A systematic review of standing and treadmill desks in the workplace

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Abstract

Objectives. Standing and treadmill desks are intended to reduce the amount of time spent sitting in today’s otherwise sedentary office. Proponents of these desks suggest that health benefits may be acquired as standing desk use discourages long periods of sitting, which has been identified as an independent health risk factor. Our objectives were thus to analyze the evidence for standing and treadmill desk use in relation to physiological (chronic disease prevention and management) and psychological (worker productivity, well-being) outcomes.

Methods. A computer-assisted systematic search of Medline, PubMed, PsycINFO, SPORTDiscus, CINAHL, CENTRAL, and EMBASE databases was employed to identify all relevant articles related to standing and treadmill desk use.

Results. Treadmill desks led to the greatest improvement in physiological outcomes including postprandial glucose, HDL cholesterol, and anthropometrics, while standing desk use was associated with few physiological changes. Standing and treadmill desks both showed mixed results for improving psychological well-being with little impact on work performance.

Discussion. Standing and treadmill desks show some utility for breaking up sitting time and potentially improving select components of health. At present; however, there exist substantial evidence gaps to comprehensively evaluate the utility of each type of desk to enhance health benefits by reducing sedentary time.

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Introduction

It has long been understood that a physically active lifestyle is important in overall health and well-being along with reducing the risk for chronic diseases (Warburton et al., 2006). In order to observe health benefits, including reduced risk for chronic diseases, the Global Physical Activity (PA) Guidelines currently recommend a minimum of 150 min of moderate to vigorous PA per week for adults aged 18–64 years (World Health Organization, 2010), which have been adopted by most developed nations. However, it has been conservatively estimated that only 15% of Canadians currently meet these guidelines with the average Canadian adult spending 69% or 9.5 of their waking hours engaging in sedentary behaviors (Colley et al., 2011). Owing to increases in non-physically demanding occupational tasks, among other factors, a majority of current sedentary behavior is associated with the workplace where a large proportion of workers spend the day sitting (Juneau and Potvin, 2010).

Increased sedentary behavior is significantly associated with an elevated risk of diabetes, cardiovascular disease, and all-cause mortality (Wilmut et al., 2012). More specifically, time spent sitting is strongly associated with increased rates of the metabolic syndrome, type-2 diabetes mellitus, and obesity (Hamilton et al., 2007). Distinct health outcomes observed between sitting, non-exercise PA, and exercise suggest that sitting has an independent association with overall health and mortality that must be considered independently of other PA (Katzmarzyk et al., 2009; Hamilton et al., 2007). Positive correlations and dose–response relationships have been shown between sitting time and mortality, even in individuals who are otherwise physically active. For example, Katzmarzyk et al. (2009) found that the group of individuals who spent the highest amount of time sitting had a significantly higher risk of mortality than did the reference group, regardless of their level of PA. This suggests that compensation for time spent sitting cannot be achieved by meeting or even exceeding the current PA guidelines (Katzmarzyk et al., 2009), thus addressing the cause of the sedentary behavior itself is of increased importance. Furthermore, Katzmarzyk et al.’s (2009) group showed that sitting time and mortality were associated independent of body mass index (BMI), thus this effect was not simply the result of the typical complications resulting from overweight or obesity. However, the highest mortality rates were observed for obese individuals who spent most of their time sitting, suggesting that prolonged sitting may be most detrimental to obese individuals.

The overall effectiveness of current workplace interventions to reduce sitting time was recently shown by Chau et al. (2010) to lack strong supporting evidence. This suggests that it is difficult for workers to incorporate non-exercise PA into their workday and thus novel interventions to offset sitting must be explored. One novel intervention to decrease sitting in the workplace utilizes a workstation wherein the user does not sit in a standard chair, but rather stands or walks using a specially designed “standing desk” or “treadmill desk” instead. Standing or treadmill working while working is intended to reduce sitting time and encourage non-exercise PA in the workplace and thus improve health. Anecdotally, many users claim that standing at work also increases their energy levels and consequent motivation for leisure time PA as well, but this remains speculative.

