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Review article

The effect of sit-stand desks on office worker behavioral and health outcomes: A scoping review

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ABSTRACT

This scoping review examines the effects of sit-stand desks (SSDs) on six domains: behavior (e.g. time sitting and standing), physiological, work performance, psychological, discomfort, and posture. Fifty-three articles met criteria. We determined the percentage of significant results for each domain. Forty-seven studies were experimental trials. Sample sizes ranged from six to 231 participants. Follow-up time-frames ranged from one day to one year. Sixty-one percent of behavioral (24 studies), 37% of physiological (28 studies), 7% of work performance (23 studies), 31% of psychological (11 studies), 43% of discomfort (22 studies), and 18% of posture domain results (4 studies) were significant. We conclude that SSDs effectively change behaviors, but these changes only mildly effect health outcomes. SSDs seem most effective for discomfort and least for productivity. Further study is needed to examine long-term effects, and to determine clinically appropriate dosage and workstation setup.

1. Introduction

Excessive sitting time has been linked to an increased likelihood of many negative health outcomes including mortality. Those who sit from 8 to 11 h per day have a 15% increase in mortality rate in the next 3 years compared to those who sit < 4 h (van der Ploeg et al., 2012). In addition, obesity, type 2 diabetes, cancer, and cardiovascular disease are more likely in those who spend excessive time sitting (Dunstan et al., 2013). Office workers typically spend more than half of their day sitting, making them an at risk group for developing sitting-related conditions (Pronk et al., 2012). Though there is research that suggests that sitting may be a health risk, other evidence reports little or no association between occupational sitting and health risk (van Uffelen et al., 2010), Despite these contrasting views, office workers have become a target of interventions aimed at decreasing sitting time, thereby reducing the potentially associated health risks. One such intervention is sit-stand desks (SSDs).

SSDs are built on the premise that reducing sitting time by standing to work during computer use has a desirable effect on health outcomes. Yet, this presumption may not hold true. Sitting is a sedentary behavior characterized by little movement and low energy expenditure. It may be these characteristics and not sitting, per se, that put health at risk. Thus, the larger concern may not just be sitting, but any sedentary activity. Sedentary activity is defined as an activity where the MET level is ≤ 1.5 for sitting or ≤ 2.0 for passive standing (Tremblay et al., 2017). People standing at SSDs may not engage in enough active behaviors to surpass sedentary levels. Thus, although multiple studies demonstrate that SSDs reduce sitting and increase standing behaviors (Commissaris et al., 2016), the connection with these changes and health benefits is less clear.

With the popularity of SSDs interventions, there have been multiple systematic reviews related to the use of these and other active workstation desks for computer use, along with the role of training in implementing sit-stand workstations (Commissaris et al., 2016; Benatti and Ried-Larsen, 2015; Chau et al., 2010; Chu et al., 2016; Agarwal et al., 2017; Karakolis and Callaghan, 2014; Karol and Robertson, 2015; MacEwen et al., 2015; Tew et al., 2015; Torbeyns et al., 2014; Tudor-Locke et al., 2014; Wilks et al., 2006). Many of these reviews have examined the ability of multiple physical workstation interventions such as SSDs, treadmill desks, and pedaling desks, to decrease sitting time (Commissaris et al., 2016; Chau et al., 2010; Chu et al., 2016; Tew et al., 2015; Shrestha et al., 2015) as a surrogate for increased physical activity beyond the sedentary level. Although these reviews have found a positive effect of SSDs on sitting, the effect on health outcomes is less

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clear. Reviews have alternatively focused on the effect of SSDs or active workstations on physiological health, discomfort or work performance (Agarwal et al., 2017; Karakolis and Callaghan, 2014; MacEwen et al., 2015; Torbeyns et al., 2014; Tudor-Locke et al., 2014). Tudor-Locke (Tudor-Locke et al., 2014) determined energy expenditure during SSD use was comparable to that of a traditional desk. MacEwan (MacEwen et al., 2015) reported that standing desks had little effect on physiological outcomes, such as post prandial glucose or HDL cholesterol. Both Karakolis (Karakolis and Callaghan, 2014) and Agarwal (Agarwal et al., 2017) examined the effect of SSD on discomfort and reported that there was some positive effect of SSDs on discomfort levels without reducing productivity, but that the results were too inconclusive to make any solid recommendations. Thus, although SSDs decrease sitting time without reducing work performance, their effect on important health outcomes may not be consequential. Improvements in physical activity levels and health-related outcomes tend to be stronger or may only be present with active workstations (Commissaris et al., 2016; Torbeyns et al., 2014; Tudor-Locke et al., 2014).

While these reviews provide important insights into the use of SSDs, there are still gaps in our current knowledge of the effectiveness of SSDs. Many of the reviews combined the results from multiple alternative workstation types making it difficult to determine the true effect of a SSD (Commissaris et al., 2016; Chau et al., 2010; Chu et al., 2016; Karol and Robertson, 2015; MacEwen et al., 2015; Tudor-Locke et al., 2014; Neuhaus et al., 2014a). This strategy was likely done due to minimal research on SSDs alone at the time of the review. However, in the last few years an explosion of SSD studies have been published, warranting an updated review. Past reviews tended to look at single outcomes; reducing sitting, reducing pain, improving physiological outcomes. No single review, to our knowledge, has looked at the multiple areas that SSDs are purported to affect. There are no reviews that isolate the effect of SSDs on total worker health and performance. Thus, it is difficult to estimate and compare the full effects of SSDs across multiple health outcomes. It is important to consider all aspects of workers health when determining the effectiveness of novel occupational interventions such as SSDs.

1.1. Scoping review aim

In this scoping review we focus on specifying the effectiveness of SSDs on multiple primary outcome domains. Specifically, this review aims to determine the most promising uses and implementation of SSDs in relationship to total worker health and performance outcomes, and what additional areas may need to be explored. We examined the following outcomes: (1) reductions in sitting and increases in non-sedentary behavior; (2) improvements in physiological outcomes such as cardiovascular health, endocrine-related health, cognition, fatigue, edema, and obesity; (3) effects on work performance; (4) improvements in psychological outcomes such as mood, self-efficacy/confidence; (5) reductions in musculoskeletal discomfort; (6) improvements in computing work postures.

2. Methodology

2.1. Search strategy

In early 2017, we searched PubMed and Web of Science for articles that contained the following terms: sit stand desk; standing desk; height adjustable desk; sit stand workstation; sit stand computer workstation, and office/computer work. We also searched previous systematic reviews and the Human Factors & Ergonomics Conference proceedings from 2007 to 2017 for additional papers. A second review of the literature was completed in December 2017 using the same terms and limiting the studies to only those published in 2017 to capture any additional articles published from January to December 2017.

2.2. Study selection

We selected quantitative studies that compared the use of SSDs for computer use to sitting-only computer workstations. The studies had to address the use of SSDs with adults, and not children or classroom use. The workstations could be evaluated in either lab or work settings, but participants had to have personal workstations. Studies had to be in English and contain sufficient information to complete extraction forms. We did not limit our studies to randomized clinical trial, but included cohort and cross-sectional studies as long as they compared sitting to standing. We excluded qualitative studies as well as studies that compared SSDs to active workstations, although if such a study compared SSDs to sit conditions they were included in the review with active workstation comparisons omitted. Systematic reviews, and theoretical and expert opinion case studies were omitted.

2.3. Data collection process

We developed data extraction sheets to capture essential information based on the aims of our scoping review. Extractions sheets consisted of six sections: (1) overall description of study results; (2) methodology; (3) sample characteristics; (4) interventions; (5) results; (6) creditability. The results section evaluated six outcome domain areas which were further broken down into sub-categories. The six domains were behavior, physiological, work performance, psychological, discomfort, and posture. Each of the outcomes were evaluated as either being measured through self-reports; instrumentation; and/or rating by an expert observer. Each study was reviewed independently by at least two authors.

Behavior domain category outcomes were defined as mean time of sitting, standing, transitioning from sit to stand, and active movements. The physiological domain had multiple categories: cardiovascular, endocrine-related, cognitive, fatigue, edema and obesity. Specifically, the cardiovascular outcomes were defined as improvements in metabolic equivalents (METs), rate of energy consumption, heart rate, and VO2 max. Endocrine-related measures were operationally defined as changes in endocrine-related functions such as glucose, cholesterol and other related derivatives. Cognitive outcomes were defined as changes in cognitive functions such as, attention, reaction time, and memory. Fatigue outcomes were defined as changes in mental or physical fatigue. Obesity was defined as changes related to BMI, waist circumference, and fat ratios. The work performance domain included two categories: absenteeism/presenteeism and productivity. In the psychological domain, the categories of outcomes consisted of general health, work satisfaction, self-efficacy/confidence, and mood. Musculoskeletal discomfort and pain were evaluated by the number of reported symptom occurrences for general areas of the body. For the posture domain, the studies were assessed by the number of changes in postures and workstation adjustments.

2.4. Statistics

Only results from the first follow-up visit one were included in this review. For completeness, results found in follow-up visits two or more are provided in the appendix, but no statistical analysis was performed as more than two visits were not included across all studies. Outcomes of interest for the first follow-up were counted. We then determined the number of these outcomes that were significant to determine the total and percent of outcomes that were significant for each separate domain and category. We used each study's results to develop overall descriptive statistics including mean, median, standard deviation, maximum, and minimum. We also determined the percentage of studies that found no significance in their results or that had all results significant.

Table 1
Characteristics of Studies included in Sit/Stand Scoping Review.

