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 may reduce sitting time and could enhance health and productivity at work.

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 and enhance positive affect and increase cognitive abilities compared with conventional seated workstations.

Key messages
What is already known about this subject?
► Physical demands in the work environment have declined in Western countries over the last decades resulting in new types of negative health concerns.
► Active workstations such as standing, walking and cycling may reduce sitting time and could enhance health and productivity at work.

What are the new findings?
► The benefits associated with each type of active workstation (eg, standing, treadmill, cycling) may not be equivalent.
► 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-related work.

How might this impact on policy or clinical practice in the foreseeable future?
► These results are relevant in order to optimise future workplace interventions.
► Workers and corporations should be able to look at the benefits and limits of each type of workstation and determine which one is most appropriate for workers’ specific needs and tasks.
to compare the benefits between standing, treadmill and cycling workstations.

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’, "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 checklist12 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...
Musculoskeletal activity

One study 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 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 0.6 km/hour and treadmill 2.5 km/hour conditions compared with standing, except for the physical activity intensity of the head at the 95th percentile for treadmill 0.6 km/hour which remained similar to the standing condition.

Physiological activity

Six studies reported physiological outcomes. Four included adults with no health issues (n=109) and two studies 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 showed no difference between workstations.

Mean HR

Increased HR was observed in all four studies when using treadmill or cycling compared with standing workstations. Specifically, Botter et al reported an increase of 12 beats per minute (bpm) using a treadmill 2.5 km/hour (91 bpm) compared with standing (79 bpm), which was corroborated by Cox et al. Moreover, Straker et al reported an increase of 5 bpm for the treadmill 1.2 km/hour and an increase of 7 bpm for cycling 30 W compared with standing workstations. All other conditions with lower power or speed (eg, treadmill 1.6 km/hour; cycling 25 W) did not result in an increase in bpm. Zeigler et al 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/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 (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bantoft et al.</td>
<td>Sit-stand counterbalanced and randomised controlled trial</td>
<td>60 min/1 task/day, 7 days</td>
<td>38 (27% female)</td>
<td>Healthy undergraduate students</td>
<td>Sitting, Standing, Treadmill (1–3 min/hour)</td>
<td>Muscle activation by EMG (% of maximal voluntary contraction; trapezius and erector spinae)</td>
<td>Increase in muscle activation for Treadmill compared to Sitting and Standing.</td>
<td>NA</td>
</tr>
<tr>
<td>Botter et al.</td>
<td>Randomised repeated measures</td>
<td>4 hours</td>
<td>23 (7 males, 16 females)</td>
<td>Healthy undergraduate students (21–25 years old)</td>
<td>Sitting, Sitting/standing, Treadmill (2.5 km/hour)</td>
<td>Muscle activation by EMG (% of maximal voluntary muscular contraction of trapezius and erector spinae)</td>
<td>Reduced muscle activation for Treadmill compared to Sitting and Sitting/standing.</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 2  continued

