouse tasks. Perceived work performance was assessed with a questionnaire. Participants rated perceived effect of the use of diverse active workstations on a scale of 1–5 (1=very enhanced to 5=very diminished). Results from the perceived typing questionnaire showed a decrease in performance for the treadmill1.6 km/hour, treadmill2 km/hour, cycling20 W and cycling50 W compared with standing. Perceived accuracy also decreased with the use of both treadmill1.6 km/hour and cycling20 W workstations compared with the standing workstation. In addition, a decline in perceived accuracy was reported for the low-intensity treadmill1.6 km/hour compared with the low-intensity cycling20 W condition.

Questionnaire outcomes for perceived mouse pointing speed showed a decrease for treadmill1.6 km/hour, treadmill2 km/hour, cycling20 W and cycling50 W compared with standing. Also, a reduction of perceived speed was observed for both treadmill1.6 km/hour and treadmill2 km/hour and both cycling20 W and cycling50 W conditions. There was a decline for the treadmill1.6 km/hour, cycling20 W and cycling50 W compared with standing in perceived mouse pointing accuracy. There was a reduction in perceived accuracy for both treadmill workstations compared with low-intensity cycling20 W.

Questionnaire outcomes for perceived combined keyboard/mouse speed tasks showed a decrease in perceived speed for treadmill1.6 km/hour, treadmill2 km/hour, cycling20 W and cycling50 W compared with standing. In addition, a decline in perceived speed for both treadmill workstation conditions compared with both cycling workstation conditions was observed. Perceived work accuracy decreased for the treadmill1.6 km/hour, treadmill2 km/hour, cycling20 W and cycling50 W compared with standing. Moreover, perceived accuracy declined for treadmill1.6 km/hour compared with the lower intensity treadmill1.6 km/hour and both cycling workstation conditions.

Actual performance tasks
Three studies15 16 20 examined the effect of active workstations on typing performance. Straker et al15 examined the effect of active workstations on typing speed performance (words/min) and accuracy (% of typing errors). Typing speed was reduced for the treadmill1.6 km/hour (49.73 words/min), treadmill1.6 km/hour (50.14 words/min), cycling20 W (53.17 words/min) and cycling50 W (52.58 words/min) compared with standing (54.09 words/min). No differences were reported for the accuracy test. Tronarp et al16 found that gross speed (ie, including erased typing errors) was reduced for the cycling50%MAP (45.5 words/min) and cycling20%MAP (46.5 words/min) compared with standing (47.0 words/min). Net speed (ie, excluding erased typing errors) was also reduced for cycling50%MAP (43.8 words/min) and cycling20%MAP (44.3 words/min) compared with standing (46.3 words/min). Moreover, typing errors (ie, number of errors) increased with both cycling50%MAP (20) and cycling20%MAP (16.3) compared with standing (13.8). No differences were reported between cycling50%MAP and cycling20%MAP. Ohlinger et al20 measured the
number of taps in a 10 s trial. A reduction in tapping speed was observed for the treadmill workstation (55.8) compared with the standing workstation (57.0). To resume, all three studies observed decreases in tapping speed with treadmill workstations compared with a standing workstation. The two studies with cycling conditions observed a decrease in tapping speed compared with a standing workstation. Only one study observed a decrease in tapping word accuracy with the use of cycling workstations compared with a standing workstation.

Two studies examined mouse pointing speed (ie, milliseconds) and accuracy (ie, actual errors). The first study reported a decrease in speed for treadmill (1059 ms); treadmill (1107 ms); and cycling (1022 ms) compared with standing (959 ms). Similar values were reported for cycling (0.20) and cycling (0.16) compared with standing (0.10), and for treadmill (0.20) compared with cycling (0.13). To resume this study observed that mouse pointing speed and accuracy decreased with treadmill workstations compared with a standing workstation. In addition, mouse pointing speed decreased with the use of treadmill workstations compared with cycling workstations. The second study reported a decrease in mouse pointing speed for standing (33.6 ms) compared with cycling (32.6 ms). But contrary to the last study, a decrease in mouse pointing speed was reported for a higher cycling intensity (33.9 ms) compared with standing (33.6 ms). Accuracy was assessed by the number of successful tasks. Results showed a reduction of successful tasks during both cycling (3.5) and cycling (5.5) compared with standing (7). And a decrease in cycling (3.5) compared with cycling (5.5).

One study examined combined keyboard and mouse task performance (ie, speed (words/s) and error rate). A decrease in speed was observed for both treadmill (9.57 words/s) and treadmill (8.26 words/s) compared with standing (11.94 words/s). Furthermore, a decrease in speed was observed for the treadmill (9.57 words/s) and treadmill (8.26 words/s) conditions compared with the cycling (10.84 words/s) and cycling (11.17 words/s) conditions. No differences in error rate were reported between active workstations.