To date, numerous studies have found that these desks are effective in reducing the amount of time spent sitting during the workday (Straker et al., 2009; Grunseit et al., 2012). Multiple studies have further examined the feasibility and usage of standing desks and treadmill workstations. It has been shown that both desks are practical for the workplace and will be used if available (Grunseit et al., 2012; Thompson et al., 2008). Consistent with the contention that education is an important component to use, Wilks et al. (2006) found that participants who received instructions on the use and benefits of sit–stand workstations used them more frequently than those who did not receive any instructions. Additionally, desks with electronically adjustable tables (for height adjustment from sitting to standing) resulted in more frequent usage than those needing manual adjustments (Wilks et al., 2006; Grunseit et al., 2012). These results suggest that standing and treadmill desks are feasible in the workplace if properly implemented. However, the extent of health benefit outcomes from the use of these desks and whether their use should reasonably be expected to decrease the incidence or progression of chronic disease are unclear. Therefore, the objective of this systematic review is to examine the current literature investigating the use of standing and treadmill desks to understand how these interventions can be used in the prevention or treatment of common chronic diseases including obesity, diabetes and cardiovascular disease. Additionally, cognitive function, workplace performance, job satisfaction, mood states and quality of life are important psychological outcomes that may influence a person’s performance at work and their overall well-being. Therefore, this review further considered psychological variables and their resulting impacts of standing desk or treadmill desk use.

Methods

Literature search

A computer assisted database search of Medline, PubMed, PsychINFO, SPORTDiscus, CINAHL, CENTRAL (Cochrane Central Register of Controlled Trials) and EMBASE up to June 2013 was conducted to find English language studies investigating sitting, standing, or treadmill walking at work with physiological or psychological outcomes. Search words (outlined in Supplementary Table 1) included variations of possible interventions and terms related to the physiological and psychological variables of interest. Reference lists of articles retrieved were manually checked for additional articles.

Inclusion criteria

Peer-reviewed studies published in academic journals which involved a standing or treadmill walking intervention (standing desk or treadmill desk) compared to regular seated desk work or investigations that compared sitting to either standing or treadmill walking at work were eligible for inclusion. Studies with participants of working age (> 18) and of any health status were included. To be eligible for inclusion, the study must have evaluated at least one relevant physiological or psychological outcome listed in Table 1. A specific
focus was given to diseases of cardiometabolic origin, as they represent
important public health issues, and have specific links to PA, or a lack thereof
(Burr et al., 2010, 2012; Katzmarzyk et al., 2009). Specific risk markers for
each disease were identified as they represent important measures and predic-
tors of disease.

It is equally important to investigate the psychological implications of
changes in work environment. If an intervention is beneficial physiologically
but aversive psychologically, or vice versa, then its utility must be considered
to reach an optimal balance of overall health. Cognitive function, workplace
performance, job satisfaction, mood states, and quality of life are important psy-
chological outcomes that must be considered as they play important roles in
influencing work performance and overall well-being.

Exclusion criteria included published supplements, abstracts, reports,
reviews, opinion articles, commentaries, magazine articles, book chapters, and
presentations. Only studies comparing sitting to standing or treadmill walking
specifically were included, those comparing sitting with general PA were
excluded.

**Article retrieval process**

The initial database search returned a total of 6369 results, which was
reduced to a total of 4702 articles after duplicates were removed. These articles
were first screened based on title and abstract, leading to the collection of 73
apparently relevant titles. Of the 73 relevant titles, 25 abstracts were considered
appropriate for further review. Additional manual reference searches yielded
another 8 studies that were retrieved and evaluated against the inclusion
criteria. Of the 33 captured studies, 10 were culled, resulting in 23 articles that
fit full inclusion criteria (Fig. 1).

**Data extraction and methodological quality assessment**

Extracted information included year of publication, study design, objectives,
participant characteristics (age, sex, ethnicity, and health status), sample size,
intervention (standing or treadmill walking), FITT (frequency, intensity, time
and type), outcomes measured, assessments used, results and conclusions.

Assessment of the methodologies used in the studies was achieved by using
a modified version of the Downs and Black (1998) checklist. The modified
version excluded three questions as they were not relevant to the present
study. Combined means and standard deviations between studies were calcu-
lated using given values, or from estimated values interpreted from tables or
figures. Table 2 outlines the included studies and data extracted.

**Results**

A total of 23 studies were included in the review, 19 of which were
quasi-experimental studies lacking appropriate randomization or control
and 4 randomized controlled trials. Consistent with the outcomes of inter-
est presented in Table 1, data are presented across the two dimensions of
physiological and psychological outcomes.