<table>
<thead>
<tr>
<th>Authors/study</th>
<th>Design</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Commissaris et al 14</td>
<td>Randomised repeated measures</td>
<td>1 workday</td>
<td>Males=7 Females=8</td>
<td>29 years old BMI=22.9 kg/m²</td>
<td>Sitting Standing</td>
<td>Typing task (number of characters typed/min) Reading and correcting task (number of characters read/min)</td>
<td>No statistical analyses have been done between active workstations. NA</td>
</tr>
<tr>
<td>Cox et al 14</td>
<td>Randomised repeated measures</td>
<td>60 min</td>
<td>Males=9 Females=22</td>
<td>37 years old</td>
<td>Sitting Standing</td>
<td>Aerobic capacity Heart rate Blood pressure Perceived effort Dyspnoea perception Speech assessment</td>
<td>Treadmill (1.6 km/hour) increased VO₂, demands compared with standing 40% ab 18% Treadmill (1.6 km/hour) increased heart rate compared with standing. SBP values matrix 50, standing (12±6) and treadmill (17±1) Treadmill (1.6 km/hour) lowered blood pressure compared with standing. Rating perceived effort values: standing (0.1±0) and treadmill (1.3±0). Treadmill (1.6 km/hour) 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>
</tr>
<tr>
<td>Gibson et al 14</td>
<td>Pilot study</td>
<td>15-hour work period/day experimental condition</td>
<td>n=20 EGG subgroups 13 Salivary cortisol subgroup=16</td>
<td>23–63 years old</td>
<td>Sitting Sittinglestanding</td>
<td>Arousal treadmill vs standing=0.77 Arousal cycling vs standing=0.95 Boredom treadmill vs standing=−1.84 Boredom cycling vs standing=−1.30 Ratings of perceived effort treadmill vs standing=0.26 Boredom treadmill vs standing=0.53 Dyspnoea treadmill vs standing=−0.89 VO₂ treadmill vs standing=−0.01 Energy expenditure treadmill vs standing=−0.01 Noise treadmill vs standing=−0.10</td>
<td></td>
</tr>
<tr>
<td>Kruse et al 14</td>
<td>Pilot study</td>
<td>10 min n=180</td>
<td>Males=10 Females=3</td>
<td>35–50 years old BMI=29.7 kg/m²</td>
<td>Standing Cycling</td>
<td>Simple motor skills decreased from treadmill vs standing. All other results were non-significant.</td>
<td></td>
</tr>
<tr>
<td>Ohlinger et al 14</td>
<td>White participants experimental</td>
<td>75 min for all assessments</td>
<td>n=60 4.2 years old</td>
<td>30–60 years old BMI=23.6 kg/m²</td>
<td>Sitting Standing</td>
<td>Simple motor skills decreased from treadmill vs standing. All other results were non-significant.</td>
<td></td>
</tr>
<tr>
<td>Mullane et al 10</td>
<td>Randomised crossover</td>
<td>2 hour experimental condition with beats of 60, 15, 30 and 60 min on active workstation</td>
<td>Males=2 Females=7</td>
<td>30 years old BMI=26.7 kg/m²</td>
<td>Sitting Standing</td>
<td>Simple motor skills decreased from treadmill vs standing. All other results were non-significant.</td>
<td></td>
</tr>
<tr>
<td>Sliper and Raum 14</td>
<td>Pilot study</td>
<td>35 min</td>
<td>n=80</td>
<td>21.2 years old BMI=23.6 kg/m²</td>
<td>Sitting Standing</td>
<td>Simple motor skills decreased from treadmill vs standing. All other results were non-significant.</td>
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<table>
<thead>
<tr>
<th>Authors/study</th>
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<th>Effect size (Cohen’s d)</th>
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<tbody>
<tr>
<td>Straker et al.</td>
<td>Experimental mixed model</td>
<td>1 workday</td>
<td>Males=16, Females=16</td>
<td>22-64 years old BMI (male)=25.1 kg/m² BMI (female)=22.1 kg/m²</td>
<td>Sitting, standing (0.64 m/min), treadmill (0.32 m/min), cycling (5.0 W), cycling (30 W)</td>
<td>Typing speed task values: standing (54.09), treadmill (51.14), cycling (2.01), cycling (3.01), cycling (6.01). Typing perceived speed: standing (0.04), treadmill (0.04), cycling (0.04). Results showed a decrease in typing speed for treadmill (5.0 W) and cycling (30 W) compared with standing. Typing perceived speed: standing (0.04), treadmill (0.04), cycling (0.04). Results showed a decrease in typing speed for treadmill (5.0 W) and cycling (30 W) compared with standing. Typing perceived accuracy: standing (0.57), treadmill (0.63), cycling (0.57). Scores showed a decrease in accuracy for treadmill (5.0 W) and cycling (30 W) compared with standing. All other results were non-significant.</td>
<td>Mouse speed treadmill (1.6 km/hour) vs standing = 0.34</td>
<td></td>
</tr>
<tr>
<td>Authors/study</td>
<td>Design</td>
<td>Intervention duration</td>
<td>Sample (n)</td>
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</table>

Table 2 continued
### 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 (Cohen’s d)</th>
<th>Missing data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tronarp et al.</strong></td>
<td>Randomised crossover</td>
<td>Standing session of 30 min Cycling, MAP: 20%</td>
<td>Males=15 Females=21</td>
<td>26 years old Healthy adults</td>
<td></td>
<td>Pressure pain threshold</td>
<td>Typing gross speed values: Standing (47), cycling (45.5), cycling (46.5)</td>
<td></td>
<td>Tying net speed was reduced for cycling (45.5), cycling (46.5)</td>
</tr>
<tr>
<td><strong>Zeigler et al.</strong></td>
<td>Randomised cross-over full factorial</td>
<td>Monitoring for 12 hours (08:00–20:00)</td>
<td>Males=2 Females=7</td>
<td>30 years old BMI=28.7 kg/m² Prehypertensive (n=7)</td>
<td></td>
<td>Heart rate</td>
<td>Work hours' heart rate values: standing (76±12), treadmill (78±14), cycling (78±14)</td>
<td></td>
<td>Work hours' heart rate values: standing (78±14), treadmill (79±15), cycling (79±15)</td>
</tr>
</tbody>
</table>

Values presented are means, unless otherwise specified.