Processing speed tasks
Processing speed tasks were assessed in one study. Researchers used a psychomotor test (ie, detection test from Cogstate) to measure speed and reaction time to accomplish a simple task. Standing z-score and treadmill, Z-score showed a lower speed of performance than cycling z-score. Cycling reaction time was faster than standing reaction time.

Attention and short memory
Out of the four studies that examined the influence of active workstations on attention and short-term memory capacity, none found differences between active workstations (ie, standing, treadmill and cycling) in selective attention. Moreover, divided attention and short-term auditory verbal memory revealed no differences between standing, treadmill and cycling workstations.

Psychobiological
One study reported psychobiological outcomes. With a 4 rating scale questionnaire, this study evaluated the level of arousal, boredom, stress and task satisfaction (eg, 1=definitely no to 4=definitely yes). The authors reported that treadmill workstations increased arousal compared with standing as well as cycling compared with standing. Boredom decreased with treadmill and cycling workstations compared with standing. Stress scores showed that treadmill workstations lowered stress compared with standing.

DISCUSSION
The purpose of this review article was to compare the benefits between standing, treadmill and cycling workstations. This article reviewed 12 studies. Our main findings were that: (1) the benefits associated with standing, treadmill and cycling workstations may not be equivalent; (2) cycling and treadmill workstations appear to provide greater short-term physiological changes than standing workstations that could potentially lead to better health; and (3) cycling, treadmill and standing workstations appear to show productivity benefits while treadmill workstations seem to diminish the performance of work-related use of computers.

Cycling workstation
Cycling workstations with resistance (ie, 20–30 W) can increase energy expenditure by twice the amount of MET compared with standing workstations. Likewise, related to energy expenditure, HR could be increased by 10% compared with standing workstations. Also pertinent, one study reported that cycling workstations with the same HR and energy expenditure as treadmill workstations produced a greater decrease in ambulatory blood pressure in adults presenting with obesity and a prehypertension. Moreover, cycling was the only active workstation that decreased DBP. Although cardiometabolic benefits accompany 20–30 W of resistance, a lower intensity (ie, 5 W) does not provide any advantages over standing or treadmill conditions. Also, bouts of 10 min/hour using a cycling workstation are not enough to reverse the negative effects of prolonged sitting time on lower limb endothelial dysfunction.

Cycling workstations increase arousal and reduce boredom significantly better than standing workstations. These outcomes are relevant as research has reported an interaction between level of physical activity at work, well-being at work and productivity. Furthermore, one study has proposed that cycling workstations could be capable of increasing short-term memory and attention more effectively than standing or treadmill workstations.

No reductions in motor task performance were reported with the use of cycling workstations. Speed processing time in simple tasks does increase compared with treadmill and standing conditions. These productivity results are important as cycling workstations, compared with treadmill and standing workstations, allow workers to experience greater cardiometabolic gains, while maintaining acceptable levels of productivity in office tasks.

Treadmill workstation
Treadmill workstations with speeds between 1.6 and 2.5 km/hour raise energy expenditure by about 1 MET beyond standing workstations and the sedentary threshold (1.5 MET). Also, with greater intensity (ie, 3.2 km/hour), treadmill workstations can increase HR similar to what is found for cycling workstations at 30 W of resistance. However, at this speed, the increase in perceived exertion and discomfort decreases implementation feasibility and motor task performance. Furthermore, the use of...
treadmills compared with standing workstations decreases SBP while no difference is found for DBP.\textsuperscript{14}

Compared with standing workstations, treadmill workstations can positively influence many psychological components related to the work environment. A reduction in task stress, an increase in arousal, a lower feeling of boredom and a higher feeling of task satisfaction were reported by participants based on a single study.\textsuperscript{10,11} More studies are required to clarify the effects of low-intensity exercise similar to the effects described for treadmill workstations on workers’ mood. Some of these improvements may be explained by the increase in cardiovascular activity associated with an active workstation, possibly contributing to improved brain oxygenation, hence an improvement in cognitive tasks (memorisation and attention).\textsuperscript{11–13} However, the results of the current review did not provide evidence of any cognitive benefits from treadmill compared with cycling or standing workstations.

With treadmill workstations, executive motor task performance, such as typing, or mouse pointing was reduced.\textsuperscript{15–17} Higher walking speeds (3.2 km/hour) produced greater muscular activity in the upper limbs than that observed in standing or cycling workstations. This increase in muscular demand of the trunk muscles and upper limb muscles in order to stabilise posture and gait may affect motor coordination related to computer tasks\textsuperscript{18–20} and could lead to muscular fatigue and muscle tension.\textsuperscript{13} In this context, safety issues should be ensured, and further studies are required to ensure the safety of workers using treadmill desks.