Author (year)	Study Design	Site	Sample (Baseline)	1st Follow-up Time Frame	Intervention & Control	Type of Desk	CP
Alkhajah et al. (2012)	Quasi-experimental	Work	Total: 33; Int: 18; Con: 15	1 wk#	Int: SSD, PEd, SubC Con: RD, NoT, SubC	Ergotron Work-Fit-S, Single LD Sit-Stand Workstation	30%
Bantoft et al. (2016)	RCT (Crossover)	Lab	Total: 45; Int: 45; Con: 45	< 1 day	Int: SSD*, NoT, ResC Con: RD, NoT, ResC	Not Reported	70%
Beers et al. (2008)	RCT (Crossover)	Lab	Total: 24; Int: 24; Con: 24	< 1 day	Int: Stand*, NoT, ResC Con: Sit, NoT, ResC	Not Reported	70%
Britten et al. (2016)	Quasi-experimental, (Crossover)	Lab	Total: 20; Int: 20; Con: 20	< 1 day	Int: Stand*, NoT, ResC Con: Sit, NoT, ResC	Not Reported	70%
Buckley et al. (2014)	Experimental (Single Group)	Field	Total: 10; Int: 10	1 wk	Int: SSD, NoT, ResC Con: RD, NoT, ResC	Ergontron Work-Fit D	60%
Burns et al. (2017)	RCT (Crossover)	Lab	Total: 22; Int: 22; Con: 22	< 1 day	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	Not Reported	80%
Carr et al. (2016)	Cohort	Work	Total: 69; SSD: 31; RD: 38	24 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	Knoll Dividend Horizon	58%
Chau et al. (2014)	RCT (Crossover)	Work	Total: 42; Int: 42; Con: 38	4 wks	Int: SSD, PEd, SubC Con: RD, NoT, SubC	Ergotron Work-Fit S	70%
Chau et al. (2016)	Quasi-experimental	Work	Total: 31; Int: 16; Con: 15	1 wk#	Int: SSD & email reminders, PEd, SubC Con: RD, NoT, SubC	Rumba "2 Stage" Sit-Stand Workstation	60%
Coenen et al. (2017)	RCT (Cluster Randomization)	Work	Total: 231; Int: 136; Con: 95	12 wks	Int: SSD & multicomponent strategies, PEd, SubC Con: RD w/no add-ons, NoT, SubC	Ergotron Work-Fit S	70%
Commissaris et al. (2014)	RCT (Crossover)	Lab	Total: 15; Int: 15; Con: 15	< 1 day	Int: SSD*, NoT, ResC Con: RD, NoT, ResC	Not Reported	80%
Cox et al. (2011)	RCT (Crossover)	Lab	Total: 31; Int: 31; Con: 31	< 1 day	Int: SSD*, NoT, ResC Con: RD, NoT, ResC	Not Reported	80%
Davis and Kotowski, (2014)	RCT (Crossover)	Work	Total: 37; Int 1: 37; Int 2: 37; Int 3: 37; Con: 37	4 wks	Int: SSD w/& w/o reminder software, NoT, SubC Con: RD w/& w/o reminder software, NoT, SubC	Not Reported	60%
Donath et al. (2015)	RCT (2 or more groups)	Work	Total: 38; Int: 19; Con: 19	12 wks	Int: SSD w/prompts, NoT, SubC Con: SSD w/o prompts, NoT, SubC	Office Plus Ergon	50%
Dutta et al. (2014)	RCT (Crossover)	Work	Total: 29; Int: 29; Con: 29	4 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	Ergotron Work-Fit (A, S, or D)	50%
Ebara et al. (2008)	RCT (Crossover)	Lab	Total: 24; Int: 24; Con: 24	< 1 day	Int: Sit/Stand*, NoT, ResC Con: Sit, NoT, ResC	NeX Desk	50%
Finch et al. (2017)	RCT (Crossover)	Lab	Total: 96; Int: 96; Con:	< 1 day	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	Not Reported	70%
Foley et al. (2016)	Experimental (Single Group)	Work	Total: 88; Int: 88	4 wks	Int: SSD & Activity Based Work, NoT, SubC Con: RD, NoT, SubC	Not Reported	50%
Gao et al. (2016a)	Cohort	Work	Total: 45; SSD: 24; RD: 21	24 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	ISKU	67%
Gao et al., (2016b)	Quasi-experimental	Work	Total: 24; SSD: 10; RD: 14	1 day	Int: SSD, NoT, SubC Con: RD, NoT, ResC	ISKU	60%
Gao et al. (2017)	RCT (Crossover)	Lab	Total: 18; Int: 18; Con:	< 1 day	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	ISKU	50%
Gibbs et al. (2017a)	RCT (Crossover)	Lab	Total: 26; Int: 25; Con:	1 day	Int: Sit/Stand, NoT, ResC Con: Sit, NoT, ResC	Float/Quickstand Humanscale	90%
Gibbs et al. (2017b)	RCT (Crossover)	Lab	Total: 18; Ints: 18; Con: 18	< 1 day	Int: Sit/Stand & Stand, NoT, ResC Con: Sit, NoT, ResC	Float/Quickstand Humanscale	90%
Gilson et al. (2017)	RCT (Crossover)	Lab	Total: 20; Int: 20; Con:	4 days	Int: Sit/Stand*, NoT, ResC Con: Sit, NoT, ResC	Varidesk Pro Plus 48	60%
Graves et al. (2015)	RCT (2 or more groups)	Work	Total: 47; Int: 26; Con: 21	4 wks#	Int: SSD, PEd, SubC Con: RD, NoT, SubC	Ergontron Work-Fit A	60%
Hadgraft et al. (2017)	Secondary data analysis	Work	Total: 231; Int: NR; Con: NR	12 wks#	Int: SSD & multicomponent strategies, PEd&AEd, SubC Con: RD, NoT, SubC	Not Reported	60%
Healy et al. (2016)	RCT (2 or more groups)	Work	Total: 231; Int: 136; Con: 95	12 wks#	Int: SSD & multicomponent strategies, PEd & AEd, SubC Con: RD, NoT, SubC	Ergotron Work-Fit S	60%
Healy et al. (2017)	RCT (2 or more groups)	Work	Total: 231; Int: 7; Con: 7	12 wks#	Int: SSD & multicomponent strategies, PEd&AEd, SubC Con: RD, NoT, SubC	Not Reported	80%
	RCT (2 or more groups)	Work	Total: 44; Int: 34; Con: 10	4 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	Not Reported	60%
Hedge et al. (2005)	RCT (Crossover)	Lab	Total: 18; Int: 18; Con: 18	< 1 day	Int: SSD w & w/o negative tilt keyboard, NoT, ResC Con: RD w & w/o negative tilt keyboard, NoT, ResC	Not Reported	20%

(continued on next page)

Table 1 (*continued*)

Author (year)	Study Design	Site	Sample (Baseline)	1st Follow-up Time Frame	Intervention & Control	Type of Desk	CP
Horswill et al. (2017)	Quasi-Experimental	Lab	Total: 16; Int: 16; Con: 16	< 1 day	Int: Stand*, NoT, ResC Con: Sit, NoT, ResC	Not Reported	60%
Husemann et al. (2009)	RCT (2 or more groups)	Lab	Total: 60; Int: 30; Con: 30	5 days	Int: Sit/Stand, NoT, ResC Con: Sit, NoT, ResC	Not Reported	70%
Kar and Hedge (2016)	RCT (Crossover)	Lab	Total: 12; Int: 12; Con: 12	< 1 day	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	Not Reported	40%
Karakolis et al. (2016)	RCT (Crossover)	Lab	Total: 24; Int 1: 24; Int 2: 24; Con: 24	< 1 day	Int: Sit/Stand & Stand, NoT, ResC Con: Sit, NoT, ResC	Teknion Xpres	40%
Le and Marras, (2016)	RCT (Crossover)	Lab	Total: 20; Int 1: 20; Int 2: 20; Con: 20	< 1 day	Int: Stand*, NoT, ResC Con: Sit, NoT, ResC	TIMOTION Technology	50%
Li et al. (2017)	RCT (2 or more groups)	Work	Total: 32; Int 1: 8; Int 2: 7; Int 3: 7; Con: 10	4 wks	Int: SSD w/3 different sit/stand protocols, PEd, ResC Con: RD, NoT, SubC	Varidesk Pro Plus 3 or Ergotron Work-Fit T or Strata Electric SSD & Workstation	60%
Lin et al. (2017)	Cross-sectional	Lab	Total: 20	< 1 day	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	Airtouch	67%
MacEwen et al. (2017)	RCT (2 or more groups)	Work	Total: 28; Int: 16; Con: 12	12 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	SC45	60%
Mansoubi et al. (2016)	Experimental (Single Group)	Work	Total: 40; Int: 40	1 wk#	Int: SSD, PEd, SubC Con: RD, NoT, SubC	Ergotron Work-Fit S	30%
Nerhood and Thompson (1994)	Cohort	Work	Total: NR; SSD: NR; RD: NR	36 wks	Int: SSD, PEd&AEd, SubC Con: RD, NoT, SubC	Not Reported	0%
Neuhaus et al. (2014b)	RCT (Cluster Randomization)	Field	Total: 44; Int 1: 16; Int 2: 14; Con: 14	12 wks	Int: SSD & multicomponent strategies, PEd&AEd, SubC Con: RD, NoT, SubC	Ergotron Work-Fit S	80%
Ognibene et al. (2016)	RCT (2 or more groups)	Field	Total: 46; Int: 25; Con: 21	12 wks	Int: SSD, Ped, SubC Con: RD, NoT, SubC	Ergotron Work-Fit A/Work-Fit S	80%
Paul (1995a)	Experimental (Single Group)	Lab	Total: 12; Int: 12	12 wks	Int: SSD, NoT, ResC Con: RD, NoT, SubC	Not Reported	50%
Paul (1995b)	Experimental (Single Group)	Work	Total: 6; Int: 6	6 wks	Int: SSD, NoT, ResC Con: RD, NoT, SubC	Not Reported	20%
Pronk et al. (2012)	Quasi-Experimental	Field	Total: 34; Int: 24; Con: 10	4 wks#	Int: SSD & multicomponent strategies, NoT, SubC Con: RD, NoT, SubC	Ergotron Work-Fit S/Work-Fit C	50%
Robertson et al. (2013)	RCT (2 or more groups)	Lab	Total: 22; Int: 11; Con: 11	3 wks	Int: SSD w/training & w/o training, PEd&AEd, SubC & ResC Con: RD, PEd, SubC & ResC	Not Reported	80%
Roemmich (2016)	RCT (Crossover)	Lab	Total: 13; Int 1: 13; Int 2: 13; Con: 13	1 wk#	Int: SSD, PEd, SubC Con: RD, NoT, SubC	Not Reported	40%
Russell et al. (2016)	RCT (Crossover)	Lab	Total: 36; Int: 36; Con: 36	5 days	Int: Stand, NoT, ResC Con: Sit, NoT, ResC	ACTIU mechanical elevation SSD, model MB212)	70%
Straker et al. (2013)	Cross-sectional	Field	Total: 131	1 day	Int: SSD, NoT, SubC Con: RD, NoT, SubC	Not Reported	92%
Thorp et al. (2014b)	RCT (Crossover)	Field	Total: 26; Int: 26; Con: 26	5 days	Int: Sit/Stand, NoT, ResC Con: Sit, NoT, ResC	Linak model 1600 × 800 mm	80%
Thorp et al. (2014a)	RCT (Crossover)	Lab	Total: 23; Int: 23; Con: 23	5 days	Int: Sit/Stand, PEd, SubC Con: Sit, NoT, ResC	Linak model 1600 × 800 mm	80%
Thorp et al. (2016)	RCT (Crossover)	Lab	Total: 23; Int: 23; Con: 23	5 days	Int: Sit/Stand, PEd, ResC Con: Sit, NoT, ResC	Linak model 1600 × 800 mm	70%
Tobin et al. (2016)	RCT (2 or more groups)	Field	Total: 52; Int: 26; Con: 26	5 wks	Int: SSD, NoT, SubC Con: RD, NoT, SubC	Ergotron Work-Fit	70%