**Physiological outcomes**

**Baseline measures**

**Standing desk.** A total of 118 participants were included in 5 different
studies measuring energy expenditure, heart rate (HR) or blood pressure

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**Fig. 1.** Flowchart of the article selection process based on inclusion/exclusion criteria.
(BP) during a single assessment of the standing posture (Beers et al., 2008; Cox et al., 2011; Levine and Miller, 2007; Speck and Schmitz, 2011). Of the 4 studies that measured energy expenditure using indirect calorimetry, 3 found that a standing posture resulted in significant increases varying from 4.1 kcal/h to 20.4 kcal/h in each study (Beers et al., 2008; Cox et al., 2011; Reiff et al., 2012). The single study that did not find a difference in energy expenditure using indirect calorimetry, 3 found a significant increase averaging 12.32 ± 9.28 bpm while using the treadmill desk (Speck and Schmitz, 2011). Alternatively, Koepp et al. (2013) found no significant change in gross energy expenditure over a 1 year period of treadmill desk use. HR was measured in 4 studies with two reporting a significant increase averaging 12.32 ± 9.28 bpm while using the treadmill desk at a speed of 1.6 km/h (Alderman et al., 2014; Reiff et al., 2012). In contrast, John et al. (2011) measured resting HR and BP and did not find any difference between active and sedentary conditions. Only one other study measured BP and observed

### Table 2

<table>
<thead>
<tr>
<th>Authors</th>
<th>Intervention</th>
<th>Length of intervention</th>
<th># of participants</th>
<th>Health status</th>
<th>Outcome measures</th>
<th>Methodological score (/24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alderman et al. (2014)</td>
<td>Treadmill workstation</td>
<td>Single assessment</td>
<td>66</td>
<td>Healthy</td>
<td>Heart rate, cognitive function, typing performance, reading comprehension</td>
<td>16</td>
</tr>
<tr>
<td>Alkahjah et al. (2012)</td>
<td>Sit–stand workstation</td>
<td>Standing</td>
<td>32</td>
<td>Not specified</td>
<td>Fasting blood lipids, glucose, weight, BMI</td>
<td>16</td>
</tr>
<tr>
<td>Cox et al. (2011)</td>
<td>Active workstation (standing and treadmill walking)</td>
<td>Standing</td>
<td>31</td>
<td>Healthy</td>
<td>Heart rate, blood pressure, energy expenditure, work performance (speech quality)</td>
<td>14</td>
</tr>
<tr>
<td>Ebara et al. (2008)</td>
<td>Treadmill workstation</td>
<td>Single assessment</td>
<td>24</td>
<td>Healthy</td>
<td>Sleepiness, work performance, arousal level</td>
<td>17</td>
</tr>
<tr>
<td>Edelson and Danoff (1989)</td>
<td>Standing height adjustable desk</td>
<td>4–6 weeks</td>
<td>54</td>
<td>Not specified</td>
<td>Typing performance, stress, arousal</td>
<td>14</td>
</tr>
<tr>
<td>Funk et al. (2012)</td>
<td>Treadmill workstation</td>
<td>Single assessment</td>
<td>24</td>
<td>Healthy</td>
<td>Typing performance</td>
<td>15</td>
</tr>
<tr>
<td>Henschel et al. (2009)</td>
<td>Sit–stand workstation</td>
<td>Single assessment</td>
<td>60</td>
<td>Healthy</td>
<td>Mood states and office behaviors, fatigue, typing performance</td>
<td>16</td>
</tr>
<tr>
<td>John et al. (2009)</td>
<td>Treadmill workstation</td>
<td>Single assessment</td>
<td>20</td>
<td>Not specified</td>
<td>Cognitive function, typing performance</td>
<td>15</td>
</tr>
<tr>
<td>John et al. (2011)</td>
<td>Treadmill workstation</td>
<td>Single assessment</td>
<td>12</td>
<td>BMI ≥ 28</td>
<td>Body composition, heart rate, blood pressure, weight, waist and hip circumference, blood lipids, glucose, insulin, glycosylated hemoglobin</td>
<td>16</td>
</tr>
<tr>
<td>Koepp et al. (2013)</td>
<td>Treadmill desk</td>
<td>12 months</td>
<td>36</td>
<td>10 lean; 15 overweight; 11 obese (BMI &gt; 30)</td>
<td>Body composition, blood lipids, glucose, waist circumference, energy expenditure, work performance</td>
<td>17</td>
</tr>
<tr>
<td>Miyashita et al. (2013)</td>
<td>Active workstation (standing and treadmill walking)</td>
<td>2 days</td>
<td>15</td>
<td>Healthy</td>
<td>Blood lipids, insulin, glucose</td>
<td>14</td>
</tr>
<tr>
<td>Ohlinger et al. (2011)</td>
<td>Treadmill desk</td>
<td>Single assessment</td>
<td>50</td>
<td>&lt;150 kg</td>
<td>Cognitive function, motor performance</td>
<td>13</td>
</tr>
<tr>
<td>Pronk et al. (2012)</td>
<td>Treadmill desk</td>
<td>Single assessment</td>
<td>34</td>
<td>Healthy</td>
<td>Mood states, office behaviors, fatigue</td>
<td>18</td>
</tr>
<tr>
<td>Reiff et al. (2012)</td>
<td>Standing desk</td>
<td>7 weeks</td>
<td>20</td>
<td>Healthy</td>
<td>Energy expenditure</td>
<td>16</td>
</tr>
<tr>
<td>Speck and Schmitz (2011)</td>
<td>Active workstation</td>
<td>Single assessment</td>
<td>14</td>
<td>Sedentary with BMI &gt; 20</td>
<td>Energy expenditure</td>
<td>10</td>
</tr>
</tbody>
</table>
a significant increase of systolic BP from $124 \pm 3$ mm Hg to $129 \pm 3$ mm Hg and diastolic BP increased from $76 \pm 3$ mm Hg to $80 \pm 3$ mm Hg while using a treadmill workstation (Cox et al., 2011).