**Standing workstation**

Several studies suggest that standing workstations can decrease sitting time at work.\textsuperscript{6,33–36} As a result, even if standing workstations do not exceed a sedentary threshold (ie, energy expenditure)\textsuperscript{37} postprandial glycaemia excursion and blood pressure\textsuperscript{8,19} are improved compared with conventional seated workstations. It is known that prolonged sitting can potentially cause low back pain due to lumbar flexion. A standing position inhibits lumbar flexion. Periods of time on a standing workstation have shown to be preventive against such injuries at work.\textsuperscript{18–20} Interestingly, contrary to a treadmill workstation, the upright posture from standing workstations does not alter executive office tasks such as typing and mouse pointing. Moreover, standing workstations do not increase perceived exertion or reduce the efficiency of computer tasks. Furthermore, studies suggest that globally, standing workstations do not alter cognitive performance tasks.\textsuperscript{13,41}

**Perspectives and limits**

Active workstations are a novel intervention. The comparison of active workstations was available in 12 studies and only 11 specifically compared outcomes between active workstations. Also, the findings of this literature review are supported by short-term measures only. In addition, a large number of outcomes were provided by only one or two studies which both had relatively small sample sizes. As mentioned by other authors,\textsuperscript{42} larger randomised controlled trials with mid-term and long-term protocols are needed to provide stronger evidence.

**CONCLUSIONS**

The benefits associated with standing, treadmill and cycling workstations may not be equivalent. Cycling and treadmill workstations appear to provide greater short-term physiological improvements compared with standing, which could potentially lead to better health outcomes. Cycling, treadmill and standing workstations appear to show short-term productivity benefits; however, treadmill workstations reduce the performance of computer-related work.

With workers and the workplace slowly moving towards active workstations, future long-term studies integrating different types of active workstations should be conducted in order to provide additional evidence. Ultimately, workers and corporations should be able to critically examine the benefits and limitations of each type of workstation and determine which is most appropriate for the worker’s specific needs and tasks.

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**Contributors**

FD and FL performed the literature review. FD and MEM designed the project. FD provided the first draft of the paper. All the authors revised and approved the manuscript.

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**REFERENCES**


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Review


Cycling and treadmill workstations may be ‘healthier’ than standing options

But treadmill versions can interfere with keyboarding, finds evidence review

Cycling and treadmill workstations may be ‘healthier’ than standing versions, because their use seems to be associated with greater positive physiological changes in the body, finds a systematic review of the available evidence, published online in *Occupational & Environmental Medicine*.

But treadmill versions can interfere with computer work, the findings indicate.

Long periods spent sitting down, including at work, are associated with certain health risks, and it is thought that the global cost of sedentary lifestyles is more than US$65 billion (£50.5 billion) a year.

A growing body of research suggests that active workstations may help to counter some of these risks and even boost productivity. But the pros and cons of each type aren’t entirely clear.

To try and shed some light on their potential impact on health and productivity, the researchers trawled databases looking for relevant studies comparing at least two out of treadmill, cycling, and standing workstations.

Twelve studies (out of 274 initially selected) were included in the final analysis, which looked at the effect on muscles and physiology—average heart rate, blood pressure, energy expenditure—perceived exertion and pain tolerance, and cognitive performance at work—processing speeds, attention and short-term memory.

All types of workstation were associated with a short-term boost in productivity.

But cycling and treadmill workstations seemed to be associated with greater short-term physiological changes than standing versions. This might be better for longer term health, suggest the researchers.

Treadmill workstations got people moving and increased upper body muscular activity more than did standing versions. But the upper body effort needed to stabilise gait and posture on a treadmill workstation might affect the fine motor skills needed for keyboarding, explain the researchers.

Both treadmill and cycling workstations boosted heart rate and energy expenditure while prompting a drop in blood pressure during the working day compared with standing workstations, the findings showed.

And treadmill and cycling workstations also increased alertness and reduced boredom more than standing versions did. What’s more, treadmill versions were associated with lower stress scores.
Cycling workstations improved simple processing task speeds the most. But treadmill workstations interfered with fine motor skills, such as typing, mouse pointing, and keyboarding.

The results of the review suggest that the pros and cons of each type of workstation may not be directly comparable, say the researchers. And employers may need to gauge which type is most appropriate for the needs of their staff.

The researchers sound a note of caution about the strength of the available evidence, however: only 11 of the studies they included directly compared different types of workstation; the outcomes measured were all short term; and the most comprehensive studies were relatively small in size.

“With workers and the workplace slowly moving towards active workstations, future long-term studies integrating different types of active workstations should be conducted in order to provide additional evidence,” they emphasise.

“Ultimately, workers and corporations should be able to critically examine the benefits and limitations of each type of workstation and determine which is most appropriate for the worker’s specific needs and tasks,” they conclude.