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

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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; however, treadmill workstations can reduce the performance of computer tasks.

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.

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INTRODUCTION

In 2013, costs associated with sedentary behaviour were estimated at $65.5 billion worldwide.[1] Moreover, a shift from manual labour jobs to highly sedentary service industry and office-based professions has been observed over the last decades.[2] 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,[3] 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,[4–6] maintain work productivity,[6] increase energy expenditure,[7] regulate high blood pressure,[8] relieve back pain,[9] enhance positive affect[10] and increase cognitive abilities[11] 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

Standing Workstation   Cycling Workstation   Treadmill Workstation

Figure 1 Type of active workstations included in the systematic review.

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.

Table 1 Participants, interventions, comparators, outcomes, study (PICOS) designs

PICOS	Details
Participants	At least 18 years old. Adults presenting cardiometabolic disorders and healthy adults.
Interventions	Intervention with conventional seats, seated active workstations (eg, cycling desk and elliptical pedal desk) and upright active workstations (eg, standing desk, treadmill desk). Interventions were performed in a laboratory or free-living environment.
Comparative factors	Different types of workstations (ie, standing, treadmill, recumbent pedal, elliptical pedal and cycling).
Outcomes	Biomechanical: measurement of muscle activation, posture and joint angles, as well as kinematics. Physiological: heart rate, oxygen consumption, energy expenditure, blood pressure, perceived exertion and pressure pain thresholds. Work performance: quantitative and qualitative measurements of typing, mouse pointing, multitasking, perception of task, attention to task, speech assessment and memory tasks. Psychobiological: quantitative and qualitative measurement of arousal, stress, boredom, task satisfaction, and quantitative measurement of salivary cortisol and encephalography.
Study designs	Pilot study, randomised cross-over full-factorial study, randomised repeated measures design, within participant experimental design, experimental mixed-model study.

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[12] 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

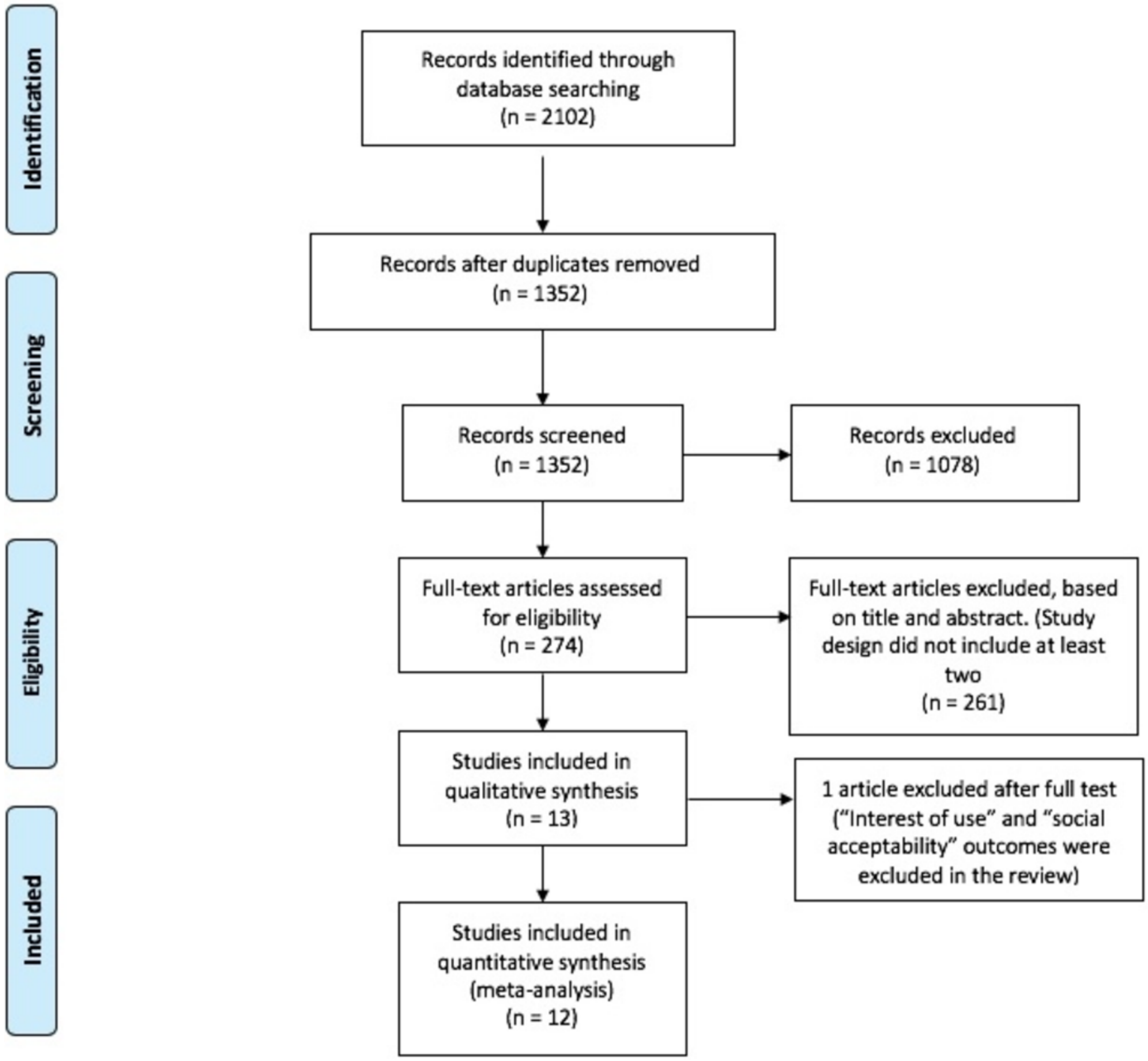

Figure 2 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

(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[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 $\text{treadmill}_{2.5\ \text{km/hour}}$ 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 $\text{treadmill}_{0.6\ \text{km/hour}}$ and $\text{treadmill}_{2.5\ \text{km/hour}}$ conditions compared with standing, except for the physical activity intensity of the head at the 95th percentile for $\text{treadmill}_{0.6\ \text{km/hour}}$ which remained similar to the standing condition.

Physiological activity

Six studies[8 13–17] reported physiological outcomes. Four[13–16] included adults with no health issues (n=109) and two studies[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[17] showed no difference between workstations.