**Traditional clinical cardiometabolic risk factors**

**Standing desk.** Only one study investigated traditional cardiometabolic risk factors with the use of a sit–stand workstation. Alkhabjah et al. (2012) included a total of 32 participants (18 intervention and 14 comparison) in their study. Measurements of fasting blood lipids, glucose, total cholesterol, HDL and triglycerides were taken at baseline, 1 week, and 3 months. The study found a significant increase in HDL cholesterol of 0.26 mmol/L between intervention and comparison groups. However, there were no significant differences in the other cardiometabolic risk factors.

**Treadmill desk.** A treadmill desk intervention in place of a traditional sitting desk was investigated in two studies with a combined total of 48 participants (John et al., 2011; Koepp et al., 2013). One study included 12 overweight or obese office workers (based on BMI), 8 of whom were pre-hypertensive or hypertensive at baseline, with high levels of LDL, total cholesterol and triglycerides. These investigators also included glycosylated hemoglobin and insulin. The participants used the treadmill desk in place of a traditional sitting desk for 9 months (John et al., 2011). The other study used the treadmill desk for 1 year and involved 36 participants of whom 10 were lean, 15 were overweight and 11 were obese (Koepp et al., 2013). Both studies measured glucose, lipid panels, waist circumference, and body composition.

In the shorter 9 month intervention (John et al., 2011), a significant reduction in total cholesterol from 123 ± 26 mg/dL to 115 ± 36 mg/dL and reductions of LDL from 206 ± 31 mg/dL to 195 ± 36 mg/dL were observed. However, similar reductions were not evident in the longer intervention (Koepp et al., 2013). This may be due to a baseline effect as the participants had high levels of LDL and total cholesterol at baseline. A significant increase in HDL from 55 ± 20 mg/dL to 60 ± 23 mg/dL was demonstrated by Koepp et al. (2013) with similar increases observed in another study involving the use of a sit–stand workstation (Alkhabjah et al., 2012). Within the pre-hypertensive or hypertensive participants approximately 33% reduced their blood pressures to normal levels (John et al., 2011). Although no differences were found in postprandial or fasting glucose and insulin, there was a significant reduction in glycosylated hemoglobin which is a more accurate measure of long-term glycemic control (John et al., 2011).

Dunstan et al. (2012) demonstrated a decreased net glucose response to a standardized test drink after a 2 min treadmill walking break every 10 min during prolonged sitting in 19 obese participants. Lower intensity of PA resulted in a 24.1% decrease in net glucose response while moderate intensity treadmill walking showed a 29.6% decrease. The study concluded that short interruptions to sitting significantly reduced postprandial glucose and insulin responses regardless of the intensity of the PA, which in turn encourages increased insulin sensitivity and reduced insulin secretion consistent with preservation of pancreatic ß-cell function. Similarly, postprandial glucose was reduced for treadmill desk use but not for standing posture in a separate study with 15 healthy participants (Miyashita et al., 2013); however, insulin showed no significant difference in either condition. These different results may be influenced by the health status of the participants, as one population was composed of obese participants and the other group was of a healthy weight.

**Anthropometrics**

**Standing desk.** Only one study specifically investigated alterations in anthropometric measures using a standing desk intervention (Alkhabjah et al., 2012). The 18 participants in the intervention group showed a reduction in weight over a 3 month period but did not show any significant changes in body composition using BMI and waist and hip circumference in relation to the comparison group (14 participants).