CP – Credibility Percentage; RCT – Randomized Clinical Trial; # Study had additional follow-up periods (see appendix for details); SSD – Sit-Stand Desk; RD - Regular Desk; * additional arm, not discussed in this scoping review; Sit – study tested sitting to work, not specifically a desk; Stand – study tested standing at work, not specifically a desk; NoT – No Training, PEd – Passive Education; AEd – Active Education; SubC – Subjects controlled timing of sit/stand; ResC – Researcher controlled timing of sit/stand.

2.5. *Creditability*

During data extraction we evaluated each study for credibility of research methods using two different sets of "yes/no" criteria. Each study was assessed by one reviewer. Experimental designs were assessed using 10 questions and observational studies (cohort and cross sectional) using 12 (for exact questions see appendix). Criteria were based on those suggested by Jewell et al. (Jewell, 2018). The score of "yes" was only assigned if the article explicitly provided information on the criteria. The "yes" results were summed and a percent score was calculated (Table 1). A high credibility percentage indicates that the study used best practice research methodology with reduced risk for bias and increased trustworthiness of the results.

3. Results

3.1. *Study descriptions*

The literature search resulted in 911 articles of which 536 had relevant titles. We identified an additional 13 through a hand search of review articles for a total of 549 relevant titles. We removed 353 duplicates leaving 196 articles. After abstract review, 53 studies remained. Studies were removed for the following reasons: they were not related to a completed study (study protocol only); they were on children; they

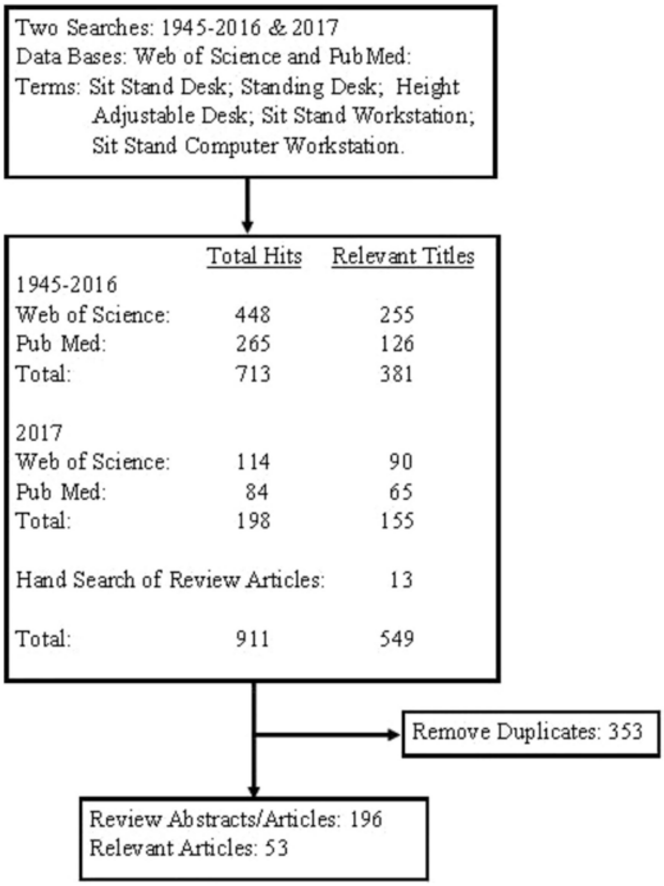

Fig. 1. Literature search input terms and results.

were qualitative; they did not address a computer workstation; SSDs were part of larger restructuring of the work environment, and the contribution of the desks could not be teased out; there was no sit only comparison group (Fig. 1).

Table 1 provides details of all studies. Overall, the majority of studies, 35 in total, were randomized controlled trials, 23 of which were crossover studies. The remaining studies were composed of seven quasi-experimental, five experimental, three cohort, two cross-sectional, and one secondary data analysis. Study data was recorded in a work setting, 21 studies, laboratory setting, 25 studies, and in the field, 7 studies. Studies tended to be small in size and short in duration. Sample sizes ranged from six to 231 participants. Twenty-six studies had less than 30 participants and 18 studies reported between 30 and 60 participants. Only eight studies recorded data from over 60 participants. Nine studies had more than one follow-up. Follow-up time frames were limited to one day or less in 19 studies and one month or less in an additional 13 studies. A 5–12 week time period was used in 13 studies. Only eight studies used a time period of greater than 12 weeks. The majority of studies recruited healthy working age adults for participation. One set of three studies included obese adults (Thorp et al., 2014a, 2014b, 2016). A variety of SSDs were used. Thirty-four studies focused on testing SSDs while the others were interested in comparing a sitting condition to a standing condition. Very few studies included training or multi-component interventions. Six studies included an active training component with some including health coaching. Seventeen studies involved passive education, involving brochures. Nine studies included additional components to their interventions such as email reminders. Sit-stand time and number of transitions was controlled by the participants in 26 of the studies.

Credibility scores ranged from 0% to 92% (Table 1). The majority of studies had moderate to excellent credibility: 23 percent of studies had scores greater than 80% suggesting excellent credibility while 62% had scores between 50 and 79%, suggesting moderate to good credibility. Of the studies with the highest credibility, slightly more than half were lab based studies. The study with a 0% in the credibility score (Nerhood and Thompson, 1994) was an early published abstract, and lacked sufficient detail to assign any of the credibility scores.

3.2. Overall outcome domains

Table 2 provides a breakdown of the results of the study by domain and sub category, and includes any results from multiple follow-ups. The most commonly reported domain was physiological, followed closely by behavioral, work performance, and discomfort. A limited number of studies included outcomes in the domains of psychological and posture (Fig. 2). The greatest number of significant results were in the behavior domain. Discomfort, physiological, and psychological reported moderate to mild significance. Minimal significance was noted in posture and work performance domains (Fig. 3).

3.3. Behavior

A total of 24 studies reported results related to the behavioral domain (Fig. 2). Almost all of these included sit time and stand time. Only eight studies included the number of transitions while 18 studies reported on changes in active movement (Fig. 4). These behavioral measures were primarily recorded using objective measurements such as accelerometer-based tools. Approximately one third of studies used self-reported measures of behavioral variables (Table 2). Overall, 61% of results for the behavioral domain were significant (Fig. 3). Twenty-nine percent of studies had no significant results, while 58% had all their outcomes significant. Significant reductions in sit time and increases in stand time were found in 76% and 89% of reported outcome measures, respectively. Significant changes in transitions were found in 54% of reported outcome measures. A significant change in active movements was found in only 30% of all reported outcome measures (Fig. 4). The majority of studies that included transitions or active movement found no significance in any of their outcome measures. When compared to the regular desk, the average amount of time people decreased their sitting time when using a SSD ranged from 0.1 to 3.6 h per day, the average amount of time they increased standing time ranged from 0.5 to 3.1 h, and the average amount of time they increased active movement ranged from 0 to 0.6 h (Table 2). The median average times for sit, stand, and active movement were 1.3, 1.4, and 0.1 respectively.

3.4. Physiological

A total of 28 studies had results related to the physiological domain (Fig. 2). For the sub-categories of physiological outcomes, 14 studies assessed cardiovascular outcomes, 8 endocrine-related, 9 fatigue, 7 cognitive, 4 obesity, and 1 edema (Table 2, Fig. 5). Physiological measures were primarily completed using instrumented measures and rater observations, except for fatigue outcomes which were measured by self-report (Table 2). Overall, 37% of all results were significant (Fig. 3). No significant results were found in 52% of studies while 24% had all outcomes significant. Of the categories, 61% of cardiovascular, 13% of endocrine-related, 63% of fatigue, 3% of cognitive, 0% of obesity and 100% of edema results were significant (Fig. 5). The edema results favored sitting, suggesting that foot and leg edema increased during standing.

3.5. Work performance

Twenty-three studies reported results related to the work performance domain (Fig. 2). Measures of productivity were included in 21 studies while only five studies included a measure of absenteeism/

Table 2
Measurement Type (in italics), number of outcome measured and number of significant results for each study in the Sit/Stand Scoping Review for the Domains of Behavior, Work Performance, Discomfort, Physiological, Psychological, and Posture at first follow-up.