Mean HR

Increased HR was observed in all four studies[8 13–15] when using treadmill or cycling compared with standing workstations. Specifically, Botter *et al*[13] reported an increase of 12 beats per minute (bpm) using a $\text{treadmill}_{2.5\ \text{km/hour}}$ (91 bpm) compared with standing (79 bpm), which was corroborated by Cox *et al*.[14] Moreover, Straker *et al*[15] reported an increase of 5 bmp for the $\text{treadmill}_{3.2\ \text{km/hour}}$ and an increase of 7 bmp for $\text{cycling}_{30\ \text{W}}$ compared with standing workstations. All other conditions with lower power or speed (eg, $\text{treadmill}_{1.6\ \text{km/hour}}$; $\text{cycling}_{5\ \text{W}}$) did not result in an increase in bmp. Zeigler *et al*[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

Authors/study	Design	Intervention duration	Sample (n)	Population characteristics	Experimental conditions	Measures	Results	Effect size (Cohen's *d*)
Bantoft *et al*[21]	Counterbalanced randomised controlled trial	60 min/task/day 7 tasks on 7 days	Males=13 Females=32	22.7 years old Healthy undergraduate students	Sitting Sitting/standing Treadmill (1–3 km/hour)	Intellectual capacity Anxiety and depression Verbal short-term memory Verbal working memory Visuomotor speed and learning Verbal working memory and attention	All results were non-significant.	NA
Botter *et al*[13]	Randomised repeated measures	±4 hours	Males=6 Females=6 EMG subgroup: Males=5 Females=5	38.7 years old	Sitting Standing Treadmill (0.6 km/hour) Treadmill (2.5 km/hour) Elliptical (9 W) Elliptical (17 W)	Muscle activation by EMG (% of maximal voluntary muscular contraction of trapezius and erector spinae) Posture and joint angles (head inclination, cervical spine flexion, L5 inclination, trunk frontal inclination, trunk lateral inclination, back flexion) Motion analysis (total body, head, thoracic spine, lumbar spine L1, lumbar spine L5 arms, legs) Heart rate Energy expenditure	Comparisons were only done between standing and treadmill experimental conditions (upright posture). Trapezius right (%MVC) mean values of the *50th percentile*: standing (3.8 %MVC) vs treadmill$_{2.5\,\text{km/hour}}$ (8.1 %MVC). Trapezius right (%MVC) mean values of the *95th percentile*: standing (9.3 %MVC) vs treadmill$_{2.5\,\text{km/hour}}$ (17.2 %MVC). Trapezius left (%MVC) mean values of the *50th percentile*: standing (5.8 %MVC) vs treadmill$_{2.5\,\text{km/hour}}$ (8.1 %MVC). Trapezius left (%MVC) mean values of the *95th percentile*: standing (10 %MVC) vs treadmill$_{2.5\,\text{km/hour}}$ (22.9 %MVC). Treadmill$_{2.5\,\text{km/hour}}$ increased muscle activation of the upper limb compared with standing. Motion analysis: Total body (%g) mean values of the *50th percentile*: standing (0.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (3.7 %g) and treadmill$_{2.5\,\text{km/hour}}$ (14.9 %g). Total body (%g) mean values of the *95th percentile*: standing (2 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (5.3 %g) and treadmill$_{2.5\,\text{km/hour}}$ (17.1 %g). Head (%g) mean values of the *50th percentile*: standing (0.7 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (2.9 %g) and treadmill$_{2.5\,\text{km/hour}}$ (8.9 %g). Thoracic spine (%g) mean values of the *50th percentile*: standing (0.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (2.3 %g) and treadmill$_{2.5\,\text{km/hour}}$ (9.6 %g). Thoracic spine (%g) mean values of the *95th percentile*: standing (1.5 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (3.5 %g) and treadmill$_{2.5\,\text{km/hour}}$ (11.5 %g). Lumbar spine L1 (%g) mean values of the *50th percentile*: standing (0.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (2.5 %g) and treadmill$_{2.5\,\text{km/hour}}$ (10.1 %g). Lumbar spine L1 (%g) mean values of the *95th percentile*: standing (1.5 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (3.9 %g) and treadmill$_{2.5\,\text{km/hour}}$ (12.2 %g). Lumber spine L5 (%g) mean values of the *50th percentile*: standing (0.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (2.8 %g) and treadmill$_{2.5\,\text{km/hour}}$ (10.9 %g). Lumber spine L5 (%g) mean values of the *95th percentile*: standing (1.6 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (4.3 %g) and treadmill$_{2.5\,\text{km/hour}}$ (13.3 %g). Arms (%g) mean values of the *50th percentile*: standing (0.7 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (2.9 %g) and treadmill$_{2.5\,\text{km/hour}}$ (9.1 %g). Arms (%g) mean values of the *95th percentile*: standing (2.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (4.8 %g) and treadmill$_{2.5\,\text{km/hour}}$ (11.2 %g). Legs (%g) mean values of the *50th percentile*: standing (0.8 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (5.2 %g) and treadmill$_{2.5\,\text{km/hour}}$ (22.5 %g). Legs (%g) mean values of the *95th percentile*: standing (2.2 %g) vs treadmill$_{0.6\,\text{km/hour}}$ (7.5 %g) and treadmill$_{2.5\,\text{km/hour}}$ (25.8 %g). Treadmill$_{0.6\,\text{km/hour}}$ and treadmill$_{2.5\,\text{km/hour}}$ increased (%g) compared with standing workstation except for the head (%g) mean values of the 95th percentile. Heart rate mean values: standing (79.8), elliptical$_{9\,\text{W}}$ (86.8), elliptical$_{17\,\text{W}}$ (96.6), treadmill$_{0.6\,\text{km/hour}}$ (81.4), treadmill$_{2.5\,\text{km/hour}}$ (91.4). Elliptical$_{17\,\text{W}}$ and treadmill$_{2.5\,\text{km/hour}}$ increased heart rate compared with standing. Energy expenditure (MET) values: standing (1.6), elliptical$_{9\,\text{W}}$ (2.4), elliptical$_{17\,\text{W}}$ (3.1), treadmill$_{0.6\,\text{km/hour}}$ (1.8), treadmill$_{2.5\,\text{km/hour}}$ (2.8). Treadmill$_{2.5\,\text{km/hour}}$ increased energy expenditure compared with standing. All other results were non-significant.	Trapezius (%MVC) right 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=0.87 Trapezius (%MVC) right 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=0.83 Trapezius left (%MVC) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=0.43 Trapezius left (%MVC) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=0.97 Total body (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=7.08 Total body (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=6.63 Total body (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=3.07 Total body (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.04 Head (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=5.47 Head (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=4.05 Head (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=1.88 Thoracic spine (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=5.91 Thoracic spine (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=6.29 Thoracic spine (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.63 Thoracic spine (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=1.96 Lumbar spine L1 (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=5.97 Lumbar spine L1 (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=6.46 Lumbar spine L1 (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.98 Lumbar spine L1 (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.35 Lumber spine L5 (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=4.92 Lumber spine L5 (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=5.28 Lumber spine L5 (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=3.12 Lumber spine L5 (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.41 Arms (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=5.55 Arms (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=3.90 Arms (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=3.15 Arms (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=1.06 Legs (%g) 50th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=6.79 Legs (%g) 95th percentile treadmill$_{2.5\,\text{km/hour}}$ vs standing=6.41 Legs (%g) 50th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.78 Legs (%g) 95th percentile treadmill$_{0.6\,\text{km/hour}}$ vs standing=2.07 Heart rate elliptical$_{17\,\text{W}}$ vs standing=1.65 Heart rate treadmill$_{2.5\,\text{km/hour}}$ vs standing=1.63 Energy expenditure missing data