**Treadmill desk.** Anthropometric measures were investigated in 3 studies that included a total of 63 participants using treadmill desks (John et al., 2011; Koepp et al., 2013; Levine and Miller, 2007). All 3 studies included body mass and composition in their measurements. In a 12 month intervention, Koepp et al. (2013) found that 65% of their participants lost an average of 3.4 ± 5.4 kg of fat mass, while John et al. (2011) showed a non-significant trend toward weight loss but did not find any differences in body fat and mass following a 9 month intervention. Both investigations reported that obese participants lost more weight than non-obese participants. Levine and Miller (2007) extrapolated further data to suggest that replacing sitting with a treadmill desk for 2–3 h each workday could result in a weight loss of 20–30 kg/year in obese individuals.

Waist circumference was measured by John et al. (2011) and Levine and Miller (2007) with both groups finding significant decreases in waist circumference. A summary of physiological changes is presented in Table 3.

**Psychological outcomes**

**Work performance**

**Standing desk.** Workplace performance while using a sit–stand workstation was measured in a total of 220 participants in 7 separate studies (Beers et al., 2008; Drury et al., 2008; Ebara et al., 2008; Hasegawa et al., 2001; Hedge and Ray, 2004; Husemann et al., 2009; Straker et al., 2009). Ebara et al. (2008) found that performance on a typing task was not impacted with sit–stand workstation use of less than 150 min. However, typing performance decreases were observed above 150 min of use per day. Conversely, no significant changes in typing performance were found between sitting and standing postures in three studies (Drury et al., 2008; Beers et al., 2008; Straker et al., 2009), which tested computer task performance over 40 min (Drury et al., 2008), typing ability over 20 min (Beers et al., 2008), and typing and mouse performance over 3 min (Straker et al., 2009). Husemann et al. (2009) assessed typing abilities while using a sit–stand workstation for 4 h per day over a five day period. The study observed a non-significant trend toward reduced efficiency in the number of characters typed per minute and no difference in errors per minute or overall error rate while standing. The study concluded that data entry was not influenced by the sit–stand intervention. Hedge and Ray (2004) used an electronic height adjustable work surface over a 4–6 week test period and investigated changes in work patterns for daily keyboard and mouse use. The study reported no changes in work patterns for daily keyboard or mouse use and reported improvements in comfort for keyboard, mouse, chair and workstation use while using the height adjustable desk.

The final study found that a change of posture reduced perceived workload. However, the longer the task time, the lower the effects of changed posture. Additionally, maintaining a standing posture for a long time was determined to be more harmful than a combination of postures (Hasegawa et al., 2001).

**Treadmill desk.** Studies investigating performance and cognitive differences between sitting and treadmill walking have shown mixed results. Eight quasi-experimental studies included a total of 242 participants (Alderman et al., 2014; Funk et al., 2012; John et al., 2009; Koepp et al., 2013; Ohlinger et al., 2011; Straker et al., 2009; Edelson and Danoff, 1989; Thompson and Levine, 2011). Five studies measured typing performance while using a treadmill workstation (Funk et al., 2012; Straker et al., 2009; John et al., 2009; Edelson and Danoff, 1989; Thompson and Levine, 2011). Consistent results were evident in two of the studies which found that walking on a treadmill at 1 mph...
Table 3
Summary of physiological findings of studies examining the effects of standing and treadmill desks.

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>Standing # of studies</th>
<th>Outcomes</th>
<th>Treadmill walking # of studies</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased energy expenditure</td>
<td>4</td>
<td>−</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Increased resting heart rate</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Increased heart rate</td>
<td>3</td>
<td>++</td>
<td>3</td>
<td>+ +</td>
</tr>
<tr>
<td>Decreased resting diastolic blood pressure</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Decreased resting systolic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Increased diastolic blood pressure</td>
<td>1</td>
<td>−</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td>Increased systolic blood pressure</td>
<td>1</td>
<td>+</td>
<td>1</td>
<td>+ +</td>
</tr>
<tr>
<td>Traditional cardiometabolic risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowered total fasting cholesterol (3 months)</td>
<td>1</td>
<td>/</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>Lowered total cholesterol (9–12 months)</td>
<td>0</td>
<td>n/a</td>
<td>2</td>
<td>−</td>
</tr>
<tr>
<td>Increased HDL</td>
<td>1</td>
<td>+</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td>Lowered LDL (9–12 months)</td>
<td>0</td>
<td>n/a</td>
<td>2</td>
<td>−</td>
</tr>
<tr>
<td>Lowered TG</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Improved fasting glucose</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Improved postprandial glucose</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>+ +</td>
</tr>
<tr>
<td>Improved glucose</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Improved AIC</td>
<td>0</td>
<td>n/a</td>
<td>2</td>
<td>−</td>
</tr>
<tr>
<td>Improved glycosylated insulin</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Improved postprandial insulin</td>
<td>0</td>
<td>n/a</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight loss</td>
<td>1</td>
<td>−</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>Lowered BMI</td>
<td>0</td>
<td>n/a</td>
<td>1</td>
<td>/</td>
</tr>
<tr>
<td>Decreased waist circumference</td>
<td>0</td>
<td>n/a</td>
<td>2</td>
<td>+ +</td>
</tr>
</tbody>
</table>