Author (Year)	Behav	Work Perf	Discom	Physiol	Psychol	Post
Alkhajah et al. (2012)	*MT:IM* Sit: 1,1[c] (↓2.4 h)[Δ] Std: 1,1 (↑2.2 h) AMvt: 1,1 (↑0.1 h) Tran: 1,1	*MT:SR* Ab/P: 0,1 Prod: 0,1	*MT:SR* Dis: 0,10[d]	*MT:IM* End: 1,5[d] Ob: 0,5[d] *MT:SR* Ftg: 0,1[d]		
Bantoft et al. (2016)				*MT:RO* Cog: 0,9	*MT:SR* Mood: 0,2	
Beers et al. (2008)		*MT:IM* Prod: 0,3	*MT:SR* Dis: 1,1[a]	*MT:IM* CV: 3,3 *MT:SR* Ftg: 1,1[a]		
Britten et al. (2016)		*MT:IM* Prod: 0,3				
Buckley et al. (2014)				*MT:IM* CV: 1,2 End: 1,4		
Burns et al. (2017)				*MT:IM* CV: 0,4		
Carr et al. (2016)	*MT:IM* Sit: 1,1 (↓1.1 h) Std: 1,1 (↑1.0 h) AMvt: 0,2 (↑0.2 h) Tran: 0,1			*MT:IM* CV: 0,5 Ob: 0,6		
Chau et al. (2014)	*MT:IM;SR* Sit: 1,2 (↓1.1 h) Std: 2,2 (↑1.0 h) AMvt: 0,3 (↑0.1 h)					
Chau et al. (2016)	*MT:IM;SR* Sit: 0,2 (↓0.7 h) Std: 2,2 (↑1.3 h) AMvt: 0,4 (↑0 h)	*MT:RO* Ab/P: 0,2 Prod: 0,4		*MT:SR* Ftg: 0,1	*MT:SR* Mood: 0,1	
Coenen et al. (2017)	*MT:IM* Sit: 2,2 (–) Std: 2,2 (–)					
Commissaris et al. (2014)		*MT:IM* Prod: 1,5[a]		*MT:IM* Cog: 0,10		
Cox et al. (2011)				*MT:IM* CV: 10,16		
Davis and Kotowski (2014)	*MT:IM* Sit: 9,12 (↓1.2 h) Std: 4,6 (↑1.1 h) AMvt: 3,3 (–) Tran: 5,6	*MT:IM* Prod: 0,30	*MT:SR* Dis: 8,27			
Donath et al. (2015)	*MT:IM* Sit: 0,1 (↓0.1 h) Std: 0,1 (↑0.7 h)			*MT: IM* Cog: 0,1		
Dutta et al. (2014)	*MT:IM;SR* Sit: 2,2 (↓1.7 h) Std: 1,1 (–) AMvt: 1,1 (–)	*MT:SR* Ab/P: 0,3 Prod: 0,1		*MT:SR* Ftg: 0,1		
Ebara et al. (2008)		*MT:SR* Prod: 0,1	*MT:SR* Dis: 2,14[a]	*MT:SR* Ftg: 0,1		
Finch et al. (2017)		*MT:RO* Prod: 0,5	*MT:SR* Dis: 1,2[a]		*MT:SR* Mood: 3,15	
Foley et al. (2016)	*MT:IM;SR* Sit: 1,2 (↓1.1 h) Std: 1,1 (↑0.9 h) AMvt: 2,5 (↑0.2 h)	*MT:SR* Prod: 0,1	*MT:SR* Dis: 1,8			
Gao et al. (2016a)	*MT:SR* Sit: 1,2 (↓1.0 h) Std: 2,2 (↑0.5 h)	*MT:SR* Prod: 1,1	*MT:SR* Dis: 1,3			
Gao et al. (2016b)	*MT:SR* Sit: 2,2 (↓1.7 h) Std: 2,2 (↑1.5 h)	*MT:SR* Prod: 0,1	*MT:SR* Dis: 1,3			
Gao et al. (2017)				*MT:IM* CV: 11,11 End: 2,12 Ftg: 3,4		
Gibbs et al. (2017a)	*MT:IM* Sit: 1,1 (↓3.6 h) Std: 1,1 (↑3.1 h) AMvt: 0,3 (↑0 h)			*MT:IM* CV: 3,7		
Gibbs et al. (2017b)						

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Table 2 (*continued*)

Author (Year)	Behav	Work Perf	Discom	Physiol	Psychol	Post
		MT:RO Prod: 0,2	*MT:SR* Dis: 0,1	*MT:RO* CV: 6,6 *MT:SR* Ftg: 0,1	*MT:SR* WSat: 0,1	
Gilson et al. (2017)				*MT:IM* End: 0,1 Cog: 0,1		
Graves et al. (2015)	*MT:SR* Sit: 1,1 (↓1.5 h) Std: 1,1 (↑1.4 h) AMvt: 0,1 (↑0.1 h)		*MT:SR* Dis: 0,3	*MT:IM* CV: 0,4 End: 1,3		
Hadgraft et al. (2017)					*MT:SR* SC/SE: 2,2	
Healy et al. (2016)	*MT:IM* Sit: 4,4 (↓1.7 h) Std: 2,2 (↑1.6 h) AMvt: 0,2 (↑0 h)					
Healy et al. (2017)[#]				*MT:IM* CV: 0,2 End: 0,9 Ob: 0,4		
	MT:SR Sit: 1,1 (↓1.3 h) Std: 1,1 (↑1.0 h)	*MT:SR* Prod: 1,1	*MT:SR* Dis: 16,28			
Hedge et al. (2005)	*MT:RO* AMvt: 2,8 (−)	*MT:RO* Prod: 0,2	*MT:SR* Dis: 2,4[a]			*MT:RO* Pos: 2,4[a]
Horswill et al. (2017)				*MT:IM* CV: 4,4 Cog: 1,1		
Husemann et al. (2009)		*MT:IM* Prod: 0,2			*MT:SR* Mood: 0,3	
Kar and Hedge (2016)		*MT:RO* Prod: 1,2	*MT:SR* Dis: 2,8[b]			
Karakolis et al. (2016)		*MT:IM* Prod: 0,4	*MT:SR* Dis: 22,24[b]			*MT:RO* Pos: 3,48
Le and Marras (2016)		*MT:IM* Prod: 0,5	*MT:SR* Dis: 2,2[a]			*MT:RO* Pos: 2,3
Li et al. (2017)	*MT:IM;SR* Sit: 3,3 (↓2.1 h) Std: 3,3 (↑1.7 h) AMvt: 0,9 (↑0.2 h) Tran: 0,1					
Lin et al. (2017)			*MT:SR* Dis: 2,3[b]			*MT:RO* Pos: 5,11[b]
MacEwen et al. (2017)	*MT:IM* Sit: 2,2 (↓2.6 h) Std: 2,2 (↑2.7 h) AMvt: 1,1 (−) Tran: 1,1			*MT:IM* CV: 0,3 End: 0,10 Ob: 0,5		
Mansoubi et al. (2016)	*MT:IM* Sit: 4,4 (↓0.8 h) Std: 2,2 (↑2.4 h) AMvt: 6,6 (↑0.6 h)					
Nerhood and Thompson (1994)		*MT:SR* Ab/P: 0,1	*MT:SR* Dis: 8,15			
Neuhaus et al. (2014b)	*MT:IM* Sit: 0,2 (↓0.6 h) Std: 0,1 (↑0.6 h) AMvt: 0,3 (↑0 h) Tran: 0,1	*MT:SR* Ab/P: 0,1	*MT:SR* Dis: 0,5			
Ognibene et al. (2016)			*MT:SR* Dis: 2,3		*MT:SR* WSat: 1,1	
Paul (1995a)					*MT:SR* WSat: 0,4 Mood: 4,5	
Paul (1995b)				*MT:IM* Edm: 1,1[a]		
Pronk et al. (2012)	*MT:SR* Sit: 1,1 (↓1.9 h) AMvt: 0,1 (↓0 h)		*MT:SR* Dis: 1,2	*MT:SR* Ftg: 1,1	*MT:SR* Mood: 5,6; SC/SE: 0,1	
Robertson et al. (2013)	*MT:RO* Std: 1,1 (−)	*MT:IM* Prod: 1,3	*MT:SR* Dis: 7,7			
Roemmich (2016)				*MT:IM* CV: 1,1	*MT:SR* Mood: 0,6	
Russell et al. (2016)						

(*continued on next page*)

Table 2 (*continued*)

Author (Year)	Behav	Work Perf	Discom	Physiol	Psychol	Post
				MT:IM Cog: 0,10		
Straker et al. (2013)	*MT:IM* Sit: 1,2 (↓0.4 h) AMvt: 1,1 (−) Tran: 0,1					
Thorp et al. (2014b)				*MT:IM* End: 1,3		
Thorp et al. (2014a)		*MT:SR* Prod: 1,2[a]	*MT:SR* Dis: 1,9	*MT:SR* Ftg: 5,5	*MT:SR* WSat: 0,1 Mood: 0,1	
Thorp et al. (2016)				*MT:IM* CV: 7,8		
Tobin et al. (2016)	*MT:IM* Sit: 1,1 (↓1.7 h) Std: 1,1 (1.6 h) AMvt: 0,2 (↑0 h) Tran: 0,1			*MT:SR* Cog: 0,2		

Behav - Behaviors; Work Perf – Work Performance; Discom – Discomfort; Physiol – Physiological; Psychol – Psychological; Post – Posture.
SR - Self Report; IM - Instrument Measure; RO – Rater Observation; FU – Follow-up; Std – Stand; Tran - Transitions between sit and stand; AMvt – Active Movement; Prod – Productivity; Ab/P – Absenteeism/Presenteeism; CV – Cardiovascular, End – Endocrine-related; Ftg – Fatigue; Cog – Cognitive; Ob – Obesity; Edm – Edema; SC/SE – Self-Confidence/Self-Efficacy; WSat – Work Satisfaction.
Δ - The numbers in parentheses are the number of hours difference between the sit desk and sit/stand desk for sitting, standing and active movement. The arrow indicates if the time for the sit/stand desk was lower or higher than the sit desk, a (−) indicates the number could not be calculated.