continued

Table 2 continued

Authors/study	Design	Intervention duration	Sample (n)	Population characteristics	Experimental conditions	Measures	Results	Effect size (Cohen's *d*)
Commissaris *et al*[25]	Randomised repeated measures	1 workday	Males=7 Females=8	29.0 years old BMI=22.3 kg/m^2	Sitting Standing Treadmill (2.5 km/hour) Elliptical (17 W) Cycling (56 W) Cycling (85 W)	Typing task (number of characters typed/min) Reading and correcting task (number of characters read/min) Reaction time test: Mouse task Multidirectional cognitive task Fast counting task Eriksen flanker N-back test Telephone task	No statistical analyses have been done between active workstations.	NA
Cox *et al*[14]	Randomised repeated measures	60 min	Males=9 Females=22	37 years old	Sitting Standing Treadmill (1.6 km/hour)	Aerobic capacity Heart rate Blood pressure Perceived effort Dyspnoea perception Speech assessment	Treadmill$_{1.61\ km/hour}$ (7.4±0.33) increased VO_2 demands compared with standing (4.0±0.18). Treadmill$_{1.61\ km/hour}$ increased heart rate compared with standing. SBP values mean±SE: standing (124±3) and treadmill$_{1.61\ km/hour}$ (129±3). Treadmill$_{1.61\ km/hour}$ lowered blood pressure compared with standing. Rating perceived effort values: standing (0.7/10) and treadmill$_{1.61\ km/hour}$ (1.3/10). Treadmill$_{1.61\ km/hour}$ 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.	VO_2 treadmill$_{1.61\ km/hour}$ vs standing=0.80 Heart rate treadmill$_{1.61\ km/hour}$ vs standing=missing data SBP treadmill$_{1.61\ km/hour}$ vs standing=0.29 Rating perceived effort treadmill$_{1.61\ km/hour}$ vs standing=0.53 Dyspnoea treadmill$_{1.61\ km/hour}$ vs standing=missing data
Gilson *et al*[18]	Pilot study	1.5-hour work periods/day/experimental condition	n=20 EEG subgroup=13 Salivary cortisol subgroup=16	23–63 years old	Sitting Sitting/standing Sitting/treadmill (self-determined speed range between 1.6 and 4 km/hour)	EGG Salivary cortisol	All results were non-significant.	NA
Kruse *et al*[17]	Pilot study	(1) 4 hours of uninterrupted sitting (2) 4 hours of sitting interrupted with four 10 min bouts of standing (3) 4 hours of sitting interrupted with four 10 min bouts of light-intensity desk cycling	Males=10 Females=3	35–50 years old BMI=29.7 kg/m^2 Sedentary, overweight and obese adults	Standing Cycling	Flow-mediated dilation Heart rate Blood pressure Calf circumferences before and after conditions	All results were non-significant.	NA
Ohlinger *et al*[20]	Within-participants experimental	75 min for all assessments	n=50	43.2 years old	Sitting Standing Treadmill (1.6 km/hour)	Short-term auditory verbal memory Selective attention Simple motor skill	Simple motor skills decreased from Treadmill$_{1.6\ km/hour}$ compared with standing. All other results were non-significant.	Simple motor skill treadmill$_{1.6\ km/hour}$ vs standing=0.15
Mullane *et al*[19]	Randomised crossover	8 hours/experimental condition with bouts of 10, 15, 20 and 30 min on active workstation	Males=2 Females=7	30.0 years old BMI=28.7 kg/m^2 Prehypertensive (n=7)	Siting Standing Treadmill (1.6 km/hour) Cycling (20 W at 25–20 RPM)	Detection test (speed expressed in z-score and mean log 10 transformed reaction times for correct responses) One back test Set-shifting test	Detection test processing speed z-score: standing (−0.43±0.97), treadmill$_{1.6\ km/hour}$ (−0.44±0.96), cycling$_{20\ W}$ (0.17±97). Processing speed time z-score of standing and treadmill$_{1.6\ km/hour}$ workstations showed lower performance speed than cycling$_{20\ W}$ workstation. Detection test reaction time values: standing (2.72±0.13 log10 ms), treadmill$_{1.6\ km/hour}$ (2.71±0.13 log10 ms) and cycling$_{20\ W}$ (2.66±0.14 log10 ms). Reaction time was faster for cycling$_{20\ W}$ compared with standing. All other results were non-significant.	Detection test processing speed cycling$_{20\ W}$ vs treadmill$_{1.6\ km/hour}$=0.63 Detection test processing speed cycling$_{20\ W}$ vs standing=0.61 Reaction time cycling$_{20\ W}$ vs standing=0.44
Sliter and Yuan[10]	Pilot study	35 min	n=180	21.2 years old BMI=23.9 kg/m^2 Undergraduate students	Sitting Standing Treadmill Cycling	Stress Arousal Boredom Task satisfaction Performance (number of correct tasks; number of errors in task)	Treadmill (2.85±0.36) increased arousal compared with standing (2.55±0.42). Cycling increased arousal compared with standing. Treadmill decreased boredom compared with standing. Cycling decreased boredom 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.	Arousal treadmill vs standing=0.77 Arousal cycling vs standing=0.95 Boredom treadmill vs standing=−1.84 Boredom cycling vs standing=−1.82 Stress treadmill vs standing=−0.77 Task satisfaction treadmill vs standing=0.58 Performance-level cycling vs standing=−0.68