Very strong: ++; strong: +; weak: −; inconclusive: /; no change: 0; n/a = not applicable.

(Thompson and Levine, 2011) or a self-selected speed (Edelson and Danoff, 1989) did not result in decreased performance. Two studies found that treadmill walking at relatively slow (1.3–1.6 km/h) or fast (3.2 km/h) speed resulted in the largest decreases in typing and mouse performance (Funk et al., 2012; Straker et al., 2009). These studies suggest that a self-selected speed between 1.6 and 3.2 km/h is ideal in optimizing typing and mouse performance. Overall, the studies concluded that the use of a treadmill desk results in a small to medium decrease in short-term performance (Straker et al., 2009) and that treadmill walking decreases performance on tests of typing and mouse proficiency and lowers performance on tasks of fine motor movement (John et al., 2009).

General task performance was measured by two studies (Koepp et al., 2013; Ohlinger et al., 2011). Koepp et al. (2013) investigated overall work performance, quality of work and quality of interactions with co-workers. Findings showed a minor loss in work performance over the first 3–5 months but found that performance after one year exceeded baseline. This indicates a learning effect, which should likely be considered when interpreting the results of other more acute interventional studies. The study concluded that work performance was not significantly different between the active and sedentary conditions (Koepp et al., 2013). Ohlinger et al. (2011) found that treadmill walking at 1.6 km/h had a significant decrease in scores of the Digital Finger Tapping Test of motor abilities between sitting, standing and treadmill walking but not between sitting and standing.

Mood states

Standing desk. Mood states were investigated for standing desk use in a total of 224 participants in 7 different studies (Beers et al., 2008; Drury et al., 2008; Ebara et al., 2008; Hasegawa et al., 2001; Hedge and Ray, 2004; Husemann et al., 2009; Pronk et al., 2012). Significant improvements in fatigue, vigor, tension, confusion, depression, and total mood disturbance were found after a 5 week sit–stand desk intervention with 34 participants (Pronk et al., 2012). Participants stated that they felt more comfortable, energized, healthier, focused, productive, happier, and less stressed after using the workstation. After withdrawing the standing intervention, vigor and total mood disturbance returned to baseline and self-esteem was reduced below baseline. However, Husemann et al. (2009) assessed present psychological state, mood, alertness, tiredness and calmness or agitation and did not find any difference in mood scores between control and intervention groups over a one week period. Hedge and Ray (2004) found that comfort increased over time with sit–stand workstation use while less favorable results were found by Beers et al. (2008) and Drury et al. (2008) whose 24 and 12 respective participants gave 1) sitting a higher comfort rating than standing, 2) fatigue and discomfort a higher rating in the standing posture (Beers et al., 2008) and 3) a decreased rating of well-being in an upright posture (Drury et al., 2008). These differences may be due to measures of prolonged sitting and standing collected separately rather than investigating a combination of postures. Subjective sleepiness was measured in 24 participants by Ebara et al. (2008) and was found to increase with time under all conditions of sit–stand workstation use, thus contributing little to the evaluation of standing desk use. However, another study (Hasegawa et al., 2001) found that dullness and drowsiness were reduced with changes of posture.

Treadmill desk. One small study investigated mood states for 5 participants using a treadmill desk (Edelson and Danoff, 1989). The study found significantly decreased stress levels, improved arousal levels and fewer physical complaints while using the treadmill workstation over five 2 h sessions during a 2 week period. Further work in this area is warranted.