[a] favored sit position.
[b] mixed results.
[c] Follow-up information – the first number is the number of significant results, the second number is the number of outcome measures addressed in this category.
[d] Outcome not measured at Follow-up 1 only Follow-up 2.

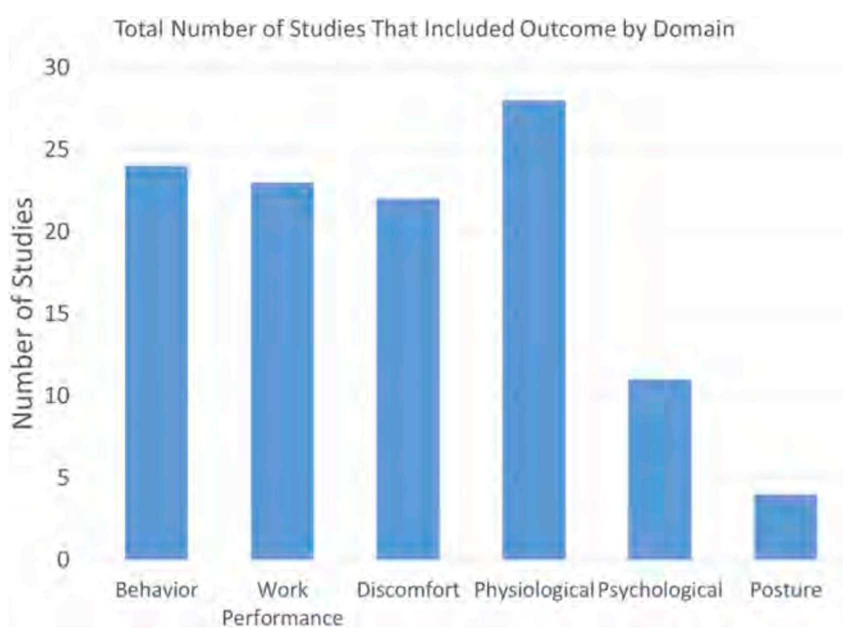

Fig. 2. Total number of studies that included outcome measures by domain.

presenteeism (Fig. 6). Work performance measures were primarily collected through self-report (Table 2). Only 7% of results reported in the work performance domain were significant (Fig. 3). Seventy-seven percent of studies had no significant results. There were no significant results for the absenteeism/presenteeism category, while only 8% of the productivity category outcomes were significant (Fig. 6). Interestingly, two studies, out of 21, reported that productivity results favored sitting not standing (Thorp et al., 2014a; Commissaris et al., 2014) (Table 2).

3.6. Psychological

Eleven studies reported results related to the psychological domain (Fig. 2). Work satisfaction, self-confidence/self-efficacy, and mood were included in four, two, and eight studies, respectively (Fig. 6, Table 2). Psychological outcomes were always measured using self-report (Table 2). Overall, 31% of results for the psychological domain were significant (Fig. 3). Significant improvements in work satisfaction were noted in 14% of these outcomes. Self-confidence/efficacy had the greatest number of significant results with 67% of outcomes significant in the two studies that included this measure. Mood was only significant in 31% of the studies (Fig. 6). The majority of studies that included psychological outcomes found no significance in any of their outcome measures.

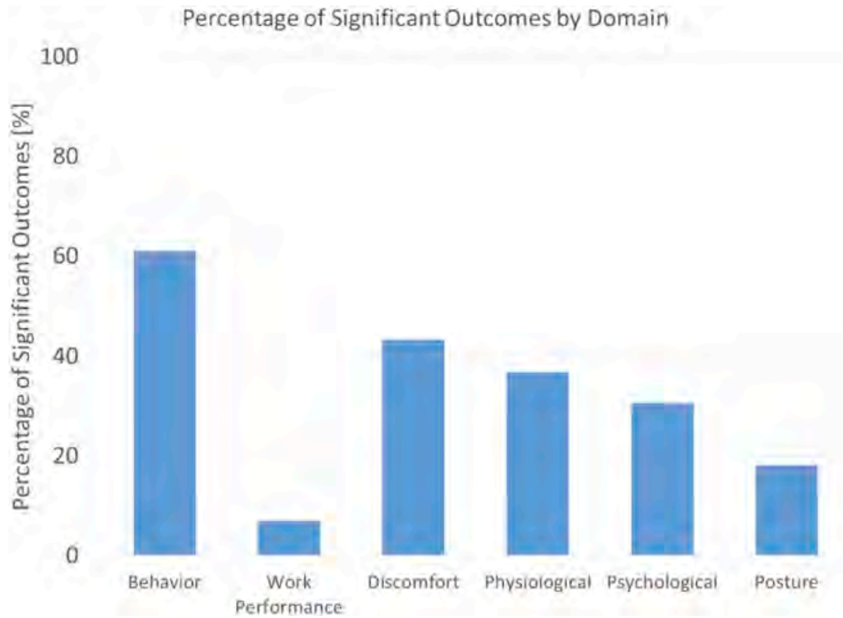

Fig. 3. Percentage of significant outcome measures across all studies by domain for follow-up one.

3.7. Discomfort

A total of 22 studies had results related to the discomfort domain (Fig. 2). Discomfort was always measured using self-report, either by individual body parts or by body sections (Table 2). Overall 43% of results were significant (Fig. 3). No significant results were found in 21% of studies while 13% had all outcomes significant. In five studies, the results favored sitting and in three the results were mixed where some outcomes favored sitting and some standing (Table 2).

3.8. Posture

Only four studies reported results related to the posture domain which were measures with both observed and objective measures (Fig. 2, Table 2). Even though only four studies reported on posture, a total of 66 outcome measures were found (Table 2). Unfortunately, as with many of the other outcomes, what was examined varied, ranging from full body positioning to body angles of the neck, back, shoulders, wrist or more. Of these, only 18% of results for the posture domain were significant (Fig. 2). The majority of studies that included posture outcomes showed limited significance in their outcome measures.

4. Discussion

Overall, this scoping review synthesized sit-stand workstation intervention studies, and related implementation strategies, to assess their effect on six primary outcome domains: behavior; physiological; work performance; discomfort; psychological; and posture. Fifty-three studies were included that recorded data from work, laboratory and field settings. Studies tended to be small in size and short in duration

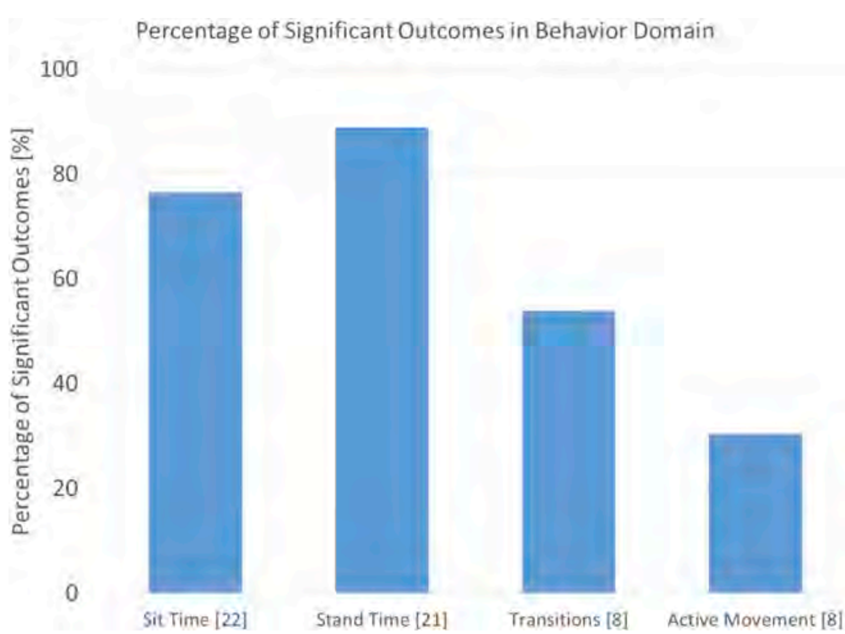

Fig. 4. Percentage of significant outcome measures by category in the behavior domain for follow-up one. Total number of studies that included outcome measures in each category is provided in square brackets.

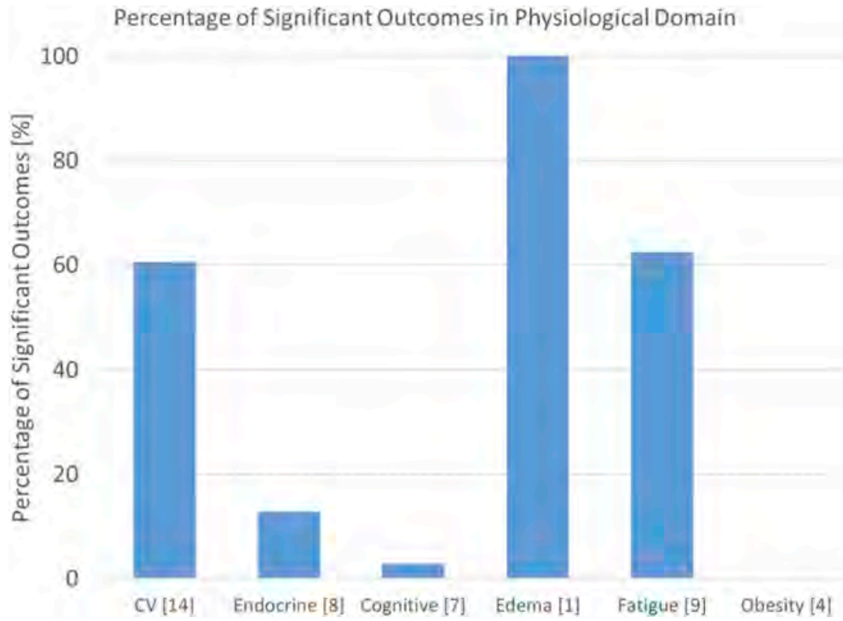

Fig. 5. Percentage of significant outcome measures by category in the physiological domain for follow-up one. Total number of studies that included outcome measures in each category is provided in square brackets. CV -Cardiovascular.