continued

Table 2 continued

Authors/study	Design	Intervention duration	Sample (n)	Population characteristics	Experimental conditions	Measures	Results	Effect size (Cohen's *d*)
Straker *et al*[15]	Experimental mixed model	±1 workday	Males=14 Females=16	22–64 years old BMI (female)=25.1 kg/m^2 BMI (male)=24.7 kg/m^2	Sitting Standing Treadmill (1.6 km/hour) Treadmill (3.2 km/hour) Cycling (5 W) Cycling (30 W)	Typing speed (words/min) Typing accuracy (% typing errors) Typing perceived speed Typing perceived accuracy Mouse pointing speed (ms) Mouse task accuracy (actual errors) Mouse perceived speed Mouse perceived accuracy Combined keyboard and mouse speed (words/s) and error Combined keyboard and mouse task perceived speed and error Heart rate Exertion	Typing speed task values: standing (54.09), treadmill$_{1.6\ km/hour}$ (50.14), treadmill$_{3.2\ km/hour}$ (49.74), cycling$_{5\ W}$ (52.58), cycling$_{30\ W}$ (53.217). Typing speed was less for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Typing perceived speed scores: standing (2.86), treadmill$_{1.6\ km/hour}$ (3.56), treadmill$_{3.2\ km/hour}$ (3.58), cycling$_{5\ W}$ (3.45), cycling$_{30\ W}$ (3.48). Results showed a decrease in typing speed perception for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Typing perceived accuracy scores: standing (2.99), treadmill$_{1.6\ km/hour}$ (3.79), treadmill$_{3.2\ km/hour}$ (3.79), cycling$_{5\ W}$ (3.49), cycling$_{30\ W}$ (3.55). Scores showed a decrease in accuracy perception for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Also, scores showed a decrease in accuracy perception for treadmill$_{1.6\ km/hour}$ compared with cycling$_{5\ W}$. Mouse speed task values: standing (959.39), treadmill$_{1.6\ km/hour}$ (1059.54), treadmill$_{3.2\ km/hour}$ (1107), cycling$_{5\ W}$ (1022.28), cycling$_{30\ W}$ (1001.62). Results showed a decrease in performance for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$ and cycling$_{5\ W}$ compared with standing. Also, results showed a decrease in speed between treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with cycling$_{5\ W}$. Results showed a decrease in speed for treadmill$_{3.2\ km/hour}$ compared with cycling$_{30\ W}$. Mouse task perceived speed scores: standing (2.55), treadmill$_{1.6\ km/hour}$ (3.47), treadmill$_{3.2\ km/hour}$ (3.54), cycling$_{5\ W}$ (3.19), cycling$_{30\ W}$ (3.26). Results showed a decrease in speed perception for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Results showed a decrease in speed perception for treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$, compared with cycling$_{5\ W}$ and cycling$_{30\ W}$. Mouse task accuracy values: standing (0.1), treadmill$_{1.6\ km/hour}$ (0.17), treadmill$_{3.2\ km/hour}$ (0.2), cycling$_{5\ W}$ (0.13), cycling$_{30\ W}$ (0.16). Accuracy results showed an increase in error for the treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with standing. Also, results showed an increase in error for treadmill$_{3.2\ km/hour}$ compared with cycling$_{5\ W}$. Mouse task perceived accuracy scores: standing (2.77), treadmill$_{1.6\ km/hour}$ (3.63), treadmill$_{3.2\ km/hour}$ (3.81), cycling$_{5\ W}$ (3.18), cycling$_{30\ W}$ (3.39). Scores showed a decrease in speed perception for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Also, results showed a decrease in speed perception for treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with cycling$_{5\ W}$. Combined keyboard and mouse task speed values: standing (11.94), treadmill$_{1.6\ km/hour}$ (9.57), treadmill$_{3.2\ km/hour}$ (8.26), cycling$_{5\ W}$ (10.84), cycling$_{30\ W}$ (11.17). Results showed a decrease in task speed for treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with standing. Also, results showed a decrease in task speed for treadmill$_{3.2\ km/hour}$ and treadmill$_{1.6\ km/hour}$ compared with cycling$_{5\ W}$ and cycling$_{30\ W}$. Combined keyboard and mouse task perceived speed scores: standing (2.99), treadmill$_{1.6\ km/hour}$ (3.7), treadmill$_{3.2\ km/hour}$ (4.08), cycling$_{5\ W}$ (3.51), cycling$_{30\ W}$ (3.52). Scores showed a decrease in the perception of speed for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Also, scores showed a decrease in the perception of speed for treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with cycling$_{5\ W}$ and cycling$_{30\ W}$. Combined keyboard and mouse perceived accuracy scores: standing (2.95), treadmill$_{1.6\ km/hour}$ (3.79), treadmill$_{3.2\ km/hour}$ (4.04), cycling$_{5\ W}$ (3.38), cycling$_{30\ W}$ (3.48). Scores showed a decrease in the perception of accuracy for treadmill$_{1.6\ km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with cycling$_{5\ W}$ and cycling$_{30\ W}$. Scores also showed a decrease in the perception of accuracy for treadmill$_{3.2\ km/hour}$ and compared with treadmill$_{1.6\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$. Heart rate mean values: standing (82), treadmill$_{1.6\ km/hour}$ (82), treadmill$_{3.2\ km/hour}$ (87), cycling$_{5\ W}$ (79), cycling$_{30\ W}$ (89). Results showed an increase in the mean heart rate for standing, treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with cycling$_{5\ W}$. Results also showed an increase in mean heart rate for treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with standing. Perceived exertion scores: standing (0.95), treadmill$_{1.6\ km/hour}$ (1.74), treadmill$_{3.2\ km/hour}$ (2.39), cycling$_{5\ W}$ (1.66), cycling$_{30\ W}$ (2.61). Perceived exertion scores showed an increase for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Also, scores showed an increase in perceived exertion for treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with treadmill$_{1.6\ km/hour}$ and an increase in perceived exertion for treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with cycling$_{5\ W}$. All other results were non-significant.	Typing speed treadmill$_{3.2\ km/hour}$ vs standing=−0.04 Typing speed treadmill$_{1.6\ km/hour}$ vs standing=−0.10 Typing speed cycling$_{5\ W}$ vs standing=−0.04 Typing speed cycling$_{30\ W}$ vs standing=−0.02 Typing perceived speed treadmill$_{3.2\ km/hour}$ vs standing=0.56 Typing perceived speed treadmill$_{1.6\ km/hour}$ vs standing=0.63 Typing perceived speed cycling$_{5\ W}$ vs standing=0.57 Typing perceived speed cycling$_{30\ W}$ vs standing=0.57 Typing perceived accuracy treadmill$_{3.2\ km/hour}$ vs standing=0.70 Typing perceived accuracy treadmill$_{1.6\ km/hour}$ vs standing=0.68 Typing perceived accuracy cycling$_{5\ W}$ vs standing=0.63 Typing perceived accuracy cycling$_{30\ W}$ vs standing=0.66 Typing perceived accuracy treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$= 0.1 Mouse speed treadmill$_{3.2\ km/hour}$ vs standing=0.58 Mouse speed treadmill$_{1.6\ km/hour}$ vs standing=0.34 Mouse speed cycling$_{5\ W}$ vs standing=0.21 Mouse speed treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.34 Mouse speed treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$=0.13 Mouse speed treadmill$_{3.2\ km/hour}$ vs cycling$_{30\ W}$=0.42 Mouse perceived speed treadmill$_{3.2\ km/hour}$ vs standing=0.93 Mouse perceived speed treadmill$_{1.6\ km/hour}$ vs standing=1.04 Mouse perceived speed cycling$_{5\ W}$ vs standing=0.67 Mouse perceived speed cycling$_{30\ W}$ vs standing=0.73 Mouse perceived speed treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.41 Mouse perceived speed treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$=0.31 Mouse perceived speed treadmill$_{3.2\ km/hour}$ vs cycling$_{30\ W}$=0.32 Mouse perceived speed treadmill$_{1.6\ km/hour}$ vs cycling$_{30\ W}$=0.23 Mouse task accuracy treadmill$_{3.2\ km/hour}$ vs standing=0.39 Mouse task accuracy treadmill$_{1.6\ km/hour}$ vs standing=0.26 Mouse task accuracy cycling$_{30\ W}$ vs standing=0.25 Mouse task accuracy treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$ = 0.24 Mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs standing=1.09 Mouse perceived accuracy treadmill$_{1.6\ km/hour}$ vs standing=0.82 Mouse perceived accuracy cycling$_{5\ W}$ vs standing=0.43 Mouse perceived accuracy cycling$_{30\ W}$ vs standing=0.65 Mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.47 Mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.76 Combined keyboard-mouse speed treadmill$_{3.2\ km/hour}$ vs standing=−0.26 Combined keyboard-mouse speed treadmill$_{1.6\ km/hour}$ vs standing=−0.41