Cognitive function

Treadmill desk. Various components of cognitive function while using the treadmill workstation were measured in a total of 167 participants in 4 studies (Alderman et al., 2014; Cox et al., 2011; John et al., 2009; Ohlinger et al., 2011). Alderman et al. (2014) found that treadmill walking at a self-selected speed does not lower cognitive functions such as information processing and task performance. John et al. (2009) found that treadmill walking at 1 mph influences math solving abilities but does not alter performance on a Stroop test or reading. Ohlinger et al.
including cardiovascular disease, diabetes, and the metabolic syndrome both obese and non-obese individuals. As a surrogate for visceral fat, a

sultations in blood pressure in pre-hypertensive or hypertensive individuals results along with the acute increases in heart rate and sustained reduc-

ference with treadmill desk use thus represent a potentially important

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(2011) found no signi

(i) ndings of studies examining the effects of standing and treadmill desks. A summary of psychological changes is presented in Table 4.

Table 4
Summary of psychological findings of studies examining the effects of standing and treadmill desks.

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>Standing # of studies</th>
<th>Outcomes</th>
<th>Treadmill walking # of studies</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change in work performance</td>
<td>7</td>
<td>++</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Improved mood states</td>
<td>7</td>
<td>/</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>No change in cognitive function</td>
<td>0</td>
<td>n/a</td>
<td>4</td>
<td>++</td>
</tr>
<tr>
<td>Job satisfaction</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>Quality of life</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Very strong: ++; strong: +; weak: −; inconclusive: /; no change: 0; n/a = not applicable.

(2011) found no significant differences between conditions on tests of cognitive function and concluded that low-intensity treadmill walking negatively affects simple motor task performance but does not impact short-term auditory verbal memory and divided attention. Cox et al. (2011) measured speech quality while using a treadmill desk and found that walking at a speed of 1.6 km/h did not compromise speech quality.

Additionally, low intensity arousal observed during treadmill walking did not cause deficits in higher order thinking (information processing speed, executive abilities, selective attention and the ability to inhibit habitual responses) (Alderman et al., 2014) while improved psychological measures, such as decreased stress, were shown to be possible advantages of treadmill workstation use (Edelson and Danoff, 1989). A summary of psychological changes is presented in Table 4.

Discussion

Physiological

Both standing and treadmill desks showed some promise of an ability for improving health outcomes with regular use. However, the use of a treadmill desk typically resulted in greater physiological improvements than the use of a standing desk. This may be the result of the treadmill desk interventions tending to be of longer duration than the standing desk interventions. However, given the increased effort of treadmill walking compared to standing, greater physiological improvement can be expected with treadmill desk use.

Both standing and treadmill desks increased energy expenditure, measured through indirect calorimetry, compared to sitting, suggesting that these desks may be useful in maintaining energy balance. Obese participants lost more weight than did non-obese participants, likely owing to a baseline effect or because posture change affected a greater absolute work in the obese, but in any event the evidence on whole indicates that active desks may be a useful weight management tool for both obese and non-obese individuals.

Even in the absence of alterations in body composition, it is now well recognized that important changes in health can occur with low load PA doses that would not be expected to alter fitness. The treadmill desk was shown to reduce LDL and total cholesterol in a sample of obese individuals with high levels of blood lipids. Additionally, two studies (one standing and one treadmill) found a significant increase in HDL. As decreases in total cholesterol and LDL and increases in HDL are traditional risk factors for cardiovascular disease (Kannel et al., 1976), these results along with the acute increases in heart rate and sustained reductions in blood pressure in pre-hypertensive or hypertensive individuals suggest that treadmill desks may be useful in attenuating the cardiovascular risk factors.

Treadmill desk use was effective in reducing waist circumference in both obese and non-obese individuals. As a surrogate for visceral fat, a high waist circumference is a risk factor for various chronic conditions including cardiovascular disease, diabetes, and the metabolic syndrome (Burr et al., 2010; Riddell and Burr, 2011). Reductions in waist circumference with treadmill desk use thus represent a potentially important reduction in cardiometabolic risk factors.

Mixed results were shown for glucose management and standing desk use; however, treadmill desk use was shown to result in reductions of both glycosylated hemoglobin and postprandial glucose. Increased insulin sensitivity and reduced insulin secretion are consistent with these results suggesting preservation of pancreatic β cell function resulting in improved glycemic control and therefore a reduced risk of diabetic complications and possibly overall prevalence (Burr et al., 2010; Riddell and Burr, 2011).

Overall, the health benefits of standing and treadmill desks seem to be more influential for obese individuals than non-obese individuals. However, even with small benefits standing and treadmill desks are shown to be an important alternative to prolonged sitting for obese and non-obese persons.