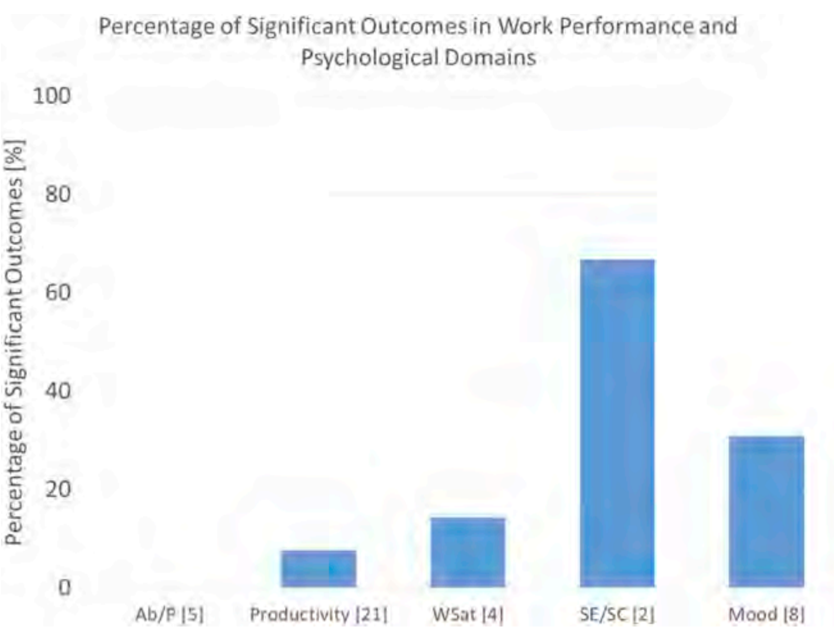

Fig. 6. Percentage of significant outcome measures by category in the work performance and psychological domains for follow-up one. Total number of studies that included outcome measures in each category is provided in square brackets. Ab/P – Absenteeism/Presenteeism and Productivity are categories in the work performance domain. WSat – Work Satisfaction, SE/SC – Self-Confidence/Self-Efficacy and Mood are categories in the psychological domain.

while collecting primarily from healthy, normal weight, younger, working adults.

4.1. Behavior

SSDs are frequently touted as improvements over sitting desks because they are thought to reduce sedentary behavior. When compared to the regular desk, the average amount of time people decreased their sitting time when using a SSD ranged from 0.1 to 3.6 h per day and the average amount of time they increased standing time ranged from 0.5 to 3.1 h with median average times for sit and stand of 1.3 and 1.4 h, respectively. Decreased sitting and, the flip side, increased standing, are viewed as measures of decreased sedentary time while on the job. Unfortunately, both fall below the MET cutoff for sedentary behavior (Tremblay et al., 2017). So, although SSDs decrease sitting and improve standing time, their use does not necessarily represent a decrease in sedentary behavior. In fact, our review finds that although greater than 75% of outcomes in those studies that examined sitting and standing behaviors improved for the better, only 30% of outcomes measured in the active movement categories were significant, and only 8 out of the 18 studies that examined active movement had any significant results. Active movement was typically defined across studies as an increased level of activity compared to sitting or standing, such as stepping or walking. The average amount of time people increased active movement ranged from 0 to 0.6 h with a median of 0.1 h. These results suggest that sit and stand time are not accurate surrogate measures for increases in physical activity behavior. It also demonstrates that SSDs are minimally efficient at increasing physical activity.

4.2. Physiological

Physiological outcomes were of great interest with 28 studies reporting in this domain. While there is strong evidence that SSDs decrease sitting time, sit and stand time are likely not accurate surrogate measures for health related benefits related to changes in physiological outcomes. Mild evidence exists to support cardiovascular improvements with SSD use. However, it is difficult to distinguish energy expenditure gained from alternating positions while using SSDs and energy expenditure related to standing. Several studies found no significant change in energy expenditure when using SSDs (Burns et al., 2017; Carr et al., 2016; Cox et al., 2011). Those that did, found minimal increases in energy expenditure ranging from 4.2 kcal/h to 10 kcal/h (Thorp et al., 2016; Beers et al., 2008; Gao et al., 2017; Gibbs et al., 2017b; Horswill et al., 2017). It is important to note that the greatest hourly change in energy expenditure was seen in an overweight and obese population (Thorp et al., 2016). Heart rate was commonly found to be higher, 7.5 bpm to 13.7 bpm, when using a SSDs (Beers et al., 2008; Cox et al., 2011; Gao et al., 2017; Gibbs et al., 2017b; Horswill et al., 2017). Changes in blood pressure and VO2 were equivocal as several studies found no change when using a SSD (Carr et al., 2016; Graves et al., 2015; Healy et al., 2017; MacEwen et al., 2017) while others found an improvement (Cox et al., 2011; Gao et al., 2017; Horswill et al., 2017). Thus, SSDs do not consistently improve cardiovascular biomarkers, and when improvements are documented, they are generally not clinically important.

SSDs also had limited effects on endocrine-related biomarkers. Eight studies included endocrine-related outcomes including glucose, triglycerides, insulin, or cholesterol. No significant change in endocrine-related outcomes was found in the majority of studies in healthy adults (Thorp et al., 2014b; Gao et al., 2017; Gilson et al., 2017; Graves et al., 2015; Healy et al., 2017; MacEwen et al., 2017). Interestingly, a beneficial change in glucose was noted in an obese population (Thorp et al., 2014b). In the four studies that examined the effects of SSDs on obesity, no significant changes were found in healthy adults (Alkhajah et al., 2012; Carr et al., 2016), overweight adults (Healy et al., 2017), or adults with abdominal obesity (MacEwen et al., 2017). These results support the limited clinical importance of the cardiovascular results found above for reducing weight.

SSDs had few effects on other physiological variables. Of the seven studies that included cognitive outcomes, only one study had a significant change in function, as measured by the Stroop word color test, and this study, admittedly, may have been biased by a strong learning effect (Horswill et al., 2017). SSDs are often cited as a way to improve energy and reduce fatigue at work. Of the nine studies that measured fatigue four found no change in energy level or sleepiness when using a SSD (Chau et al., 2016; Dutta et al., 2014; Ebara et al., 2008; Gibbs et al., 2017b). While two studies (Pronk et al., 2012; Thorp et al., 2014a), noted less fatigue during standing, two others reported increased self-reported tiredness and increased potential for leg muscle fatigue during standing (Beers et al., 2008; Gao et al., 2017). One possible explanation for these conflicting results is the differences in dosage across studies. Prolonged static postures, sitting or standing, can cause low-level muscle fatigue. Frequent alternating between postures, which occurs when using SSDs, may help reduce muscle fatigue and in turn decrease self-reported fatigue (Thorp et al., 2014a). Additional research is necessary to determine if effective sit-stand dosage can reduce worker fatigue. One study included a measure of edema and found that increased foot swelling was present during standing (Paul, 1995b). This result is not a new finding, as lower extremity swelling has been commonly noted during occupational standing (Cham and Redfern, 2001).

4.3. Work performance

One argument against SSDs is that standing may reduce the productivity of workers. Twenty-one of the studies included productivity outcomes, and only 8% found significant differences between sitting and standing or sitting and combination of sitting and standing. Four of the studies with significant differences in productivity reported that standing was superior to sitting (Gao et al., 2016a; Hedge and Ray, 2004; Kar and Hedge, 2016; Robertson et al., 2013) while two favored sitting (Thorp et al., 2014a; Commissaris et al., 2014). Additionally, others have found that standing did not reduce performance and resulted in improved mouse function (Sangachin et al., 2016). One weakness of the assessment of productivity was the statistical methods used to identify “no difference” in productivity levels. Many of the studies that examined productivity interpreted a non-significant result as indicating that workstation type did not affect performance. However, a non-significant result based on inferential testing cannot be used to interpret “no difference” between groups. To better assess the effect of SSDs on productivity, studies will need to use non-inferiority methodology (Walker and Nowacki, 2011).

4.4. Psychological

SSDs are perceived as potentially improving mood and work satisfaction though very few studies, 11 in total, included self-reported outcomes related to the psychological domain. Comparing these outcomes is challenging since all psychological surveys varied from study to study. Additionally, these outcomes were recorded in both lab and work environments with follow-up periods of 30 min to 12 weeks exposure. Even with these differences, the majority of studies that included psychological outcomes found no significant effect of using a SSDs. Ognibene et al. (2016) was the only study to note a significant changes in work satisfaction. It should be noted though, that this was an interaction effect of pain on ability to concentration in a population with low back pain. Mood was largely uninfluenced by SSDs with the exception of two studies in which improvements in mood states including happiness, stress, sluggishness, alertness, and energy were reported (Pronk et al., 2012; Paul, 1995b).