continued

Table 2 continued

Authors/study	Design	Intervention duration	Sample (n)	Population characteristics	Experimental conditions	Measures	Results	Effect size (Cohen's *d*)
								Combined keyboard-mouse speed treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=−0.28 Combined keyboard-mouse speed treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$=−0.13 Combined keyboard-mouse speed treadmill$_{3.2\ km/hour}$ vs cycling$_{30\ W}$=−1.53 Combined keyboard-mouse speed treadmill$_{1.6\ km/hour}$ vs cycling$_{30\ W}$=−1.36 Combined keyboard-mouse perceived speed treadmill$_{3.2\ km/hour}$ vs standing=1.10 Combined keyboard-mouse perceived speed treadmill$_{1.6\ km/hour}$ vs standing=0.60 Combined keyboard-mouse perceived speed cycling$_{5\ W}$ vs standing=0.47 Combined keyboard-mouse perceived speed cycling$_{30\ W}$ vs standing=0.55 Combined keyboard-mouse perceived speed treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.51 Combined keyboard-mouse perceived speed treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$=0.15 Combined keyboard-mouse perceived speed treadmill$_{3.2\ km/hour}$ vs cycling$_{30\ W}$=0.58 Combined keyboard-mouse perceived speed treadmill$_{1.6\ km/hour}$ vs cycling$_{30\ W}$=0.15 Combined keyboard-mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs standing=3.32 Combined keyboard-mouse perceived accuracy treadmill$_{1.6\ km/hour}$ vs standing=2.43 Combined keyboard-mouse perceived accuracy cycling$_{5\ W}$ vs standing=1.31 Combined keyboard-mouse perceived accuracy cycling$_{30\ W}$ vs standing=1.57 Combined keyboard-mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs treadmill$_{1.6\ km/hour}$=0.64 Combined keyboard-mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=1.75 Combined keyboard-mouse perceived accuracy treadmill$_{3.2\ km/hour}$ vs cycling$_{30\ W}$=1.45 Heart rate treadmill$_{3.2\ km/hour}$ vs standing=0.22 Heart rate cycling$_{30\ W\ m/hour}$ vs standing=0.31 Heart rate treadmill$_{3.2\ km/hour}$ vs treadmill$_{1.6\ km/hour}$=0.22 Heart rate cycling$_{30\ W\ m/hour}$ vs treadmill$_{1.6\ km/hour}$=0.31 Heart rate treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.37 Heart rate treadmill$_{1.6\ km/hour}$ vs cycling$_{5\ W}$=0.15 Heart rate cycling$_{30\ W\ m/hour}$ vs cycling$_{5\ W}$=0.47 Perceived exertion treadmill$_{3.2\ km/hour}$ vs standing=0.56 Perceived exertion treadmill$_{1.6\ km/hour}$ vs standing=0.33 Perceived exertion cycling$_{5\ W}$ vs standing=0.29 Perceived exertion cycling$_{30\ W}$ vs standing=0.66 Perceived exertion treadmill$_{3.2\ km/hour}$ vs treadmill$_{1.6\ km/hour}$=0.65 Perceived exertion cycling$_{30\ W}$ vs treadmill$_{1.6\ km/hour}$=0.87 Perceived exertion treadmill$_{3.2\ km/hour}$ vs cycling$_{5\ W}$=0.25 Perceived exertion cycling$_{30\ W}$ vs cycling$_{5\ W}$=0.34