Psychological

Standing allowed performance to stay steady and showed no decrease in work performance over time. It was shown that a change of posture was useful in reducing perceived workload. However, the longer the task time, the lower the effects of changed posture. Substituting prolonged standing for prolonged sitting results in a greater feeling of discomfort as a likely result of discomfort in the legs, back or shoulders due to prolonged standing. With a sit–stand workstation, the individual would be able to adjust their posture at the onset of discomfort and therefore reduce the total amount of discomfort resulting from prolonged time in the same posture. These results suggest that changing posture throughout the day while using a sit–stand workstation may lead to reductions in work stress, discomfort and psychological strain, while contributing not only to increases in productivity but also to greater worker satisfaction and quality of life.

Although the treadmill desk did have a positive impact on health outcomes, a decrease in typing and mouse performance was shown with its use. The magnitude of the decrease in performance seems to depend on the speed at which one is walking. A treadmill speed between 1.6 km/h and 3.2 km/h appears to be ideal to minimize decreases in typing and mouse performance; however, individual differences must be taken into consideration, and the long term stability of these changes still remains to be conclusively demonstrated. Performance may be compromised with the initial installation of a treadmill workstation but improvements exceeding baseline were shown suggesting that learning and acclimatization to the new workstation may play an important role in returning performance to an acceptable level. Given an ideal speed and appropriate acclimatization for each individual, the treadmill desk would allow the worker to continue their daily tasks without compromising long term typing and mouse performance.

There were no differences in cognitive processes while standing or treadmill walking suggesting that these activities do not alter thought processes important to performing desk work and thus have no detrimental impact on the quality of work being produced.

Limitations and future directions

This study recognizes several limitations. Only English language studies were included which may limit the data extracted and result
in exclusion of some relevant literature. Differences in assessment techniques, setting, participants, length of interventions, and measured outcomes made it challenging to compare results and reduced the ability to generalize the results to a specific population. This review did not involve a meta-analysis and therefore, the statistical significance of combined results could not be determined.

Additionally, adverse outcomes unrelated to the chronic diseases of interest were not addressed. For example, musculoskeletal conditions which may be influenced by standing or treadmill walking for extended periods of time were not addressed due to an overwhelming body of literature that would be more appropriately discussed in a separate systematic review.

Since standing and treadmill desks are a relatively novel intervention, there is currently a limited evidence base and additional research is still required. As society is currently suffering from a pandemic of chronic disease, further studies need to focus specifically on the possible impacts these desks may have on chronic disease. While a handful of studies measured energy expenditure specifically in obese participants, no studies focused specifically on chronic disease prevention or reduction as a primary outcome. The majority of studies involved relatively healthy participants and could therefore not compare these results to those already suffering from a chronic disease. Other than those including obese participants, there were no studies specifically focusing on participants with specific chronic diseases, or high risk populations. For this reason, more variability in participants is necessary in order to accurately assess the benefits.

There is limited evidence to make conclusions regarding the physiological outcomes of sit–stand workstations. Given that the sit–stand workstation seems to provide the best advantage psychologically, more research is warranted in regard to their ability to illicit a physiological response.

The majority of the studies reviewed involved only a single assessment of the intervention. With chronic disease treatment and prevention in mind, it is necessary to conduct longitudinal studies to understand the long term impacts and possible side effects of standing desk and treadmill desk use. Further research should consist of randomized controlled trials addressing questions such as how these desks may influence specific health conditions, if changes return to baseline after time even with continued use, and what impact does discontinuing the use of these desks have on the individual?

Additionally, none of the reviewed studies investigated job satisfaction and quality of life as a primary outcome for either standing or treadmill desks.

**Conclusion**

Based on the empirical evidence of current literature, this review concludes that standing and treadmill desks are potentially useful in reducing workplace sedentariness while having a positive influence on workplace stress and overall mood. The treadmill desk provides the greatest physiological improvements and is most beneficial for overweight and obese participants. However, the use of a treadmill desk results in larger decreases in work productivity and motor abilities than the standing desk.

Standing desk use does not elicit the same physiological impact as the treadmill desk but does result in the least change in productivity and motor abilities. Of the standing desks, a sit–stand desk seems to provide the most benefit allowing the employee to adjust their desks throughout the day. The standing-only desk could potentially result in additional complications with musculoskeletal conditions and feelings of fatigue and discomfort.

Overall, current evidence suggests that both standing and treadmill desks may be effective in improving overall health considering both physiological and mental health components. However, at present there still exist substantial gaps in the research to fully comprehend the utility of each type of desk to promote health. Therefore additional research is necessary in order to determine the appropriateness of these desks with respect to enhancing health benefits by reducing sedentary time.

**Conflict of interest statement**

The authors declare that there are no conflicts of interests.

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**Appendix A. Supplementary data**

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2014.11.011.

**References**