4.5. Discomfort

Standing significantly improved musculoskeletal discomfort in about half the measures. The body part that most often showed reductions in pain on standing was the low back, with eight (Thorp et al., 2014a; Nerhood and Thompson, 1994; Davis and Kotowski, 2014; Foley et al., 2016; Gao et al., 2016b; Hedge and Ray, 2004; Ognibene et al., 2016; Robertson et al., 2013) out of the 17 studies that directly measured low back pain (Pronk et al., 2012; Thorp et al., 2014a; Nerhood and Thompson, 1994; Alkhajah et al., 2012; Davis and Kotowski, 2014; Ebara et al., 2008; Foley et al., 2016; Gao et al., 2016a, 2016b; Graves et al., 2015; Hedge and Ray, 2004; Karakolis et al., 2016; Le and Marras, 2016; Lin et al., 2017; Neuhaus et al., 2014b; Ognibene et al., 2016; Robertson et al., 2013) reporting significant reductions. No other body part had as consistent reductions in discomfort among multiple studies. Several studies reported increases in pain with standing. These were most often in the lower extremities (Kar and Hedge, 2016; Le and Marras, 2016) and in the case of Lin (Lin et al., 2017), the users reported that they had double the discomfort in their low back after standing than while sitting. Ognibene et al. looked specifically on the effects of using SSDs on people with chronic low back pain (Ognibene et al., 2016). They reported that after 12 weeks those in the intervention were reporting significantly less back pain and significantly less impact of pain on daily activities. These results suggest that SSDs has some potential as an effective way to address low back pain. However, the best postures and dosage to promote reduced discomfort are unknown.

4.6. Posture

Standing as an intervention to improve pain requires proper standing posture to prevent additional discomfort including, but not limited to, neutral postures of the neck, back, and upper extremities.

Few studies looked at posture, a total of four. Unfortunately, as with many of the other outcomes, what was examined varied, resulting in limited information available to inform decisions about SSD postures. One study reported that working in a sit-stand paradigm was found to be associated with reduced lumbar flexion during sitting compared to sitting alone. This would imply that SSDs could potentially reduce pain or injury risk in the low back (Karakolis et al., 2016). A recent study also found increased upper body posture variability during SSD use compared to sitting (Barbieri et al., 2019). It is possible that alternating position improves musculoskeletal health and posture. However, additional research is necessary to further investigate these limited results as it was also found that extended standing time with a SSD eventually decreased posture variability (Barbieri et al., 2019). Interestingly, not all significant results favored SSDs or standing. More neutral wrist angles, a crucial factor in preventing the development of occupational injuries like carpal tunnel syndrome, were reported during sitting compared to standing with SSDs (Hedge and Ray, 2004; Lin et al., 2017). Therefore, SSDs exhibit a potentially beneficial response, in reduced lumbar flexion, and negative responses, in excess wrist extension, that could potentially prevent or cause musculoskeletal pain or injury. Many of the studies that did examine posture examined body parts in isolation, back posture or wrist postures, rather than overall postures during SSD use. The lack of research into posture, only 4 studies, and conflicting pain, discomfort, or injury potential, indicates that additional research is needed to develop better guidelines on proper SSD ergonomics including desk setup and posture.

4.7. Limitations

This review had several limitations that are worth noting. Demographics of the populations in the reviewed studies were difficult to summarize. Unfortunately the majority of studies reviewed did not accurately report demographics of their populations or only included recruitment parameters. Follow-up one time frames ranged from one day to one year. The strength of previously reported outcome measures likely critically depends on the parameters of a SSDs intervention, including length of use, follow-up time frame, dosage, compliance, and training. Follow-up and intervention characteristics varied greatly across the literature, which should be considered and corrected in future work. Studies examined the impact of SSDs using different protocols which resulted in comparisons of sitting to standing or sitting to alternating sitting and standing. Few studies were concerned about this difference yet it may impact our understanding of the potential benefits of SSDs. The manner in which measures were collected also effects their strength and the quality of the studies reviewed. It is possible that better objective measures in future work may enhance the strength of outcomes in different domains. Several domains were included in this review in an attempt to represent total work health. Other aspects of lifestyle behaviors that were outside the scope of this review, such as leisure activity levels, may also be associated with occupational sitting behaviors and SSD use.

4.8. Future directions

The majority of studies in our scoping review used a small, healthy population with a short follow-up time period. While behaviors were changed in these short term follow-ups, compliance and health benefits over a longer time period are largely unknown. Few studies discussed the importance of training as part of the introduction of the new workstations, although research indicates that training is a key aspect of changing behaviors (Verbeek, 1991). Compliance of use is usually minimal if training and reminders are not provided to encourage user's to knowledgeably exert control over their workstations (Wilks et al., 2006; Robertson et al., 2013). Identifying best training methods to incorporate SSDs may be a key aspect for improving health benefits, as it can address dosage and correct positioning. Typically, an ergonomic intervention consists of a new piece of equipment, tool or workstation to support and encourage new working postures along with providing training on how to use the new device and why it is important to adopt these new working postures to reduce discomfort and improve performance. Other traditional ergonomic interventions that have been shown to improve comfort or reduce injury risks, such as anti-fatigue mats, foot rests, and wrist supports, were absent from the current examination of SSDs.

This review extracted information to examine the impact of SSDs on total worker health. While current research suggests that only some domains benefit from SSD use, it is important in future research to continue to consider all aspects of worker health. Limited research has been done in the posture and psychological domains, and few results were found. We must include these measures in future studies as they are associated with other aspects of worker health such as discomfort or workplace behaviors. A better understanding in these areas may help explain SSD usage and behaviors. While many aspects of worker health have been explored in relation to SSDs, the use of SSDs in special populations, such as middle-aged, obese, pain, or gender-specific populations is largely unexplored. SSDs likely effect these populations differently which should be considered in future work as well.

Standing may be a potentially sedentary behavior, so it is necessary to evaluate the effect that adding standing to a computer task has on the actual health outcomes of interest. In general, prolonged static postures, including both sitting and standing, are associated with poor health and increased injury risk and discomfort. SSDs benefits may lie in their ability to encourage alteration of postures and reductions in time spent in any one static posture. However, the optimal sit to stand dosage is unknown and likely varies across populations and occupations. Half the studies in this scoping review had the amount of standing to sitting time controlled by the researcher, and, except for those completed by Li (Li et al., 2017) and Paul (1995a) these were all laboratory based studies. Thus, dosing was almost always self-selected at work. In general, studies that reported amounts of time in sitting and standing when using SSDs found a wide range of time: from 1 h of standing per day (Neuhaus et al., 2014b) to 5 h (MacEwen et al., 2017). Dosing in research controlled study was also very broad and ranged from 5 min (Burns et al., 2017) to 4 h (Buckley et al., 2014). Li et al. were the only group to test 3 different sit/stand protocols, with a 2:1, 1:1 and a 1:2 sit:stand hourly protocol tested over a 4-week period (Li et al., 2017). Recently, Bao and Lin tested different sit stand schedules (Bao and Lin, 2018). In both studies workers reported that they preferred different schedules or an unstructured approach to determine sitting and standing durations (Li et al., 2017; Bao and Lin, 2018). Additional research is needed to assess the benefits of alternating posture using SSDs, what those postures should be, and incorporating the proper knowledgeable dosage for both sitting and standing. This research would benefit from longer follow-ups with better tracking of SSD usage.

5. Conclusion

The recent interest in SSDs has resulted in a surge in available literature on their potential benefits in the workplace. Obvious behavior changes were found across numerous publications, mostly of short intervention duration and small healthy populations, with decreased time spent sitting and increased time spent standing. Though additional research is necessary to determine the appropriate dosage of sitting and standing. Unfortunately, modest cardiometabolic health benefits were noted when using SSDs. Generally, SSDs did not reduce work performance or improve psychological health. SSDs were most effective at reducing discomfort. Additional research is necessary to determine the effect of SSDs on posture as this measure was not commonly included, and yet is important in long term worker health. Further research is needed to examine long-term effects, and to determine clinically appropriate dosage and workstation setup.

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Appendix

Appendix Table 1
Criteria for credibility review for experimental and non-experimental studies.

Experimental Criteria		
E1	Random Allocation	Groups were randomly allocated to treatment or no treatment
E2	Allocation Concealment	Allocation to group was concealed
E3	Groups Similar at Baseline	A comparison of group characteristics was made, and they were similar, or difference were controlled in analysis OR The reviewer compared the two groups and they seem similar in basic characteristics
E4	Outcome Assessor Blinded	Those completing assessment of outcome measures were blinded to group status
E5	Reliable Measures	Authors provide evidence of reliability OR the measures are instruments well known to be reliable (standard measures in the field)
E6	Competent Assessors	Assessors were trained and checked for accuracy periodically OR measures were instrumented
E7	Fidelity	Authors indicate that the intervention/control were checked periodically to see if protocols for treatment were being followed appropriately
E8	Appropriate Control Group	Control group matched hypothesis and ruled out plausible alternative explanations appropriate
E9	Attrition < 20%	Attrition rate was less than 20% for each group
E10	Intention to Treat Analysis	Authors indicate that people were analyzed in the groups to which they were assigned.
Non-experimental Criteria		
NE1	Response Rate > 75%	75% or greater of those approached took part in the study
NE2	More than 1 Group	Outcomes were tracked in more than 1 group to ensure a comparator
NE3	Groups Similar at Baseline	A comparison of group characteristics was made, and they were similar, or difference were controlled in analysis OR The reviewer compared the two groups and they seem similar in basic characteristics, OR If the groups were not similar the authors controlled for the difference
NE4	Variables Operationally Defined	Specification of variables for the study were provided
NE5	Outcome Assessors Blinded	Those completing assessment of outcome measures were blinded to group status
NE6	Reliable Measures	Authors provide evidence of reliability OR the measures are instruments well known to be reliable (standard measures in the field)
NE7	Competent Assessors	Assessors were trained and checked for accuracy periodically OR measures were instrumented
NE8	Standardized Data Collection	Data was collected using standardized forms and protocols
NE9	Intervention Preceded Outcome	Results clearly followed from the intervention (sufficient measurment time, baseline taken before intervention initiated)
NE10	Attrition < 20%	Attrition rate was less than 20% for each group
NE11	Confounding Accounted for	Authors discussed possible confounding and how they accounted for it
NE12	Intention to Treat Analysis	Authors indicate that people were analyzed in the groups that they were assigned to

Criteria was scored: 0 = No/not reported; 1 = Yes.