continued

Table 2 continued

Authors/study	Design	Intervention duration	Sample (n)	Population characteristics	Experimental conditions	Measures	Results	Effect size (Cohen's *d*)
Tronarp *et al*[16]	Randomised crossover	Standing session of 30 min Cycling$_{20\%\mathrm{MAP}}$ session of 75 min Cycling$_{50\%\mathrm{MAP}}$ session of 30 min	Males=15 Females=21	26.8 years old Healthy adults	Standing Cycling (20%MAP) Cycling (50%MAP)	Pressure pain threshold Thermal pain threshold Typing gross speed (included errors; words/min) Typing net speed (excluded errors; words/min) Typing accuracy Mouse successful task Mouse speed to complete task Stroop colour word test (% of correct words) Energy expenditure	Typing gross speed values: Standing (47), cycling$_{20\%\mathrm{MAP}}$ (46.5), cycling$_{50\%\mathrm{MAP}}$ (45.5). Typing gross speed was reduced for cycling$_{50\%\mathrm{MAP}}$ and cycling$_{20\%\mathrm{MAP}}$ compared with standing. Typing net speed values: standing (46.3), cycling$_{20\%\mathrm{MAP}}$ (44.3), cycling$_{50\%\mathrm{MAP}}$ (43.8). Typing net speed was reduced for cycling$_{50\%\mathrm{MAP}}$ and cycling$_{20\%\mathrm{MAP}}$ compared with standing. Typing error values: standing (13.8), cycling$_{20\%\mathrm{MAP}}$ (16.3), cycling$_{50\%\mathrm{MAP}}$ (20.0). Typing errors improved with cycling$_{50\%\mathrm{MAP}}$ and cycling$_{20\%\mathrm{MAP}}$ compared with standing. Mouse pointing successful task values: standing (7), cycling$_{20\%\mathrm{MAP}}$ (5.5), cycling$_{50\%\mathrm{MAP}}$ (3.5). Accuracy was reduced during both cycling$_{50\%\mathrm{MAP}}$ and cycling$_{20\%\mathrm{MAP}}$ compared with standing, as well as in cycling$_{50\%\mathrm{MAP}}$ compared with cycling$_{20\%\mathrm{MAP}}$. Mouse speed values: standing (33.6), cycling$_{20\%\mathrm{MAP}}$ (32.6), cycling$_{50\%\mathrm{MAP}}$ (33.9). Mouse speed was reduced for standing compared with cycling$_{20\%\mathrm{MAP}}$ and for cycling$_{50\%\mathrm{MAP}}$ compared with standing (33.6 s). Energy expenditure median values (kcal/min): standing (1.4), cycling$_{20\%\mathrm{MAP}}$ (3.3), cycling$_{50\%\mathrm{MAP}}$ (7.5). Energy expenditure increased for cycling$_{50\%\mathrm{MAP}}$ and cycling$_{20\%\mathrm{MAP}}$ compared with standing. It also increased for cycling$_{50\%\mathrm{MAP}}$ compared with cycling$_{20\%\mathrm{MAP}}$. All other results were non-significant.	Missing data
Zeigler *et al*[8]	Randomised cross-over full factorial	Monitoring for 12 hours (08:00–20:00). Analysed hours: (1) 12 hours (08:00–20:00) (2) Work hours (08:00–16:00) with bout of active workstation for a cumulative of 2.5 hours (3) Postwork hours (16:00–20:00)	Males=2 Females=7	30 years old BMI=28.7 kg/m^2 Prehypertensive (n=7)	Siting Standing Treadmill (1.6 km/hour) Cycling (20 W at 25–20 RPM)	Heart rate Blood pressure	12-hour period (08:00–20:00) mean heart rate values: standing (74±12), treadmill$_{1.6\ \mathrm{km/hour}}$ (78±12), cycling$_{20\ \mathrm{W}}$ (78±13). Treadmill$_{1.6\ \mathrm{km/hour}}$ and cycling$_{20\ \mathrm{W}}$ increased heart rate compared with standing. 12-hour mean SBP values: standing (132±17), treadmill$_{1.6\ \mathrm{km/hour}}$ (133±17), cycling$_{20\ \mathrm{W}}$ (130±16). Cycling$_{20\ \mathrm{W}}$ and treadmill$_{1.6\ \mathrm{km/hour}}$ lowered SBP compared with standing. Cycling$_{20\ \mathrm{W}}$ lowered SBP compared with treadmill$_{1.6\ \mathrm{km/hour}}$. 12-hour mean DBP values: standing (72±12), treadmill$_{1.6\ \mathrm{km/hour}}$ (71±17), cycling$_{20\ \mathrm{W}}$ (69±16). Cycling$_{20\ \mathrm{W}}$ lowered DBP compared with treadmill$_{1.6\ \mathrm{km/hour}}$ and standing. Work hours' heart rate values: standing (72±12), treadmill$_{1.6\ \mathrm{km/hour}}$ (77±13), cycling$_{20\ \mathrm{W}}$ (78±14). Cycling$_{20\ \mathrm{W}}$ and treadmill$_{1.6\ \mathrm{km/hour}}$ increased heart rate compared with standing. Work hours' SBP mean values: standing (131±16), treadmill$_{1.6\ \mathrm{km/hour}}$ (131±16), cycling$_{20\ \mathrm{W}}$ (129±15). Cycling$_{20\ \mathrm{W}}$ lowered SBP compared with treadmill$_{1.6\ \mathrm{km/hour}}$ and standing. Work hours' DBP mean values: standing (74±11), treadmill$_{1.6\ \mathrm{km/hour}}$ (73±11), cycling$_{20\ \mathrm{W}}$ (71±11). Cycling$_{20\ \mathrm{W}}$ lowered DBP compared with standing. Postwork hours' SBP mean values: standing (134±18), treadmill$_{1.6\ \mathrm{km/hour}}$ (135±17), cycling$_{20\ \mathrm{W}}$ (127±15). Cycling$_{20\ \mathrm{W}}$ lowered SBP compared with treadmill$_{1.6\ \mathrm{km/hour}}$ and standing.	Heart rate (08:00–20:00) treadmill$_{1.6\ \mathrm{km/hour}}$ vs standing=0.33 Heart rate (08:00–20:00) cycling$_{20\ \mathrm{W}}$ vs standing=0.33 SBP (08:00–20:00) treadmill$_{1.6\ \mathrm{km/hour}}$ vs standing=0.06 SBP (08h00-20h00) cycling$_{20\ \mathrm{W}}$ vs standing=−0.12 SBP (08:00–20:00) cycling$_{20\ \mathrm{W}}$ vs treadmill$_{1.6\ \mathrm{km/hour}}$=−0.18 DBP (08:00–20:00) cycling$_{20\ \mathrm{W}}$ vs treadmill$_{1.6\ \mathrm{km/hour}}$=−0.12 Heart rate (work hours) (20:00) treadmill$_{1.6\ \mathrm{km/hour}}$ vs standing=0.4 Heart rate (work hours) cycling$_{20\ \mathrm{W}}$ vs standing=0.33 SBP (work hours) cycling$_{20\ \mathrm{W}}$ vs standing=−0.13 SBP (work hours) cycling$_{20\ \mathrm{W}}$ vs treadmill$_{1.6\ \mathrm{km/hour}}$=−0.13 DBP (work hours) cycling$_{20\ \mathrm{W}}$ vs standing=−0.27 SBP (postwork) cycling$_{20\ \mathrm{W}}$ vs standing=−0.42

Values presented are means, unless otherwise specified.
%g, gravitational force; %MVC, maximum voluntary contractions; BMI, body mass index; DBP, diastolic blood pressure; EEG, electroencephalography; EGG, 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