**Note:** MAP, % of maximum aerobic power; Met, metabolic equivalent; NA, not applicable; 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>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</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</td>
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<tr>
<td>4</td>
<td>Are the interventions of interest clearly described?</td>
<td>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</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</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</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 1 1 0 0 0 1 1 1 0 0</td>
</tr>
<tr>
<td>9</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</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 the probability value is less than 0.001?</td>
<td>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 0 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 0 0 0 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</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 0 1 0 0 0</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 follow-up of patients, or in case-control studies, is the time period between the intervention and outcome 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</td>
</tr>
<tr>
<td>19</td>
<td>Was compliance with the interventions reliable?</td>
<td>1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>20</td>
<td>Were the main outcome measures used accurate (valid and reliable)?</td>
<td>1 1 1 1 1 1 1 1 1 1</td>
</tr>
</tbody>
</table>

continued
<table>
<thead>
<tr>
<th>Item</th>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<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>Bantoft et al&lt;sup&gt;1&lt;/sup&gt; Botter et al&lt;sup&gt;2&lt;/sup&gt; Commissaris et al&lt;sup&gt;3&lt;/sup&gt; Cox et al&lt;sup&gt;4&lt;/sup&gt; Gilson et al&lt;sup&gt;5&lt;/sup&gt; Kruse et al&lt;sup&gt;6&lt;/sup&gt; Ollinger et al&lt;sup&gt;7&lt;/sup&gt; Mullane et al&lt;sup&gt;8&lt;/sup&gt; Sibler and Yuan&lt;sup&gt;9&lt;/sup&gt; Straker et al&lt;sup&gt;10&lt;/sup&gt; Tronarp et al&lt;sup&gt;11&lt;/sup&gt; Zeigler et al&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<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</td>
</tr>
<tr>
<td>23</td>
<td>Were study subjects randomised to intervention groups?</td>
<td>1 1 1 1 1 0 1 1 0 0 1 1</td>
</tr>
<tr>
<td>24</td>
<td>Was the randomised intervention assignment concealed from both patients and healthcare staff until recruitment was complete and irrevocable?</td>
<td>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 0 0 0 1 0 1 0 0 1 0</td>
</tr>
<tr>
<td>26</td>
<td>Were losses of patients to follow-up taken into account?</td>
<td>0 1 0 0 0 1 0 0 1 1 0 1</td>
</tr>
<tr>
<td>Power</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 0 1 0 1 0</td>
</tr>
<tr>
<td>Total score</td>
<td>19/28 14/28 17/28 14/28 16/28 16/28 20/28 19/28 17/28 15/28 21/28 19/28</td>
<td></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 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 both 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 and VO₂ were measured in three studies.13 14 16 Botter et al16 showed an increase in energy expenditure of 1.2 metabolic equivalent (MET) for treadmill1.5 km/hour workstations compared with standing. Cox et al14 measured a similar increase of 1 MET from standing to treadmill1.6 km/hour. Taronarp et al15 measured energy expenditure in kcal. In this study, energy expenditure increased between all three conditions: an increase of 2.9 kcal/min between cycling50%MAP and standing; an increase of 6.9 kcal/min between cycling30%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), cycling5 W (1.66/10) and cycling30 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 cycling30 W compared with treadmill1.6 km/hour and cycling5 W).

Pressure pain threshold was measured in kilopascals (kPa) using a Somedic algometer on the right quadriceps, right ventral forearm and right trapezius.16 Only differences in the pressure pain threshold of the right trapezius between standing (16.8 kPa) and cycling30%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 (ie, 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, cycling50%MAP and cycling20%MAP compared with standing. Perceived accuracy also decreased with the use of both treadmill1.6 km/hour and cycling20%MAP 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 cycling5 W condition.

Questionnaire outcomes for perceived mouse pointing speed showed a decrease for treadmill1.6 km/hour, treadmill2 km/hour, cycling5 W and cycling30 W compared with standing. Also, a reduction of perceived speed was observed for both treadmill1.6 km/hour and treadmill1.2 km/hour compared with both cycling5 W and cycling30 W conditions. There was a decline for the treadmill1.6 km/hour, treadmill1.2 km/hour, cycling5 W and cycling30 W compared with standing in perceived mouse pointing accuracy. There was a reduction in perceived accuracy for both treadmill workstations compared with low-intensity cycling5 W condition.