Appendix Table 2
Individual experimental study scores on each credibility item.

Study	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Total	Credibility %
Alkhajah et al. (2012)	0	0	0	1	0	0	0	1	1	0	3	30%
Bantoft et al. (2016)	1	0	1	0	1	0	1	1	1	1	7	70%
Beers et al. (2008)	0	0	1	0	1	1	1	1	1	1	7	70%

(continued on next page)

Appendix Table 2 (*continued*)

Study	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Total	Credibility %
Britten et al. (2016)	1	0	1	0	1	0	1	1	1	1	7	70%
Buckley et al. (2014)	0	0	1	0	1	1	1	0	1	1	6	60%
Burns et al. (2017)	1	0	1	0	1	1	1	1	1	1	8	80%
Chau (2014)	1	0	1	0	1	1	0	1	1	1	7	70%
Chau et al. (2016)	0	0	1	1	1	1	0	1	0	1	6	60%
Coenen et al. (2017)	1	0	1	0	1	1	0	1	1	1	7	70%
Commissaris et al. (2014)	1	0	1	0	1	1	1	1	1	1	8	80%
Cox et al. (2011)	1	0	1	0	1	1	1	1	1	1	8	80%
Davis (2014)	1	0	1	0	0	0	1	1	1	1	6	60%
Donath et al. (2015)	1	0	1	0	1	0	0	1	1	0	5	50%
Dutta et al. (2014)	1	0	1	0	1	0	0	1	1	0	5	50%
Ebara et al. (2008)	0	0	0	0	1	0	1	1	1	1	5	50%
Finch et al. (2017)	1	1	1	0	1	0	0	1	1	1	7	70%
Foley et al. (2016)	0	0	0	0	1	0	1	1	1	1	5	50%
Gao (2016b)	0	0	0	0	1	1	1	1	1	1	6	60%
Gao et al. (2017)	1	0	1	0	1	0	0	1	1	0	5	50%
Gibbs (2017a)	1	0	1	1	1	1	1	1	1	1	9	90%
Gibbs (2017b)	1	0	1	1	1	1	1	1	1	1	9	90%
Gilson et al. (2017)	1	0	1	0	1	1	1	1	0	0	6	60%
Graves et al. (2015)	1	0	1	0	1	0	0	1	1	1	6	60%
Hadgraft et al. (2017)	1	0	1	0	1	0	1	1	0	1	6	60%
Healy et al. (2016)	1	0	1	0	1	0	1	1	0	1	6	60%
Healy et al. (2017)	1	0	1	0	1	1	1	1	1	1	8	80%
Hedge (2004)	1	0	0	0	1	1	1	1	0	1	6	60%
Hedge et al. (2005)	1	0	0	0	1	0	0	0	0	0	2	20%
Horswill et al. (2017)	0	0	1	0	1	1	0	1	1	1	6	60%
Husemann et al. (2009)	1	0	1	0	1	0	1	1	1	1	7	70%
Kar (2016)	1	0	0	0	1	0	0	1	1	0	4	40%
Karakolis et al. (2016)	0	0	0	0	1	0	1	0	1	1	4	40%
Le (2016)	0	0	0	0	1	0	1	1	1	1	5	50%
Li et al. (2017)	1	0	1	0	1	0	0	1	1	1	6	60%
MacEwen et al. (2017)	1	0	1	1	1	0	0	1	1	0	6	60%
Mansoubi et al. (2016)	0	0	0	0	1	0	0	0	1	1	3	30%
Neuhaus (2014)	1	1	1	0	1	1	1	1	0	1	8	80%
Ognibene et al. (2016)	1	0	1	0	1	1	1	1	1	1	8	80%
Paul (1995a)	0	0	1	0	1	0	0	1	1	1	5	50%
Paul (1995b)	0	0	1	0	0	0	0	0	0	1	2	20%
Pronk et al. (2012)	0	0	0	0	1	1	1	1	0	1	5	50%
Robertson et al. (2013)	1	0	1	0	1	1	1	1	1	1	8	80%
Roemmich (2016)	1	0	0	0	1	0	0	1	0	1	4	40%
Russell et al. (2016)	1	0	1	0	1	0	1	1	1	1	7	70%
Thorp (2014a)	1	0	1	0	1	1	1	1	1	1	8	80%
Thorp (2014b)	1	0	1	0	1	1	1	1	1	1	8	80%
Thorp et al. (2016)	1	0	0	0	1	1	1	1	1	1	7	70%
Tobin (2016)	1	0	1	0	1	0	1	1	1	1	7	70%

E1 - Random Allocation; E2 - Allocation Concealment; E3 - Groups Similar at Baseline; E4 - Outcome Assessor Blinded; E5 - Reliable Measures; E6 - Competent Assessors; E7- Fidelity; E8 - Appropriate Control Group; E9 - Attrition < 20%; E10 - Intention to Treat Analysis.

Appendix Table 3
Individual non-experimental study scores on each credibility item.

Study	NE1	NE2	NE3	NE4	NE5	NE6	NE7	NE8	NE9	NE10	NE11	NE12	Total	Credibility %
Carr et al. (2016)	0	1	0	1	0	1	1	1	0	1	0	1	7	58%
Gao (2016a)	0	1	1	1	0	1	0	1	1	0	1	1	8	67%
Lin et al. (2017)	0	0	1	1	0	1	1	1	1	1	0	1	8	67%
Nerhood (1994)	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Straker et al. (2013)	1	1	1	1	0	1	1	1	1	1	1	1	11	92%

NE1 - Response Rate > 75%; NE2 - More than 1 Group; NE3 - Groups Similar at Baseline; NE4 - Variables Operationally Defined; NE5 - Outcome Assessors Blinded; NE6 - Reliable Measures; NE7 - Competent Assessors; NE8 - Standardized Data Collection; NE9 - Intervention Preceded Outcome.
NE10 - Attrition < 20%; NE11 - Confounding Accounted for; NE12 - Intention to Treat Analysis.

Appendix Table 4
Timing, number of follow-up visits, and results for studies that had multiple follow-up points

Author (year)	Follow-up Time Frame (s)	Behavior	Work Performance	Discomfort	Physiological	Psychological	Posture
Alkhajah et al. (2012)	FU 1: 1 wk; FU 2: 12 wks	Sit - FU 1: 1,1*; FU 2: 1,1 Std - FU 1: 1,1; FU 2: 1,1 Tran - FU 1: 1,1; FU 2: 1,1 AMvt - FU 1: 1,1; FU 2: 0,1	Ab/P - FU 1: 0,1; FU 2: 0,1 Prod - FU 1: 0,1; FU 2: 0,1	FU 2: 0,10[X]	End- FU 2: 1,5[X] Ftg - FU 2: 0,1[X] Ob - FU 2: 0,5[X]		
Chau et al. (2016)	FU 1: 1 wk; FU 2: 4 wks; FU 3: 19 wks	Sit - FU 1: 0,2; FU 2: 0,2; FU 3: 0,2 Std - FU 1: 2,2 AMvt - FU 1:0,4; FU 2: 0,4; FU 3: 0,4	Ab/P - FU 1: 0,2; FU 2: 0,2; FU 3: 0,2 Prod - FU 1: 0,4; FU 2: 0,4; FU 3: 0,4		Ftg - FU 1: 0,1; FU 2: 0,1; FU 3: 0,1	Mood - FU 1: 0,1; FU 2: 0,1; FU 3: 0,1	
Graves et al. (2015)	FU 1: 4 wks; FU 2: 8 wks	Sit - FU 1: 1,1 FU 2: 1,1 Std - FU 1: 1,1 FU 2: 1,1 AMvt - FU 1: 0,1 FU 2: 0,1		FU 2: 0,3[X]	CV - FU 2: 0,4[X] End - FU 2: 1,3[X]		
Hadgraft et al. (2017)	FU 1: 12 wks; FU 2: 52 wks					SC/SE - FU 1: 2,2; FU 2: 2,2	
Healy et al. (2016)	FU 1: 12 wks; FU 2: 52 wks	Sit - FU 1: 4,4 FU 2: 4,4 Std - FU 1: 2,2 FU 2: 2,2 AMvt - FU 1: 0,2 FU 2: 0,2					
Healy et al. (2017)	FU 1: 12 wks; FU 2: 52 wks				CV – FU 1: 0,2; FU 2: 0,2 End - FU 1: 0,9; FU 2: 2,9 Ob - FU 1: 0,4; FU 2: 0,4		
Mansoubi et al., 2016	FU 1: 1 wk; FU 2: 6 wks; FU 3: 12 wks	Sit - FU 1: 4,4; FU 2: 4,4; FU 3: 3,4 Std - FU 1: 2,2 AMvt - FU 1: 6,6					
Pronk et al. (2012)	FU 1: 4 wks; FU 2: 6 wks	Sit - FU 1: 1,1 AMvt - FU 1: 0,1		FU 1: 1,2	Ftg - FU 1: 1,1	Mood - FU 1: 5,6; FU 2: 2,6 SC/SE - FU 1: 0,1	
Roemmich (2016)	FU 1: 1 wk; FU 2: 24 wks; FU 3: 52 wks						

SR - Self Report; IM - Instrument Measure; RO – Rater Observation; FU – Follow-up; Std – Stand; Tran - Transitions between sit and stand; AMvt – Active Movement; Prod – Productivity; Ab/P – Absenteeism/Presenteeism; CV – Cardiovascular, End – Endocrine-related; Ftg – Fatigue; Cog – Cognitive; Ob – Obesity; Edm – Edema; SC/SE – Self-Confidence/Self-Efficacy; WSat – Work Satisfaction.
[$]favored sit position.
[&]mixed results.
*Follow-up information – the first number is the number of significant results, the second number is the number of outcome measures addressed in this category.
[X]Outcome not measured at Follow-up1 only Follow-up 2.

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