Item	Criteria	Score											
		Bantoft *et al*[21]	Botter *et al*[13]	Commissaris *et al*[25]	Cox *et al*[14]	Gilson *et al*[18]	Kruse *et al*[17]	Ohlinger *et al*[20]	Mullane *et al*[19]	Sliter and Yuan[10]	Straker *et al*[15]	Tronarp *et al*[16]	Zeigler *et al*[8]
Reporting													
1	*Is the hypothesis/aim/objective of the study clearly described?*	1	1	1	1	1	1	1	1	1	1	1	1
2	*Are the main outcomes to be measured clearly described in the introduction? or Methods section?*	1	1	1	1	1	1	1	1	1	1	1	1
3	*Are the characteristics of the patients included in the study clearly described?*	1	1	1	1	1	1	1	1	1	1	1	1
4	*Are the interventions of interest clearly described?*	1	1	1	1	1	1	1	1	1	1	1	1
5	*Are the distributions of principal confounders in each group of subjects to be compared clearly described?*	2	0	2	0	1	2	2	2	0	1	1	2
6	*Are the main findings of the study clearly described?*	1	1	1	1	1	1	1	1	1	1	1	1
7	*Does the study provide estimates of the random variability in the data for the main outcomes?*	1	1	1	1	1	1	1	1	1	1	1	1
8	*Have all important adverse events that may be a consequence of the intervention been reported?*	1	0	1	0	0	1	1	1	0	0	0	0
9	*Have the characteristics of patients lost to follow-up been described?*	0	0	0	0	1	0	0	1	1	0	1	1
10	*Have actual probability values been reported (eg, 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?*	1	1	1	1	1	1	1	1	1	1	1	1
External validity													
11	*Were the subjects asked to participate in the study representative of the entire population from which they were recruited?*	1	1	0	0	0	0	1	0	1	1	1	1
12	*Were those subjects who were prepared to participate representative of the entire population from which they were recruited?*	1	1	0	0	0	0	1	0	0	0	1	1
13	*Were the staff, places and facilities where the patients were treated representative of the treatment the majority of patients receive?*	0	0	1	0	0	0	0	0	0	0	0	0
Internal validity—bias													
14	*Was an attempt made to blind study subjects to the intervention they have received?*	0	0	0	0	0	0	0	0	0	0	0	0
15	*Was an attempt made to blind those measuring the main outcomes of the intervention?*	0	0	0	1	0	0	0	0	0	0	0	0
16	*If any of the results of the study were based on 'data dredging', was this made clear?*	1	1	1	1	1	1	1	1	1	1	1	1
17	*In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case–control studies, is the time period between the intervention and outcome the same for cases and controls?*	1	0	1	1	1	1	1	1	1	1	1	1
18	*Were the statistical tests used to assess the main outcomes appropriate?*	1	1	1	1	1	1	1	1	1	1	1	1
19	*Was compliance with the intervention/s reliable?*	1	1	1	1	1	1	1	1	1	1	1	1
20	*Were the main outcome measures used accurate (valid and reliable)?*	1	1	1	1	1	1	1	1	1	1	1	1

continued

Table 3 continued

Item	Criteria	Score: Bantoft *et al*[21]	Botter *et al*[13]	Commissaris *et al*[25]	Cox *et al*[14]	Gilson *et al*[18]	Kruse *et al*[17]	Ohlinger *et al*[20]	Mullane *et al*[19]	Sliter and Yuan[10]	Straker *et al*[15]	Tronarp *et al*[16]	Zeigler *et al*[8]
Internal validity—confounding (selection bias)													
21	*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?*	1	1	0	0	0	0	1	0	1	1	1	0
22	*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?*	0	0	0	0	0	0	0	0	0	0	0	0
23	*Were study subjects randomised to intervention groups?*	1	1	1	1	1	0	1	1	0	0	1	1
24	*Was the randomised intervention assignment concealed from both patients and healthcare staff until recruitment was complete and irrevocable?*	0	0	0	0	0	0	0	0	0	0	0	0
25	*Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?*	1	0	0	0	0	1	0	1	0	0	1	0
26	*Were losses of patients to follow-up taken into account?*	0	1	0	0	1	0	0	1	1	0	1	1
Power													
27*	*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%.*	0	0	0	0	0	0	1	0	1	0	1	0
Total score		19/28	16/28	17/28	14/28	16/28	16/28	20/28	19/28	17/28	15/28	21/28	19/28

*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 treadmill$_{1.6\ km/hour}$ and cycling$_{20\ W}$ conditions compared with standing. Results from the working hour-specific period showed an increase of 5 bpm for treadmill$_{1.6\ km/hour}$ and 6 bpm for cycling$_{20\ W}$ compared with standing. Results from postwork period showed no difference in HR between conditions.

Blood pressure

Two studies[8 14] with different populations and active workstations examined mean systolic blood pressure (SBP) and mean diastolic blood pressure (DBP). Cox *et al*[14] found no difference in SBP and DBP measured during an intervention comparing standing and treadmill workstations. The second study[8] 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 cycling$_{20\ W}$ and 1 mm Hg for treadmill$_{1.6\ km/hour}$ 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 cycling$_{20\ W}$ compared for both treadmill$_{1.6\ km/hour}$ 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 cycling$_{20\ W}$ decreased by 8 mm Hg compared with treadmill$_{1.6\ km/hour}$ and 9 mm Hg compared with the standing workstation. DBP was similar between standing and treadmill$_{1.6\ km/hour}$ conditions for all three periods. However, cycling$_{20\ W}$ decreased DBP by 3 mm Hg compared with standing, and 2 mm Hg compared with treadmill$_{1.6\ km/hour}$ 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 VO_2 were measured in three studies.[13 14 16] Botter *et al*[13] showed an increase in energy expenditure of 1.2 metabolic equivalent (MET) for treadmill$_{2.5\ km/hour}$ workstations compared with standing. Cox *et al*[14] measured a similar increase of 1 MET from standing to treadmill$_{1.61\ km/hour}$. Tronarp *et al*[16] measured energy expenditure in kcal. In this study, energy expenditure increased between all three conditions: an increase of 2.9 kcal/min between cycling$_{20\%MAP}$ and standing; an increase of 6.9 kcal/min between cycling$_{50\%MAP}$ and standing.

Perceived exertion and pain tolerance

Two studies[14 15] measured perceived exertion, both using the 10-point Borg Scale. In the first study, Cox *et al*[14] 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[15] reported higher perceived exertion for treadmill$_{1.6\ km/hour}$ (1.74/10), treadmill$_{3.2\ km/hour}$ (2.39/10), cycling$_{5\ W}$ (1.66/10) and cycling$_{30\ W}$ (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, treadmill$_{3.2\ km/hour}$ and cycling$_{30\ W}$ compared with treadmill$_{1.6\ km/hour}$ and cycling$_{5\ W}$).

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 cycling$_{20\%MAP}$ (39.3 kPa) were reported.