Questionnaire outcomes for perceived combined keyboard/mouse speed tasks showed a decrease in perceived speed for treadmill1.6 km/hour, treadmill1.2 km/hour, cycling5 W and cycling30 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 accuracy decreased for the treadmill1.6 km/hour, treadmill1.2 km/hour, cycling5 W and cycling30 W compared with standing. Moreover, perceived accuracy declined for treadmill1.2 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 treadmill1.2 km/hour (49.73 words/min), treadmill1.6 km/hour (50.14 words/min), cycling5 W (53.17 words/min) and cycling30 W (52.58 words/min) compared with standing (54.09 words/min). No differences were reported for the accuracy test. Taronarp et al15 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 10s trial. A reduction in taping speed was observed for the treadmill workstation (5.8) compared with the standing workstation (5.0). To resume, all three studies observed decreases in typing speed with treadmill workstations compared with a standing workstation. The two studies\textsuperscript{15} with cycling conditions observed a decrease in typing speed compared with a standing workstation. Only one study\textsuperscript{16} observed a decrease in typing word accuracy with the use of cycling workstations compared with a standing workstation.

Two studies\textsuperscript{15} \textsuperscript{16} examined mouse pointing speed (ie, milliseconds) and accuracy (ie, actual errors). The first study\textsuperscript{15} reported a decrease in speed for treadmill (1.6 km/hour) (1059 ms); treadmill (1.2 km/hour) (1107 ms); and cycling 3.2 km/hour (1022 ms) compared with standing (959 ms). Similar values were reported for cycling 5 W and cycling 30 W workstations (1022 ms). Both treadmill (1.6–3.2 km/hour) workstations resulted in decreased mouse pointing speed compared with both cycling 5–30 W workstations. Furthermore, pointing error increased using treadmill (1.6 km/hour) (0.17), treadmill (1.2 km/hour) (0.20) and cycling 30 W (0.16) compared with standing (0.10), and for treadmill (1.2 km/hour) (0.20) compared with cycling 5 W (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\textsuperscript{16} reported a decrease in mouse pointing speed for standing (33.6 ms) compared with cycling 50%MAP (32.6 ms). But contrary to the last study, a decrease in mouse pointing speed was reported for a higher cycling 50%MAP 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 50%MAP (3.5) and cycling 50%MAP (5.5) compared with standing (7), and a decrease in cycling 50%MAP (3.5) compared with cycling 50%MAP (5.5).

One study\textsuperscript{15} examined combined keyboard and mouse task performance (ie, speed (words/s) and error rate). A decrease in speed was observed for both treadmill (1.6 km/hour) (9.57 words/s) and treadmill (1.2 km/hour) (8.26 words/s) compared with standing (11.94 words/s). Furthermore, a decrease in speed was observed for the treadmill (1.2 km/hour) (9.57 words/s) and treadmill (1.6 km/hour) (8.26 words/s) conditions compared with the cycling (8.84 words/s) and cycling 50 W (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.\textsuperscript{19} 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 1.6 km/hour z-score showed a lower speed of performance than cycling 30 W z-score. Cycling 30 W reaction time was faster than standing reaction time.

Attention and short memory
Out of the four studies\textsuperscript{18–21} 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\textsuperscript{16} 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.\textsuperscript{13} Likewise, related to energy expenditure, HR could be increased by 10% compared with standing workstations.\textsuperscript{13} 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.\textsuperscript{8} 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.\textsuperscript{13} 15 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.\textsuperscript{17}

Cycling workstations increase arousal and reduce boredom significantly better than standing workstations.\textsuperscript{30} These outcomes are relevant as research has reported an interaction between level of physical activity at work, well-being at work and work productivity.\textsuperscript{22,23} 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.\textsuperscript{19}

No reductions in motor task performance were reported with the use of cycling workstations.\textsuperscript{15} 24–27 Speed processing time in simple tasks does increase compared with treadmill and standing conditions.\textsuperscript{19} 28 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{13} \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{10,16} 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 }\textsuperscript{29–33} 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 }\textsuperscript{25} \textsuperscript{34} 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{13} \textsuperscript{35} and could lead to muscular fatigue and muscle tension.\textsuperscript{13} In this context, safety issues should be raised, 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} \textsuperscript{33} \textsuperscript{36} As a result, even if standing workstations do not exceed a sedentary threshold (ie, energy expenditure),\textsuperscript{37} postprandial glycaemia excursion and blood expenditure,\textsuperscript{37} postprandial glycaemia excursion and blood pressure\textsuperscript{6} \textsuperscript{18} \textsuperscript{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 been shown to be preventive against such injuries at work.\textsuperscript{9} \textsuperscript{40} 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} \textsuperscript{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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