Work performance

Seven studies[10 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 study[15] 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 treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Perceived accuracy also decreased with the use of both treadmill$_{1.6–3.2\ km/hour}$ and cycling$_{5–30\ W}$ workstations compared with the standing workstation. In addition, a decline in perceived accuracy was reported for the low-intensity treadmill$_{1.6\ km/hour}$ compared with the low-intensity cycling$_{5\ W}$ condition.

Questionnaire outcomes for perceived mouse pointing speed showed a decrease for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Also, a reduction of perceived speed was observed for both treadmill$_{1.6km/hour}$ and treadmill$_{3.2\ km/hour}$ compared with both cycling$_{5\ W}$ and cycling$_{30\ W}$ conditions. There was a decline for the treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing in perceived mouse pointing accuracy. There was a reduction in perceived accuracy for both treadmill workstations compared with low-intensity cycling$_{5\ W}$.

Questionnaire outcomes for perceived combined keyboard/mouse speed tasks showed a decrease in perceived speed for treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ 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 treadmill$_{1.6\ km/hour}$, treadmill$_{3.2\ km/hour}$, cycling$_{5\ W}$ and cycling$_{30\ W}$ compared with standing. Moreover, perceived accuracy declined for treadmill$_{3.2\ km/hour}$ compared with the lower intensity treadmill$_{1.6\ km/hour}$ and both cycling workstation conditions.

Actual performance tasks

Three studies[15 16 20] examined the effect of active workstations on typing performance. Straker *et al*[15] examined the effect of active workstations on typing speed performance (words/min) and accuracy (% of typing errors). Typing speed was reduced for the treadmill$_{3.2\ km/hour}$ (49.73 words/min), treadmill$_{1.6\ km/hour}$ (50.14 words/min), cycling$_{5\ W}$ (53.17 words/min) and cycling$_{30\ W}$ (52.58 words/min) compared with standing (54.09 words/min). No differences were reported for the accuracy test. Tronarp *et al*[16] found that gross speed (ie, including erased typing errors) was reduced for the cycling$_{50\%MAP}$ (45.5 words/min) and cycling$_{20\%MAP}$ (46.5 words/min) compared with standing (47.0 words/min). Net speed (ie, excluding erased typing errors) was also reduced for cycling$_{50\%MAP}$ (43.8 words/min) and cycling$_{20\%MAP}$ (44.3 words/min) compared with standing (46.3 words/min). Moreover, typing errors (ie, number of errors) increased with both cycling$_{50\%MAP}$ (20) and cycling$_{20\%MAP}$ (16.3) compared with standing (13.8). No differences were reported between cycling$_{50\%MAP}$ and cycling$_{20\%MAP}$. Ohlinger *et al*[20] measured the number of taps in a 10 s trial. A reduction in taping speed was observed for the treadmill workstation (55.8) compared with the standing workstation (57.0). To resume, all three studies observed decreases in typing speed with treadmill workstations compared with a standing workstation. The two studies[15 16] with cycling conditions observed a decrease in typing speed compared with a standing workstation. Only one study[16] observed a decrease in typing word accuracy with the use of cycling workstations compared with a standing workstation.

Two studies[15 16] examined mouse pointing speed (ie, milliseconds) and accuracy (ie, actual errors). The first study[15] reported a decrease in speed for $\text{treadmill}_{1.6\ \text{km/hour}}$ (1059 ms); $\text{treadmill}_{3.2\ \text{km/hour}}$ (1107 ms); and $\text{cycling}_{5\ \text{W}}$ (1022 ms) compared with standing (959 ms). Similar values were reported for $\text{cycling}_{5\ \text{W}}$ and $\text{cycling}_{30\ \text{W}}$ workstations (1022 ms). Both $\text{treadmill}_{1.6\text{–}3.2\ \text{km/hour}}$ workstations resulted in decreased mouse pointing speed compared with both $\text{cycling}_{5\text{–}30\ \text{W}}$ workstations. Furthermore, pointing error increased using $\text{treadmill}_{1.6\ \text{km/hour}}$ (0.17), $\text{treadmill}_{3.2\ \text{km/hour}}$ (0.20) and $\text{cycling}_{30\ \text{W}}$ (0.16) compared with standing (0.10), and for $\text{treadmill}_{3.2\ \text{km/hour}}$ (0.20) compared with $\text{cycling}_{5\ \text{W}}$ (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[16] reported a decrease in mouse pointing speed for standing (33.6 ms) compared with $\text{cycling}_{20\%\text{MAP}}$ (32.6 ms). But contrary to the last study, a decrease in mouse pointing speed was reported for a higher $\text{cycling}_{50\%\text{MAP}}$ 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 $\text{cycling}_{50\%\text{MAP}}$ (3.5) and $\text{cycling}_{20\%\text{MAP}}$ (5.5) compared with standing (7), and a decrease in $\text{cycling}_{50\%\text{MAP}}$ (3.5) compared with $\text{cycling}_{20\%\text{MAP}}$ (5.5).

One study[15] examined combined keyboard and mouse task performance (ie, speed (words/s) and error rate). A decrease in speed was observed for both $\text{treadmill}_{1.6\ \text{km/hour}}$ (9.57 words/s) and $\text{treadmill}_{3.2\ \text{km/hour}}$ (8.26 words/s) compared with standing (11.94 words/s). Furthermore, a decrease in speed was observed for the $\text{treadmill}_{1.6\ \text{km/hour}}$ (9.57 words/s) and $\text{treadmill}_{3.2\ \text{km/hour}}$ (8.26 words/s) conditions compared with the $\text{cycling}_{5\ \text{W}}$ (10.84 words/s) and $\text{cycling}_{30\ \text{W}}$ (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.[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 $\text{treadmill}_{1.6\ \text{km/hour}}$ z-score showed a lower speed of performance than $\text{cycling}_{20\ \text{W}}$ z-score. $\text{Cycling}_{20\ \text{W}}$ reaction time was faster than standing reaction time.

Attention and short memory

Out of the four studies[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[10] 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.[13] Likewise, related to energy expenditure, HR could be increased by 10% compared with standing workstations.[13 15] 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.[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.[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.[17]

Cycling workstations increase arousal and reduce boredom significantly better than standing workstations.[10] These outcomes are relevant as research has reported an interaction between level of physical activity at work, well-being at work and work productivity.[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.[19]

No reductions in motor task performance were reported with the use of cycling workstations.[15 24–27] Speed processing time in simple tasks does increase compared with treadmill and standing conditions.[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.[8 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.[10] 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).[11 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.[15 25 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[13 35] and could lead to muscular fatigue and muscle tension.[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.[6 33 36] As a result, even if standing workstations do not exceed a sedentary threshold (ie, energy expenditure),[37] postprandial glycaemia excursion and blood pressure[8 38 39] 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.[9 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.[33 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,[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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