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Sedentariness, productivity, perception and long term health effects of sit-stand workstation at work: a literature review

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ABSTRACT

SEDENTARINESS, PRODUCTIVITY, PERCEPTION AND LONG TERM HEALTH EFFECTS OF SIT-STAND WORKSTATIONS AT WORK: A LITERATURE REVIEW

by
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Sedentary behavior has been increasingly identified as a contributor to poor health outcomes and sit-stand workstations (SSW) have been introduced in offices to potentially reduce these adverse effects. This thesis presents a review of literature on SSW as they relate to musculoskeletal complaints, sedentary behavior, users' perception after short- and long-term use, productivity and cardiometabolic markers. To be included in the review, studies were required to include the adult working population subject to a sit-stand workstation intervention with above outcome measures. The review indicates that on an average, SSW has decreased sitting time by about 85 minutes per eight hour work day which was mostly utilized in increasing standing time during the workday. Studies found potential reduction in neck and shoulder discomfort using SSW with no negative impact on productivity. Employer support and ergonomics training appear to have a positive impact on the reception and use of sit-stand workstations. User perception after long term use of SSW is mostly positive. Long term longitudinal studies have found some improvements in the biomarkers related to obesity and cardiovascular diseases of the SSW user group, however, not all test results are significant. It can be concluded from this literature survey, that use of SSW has a strong potential in improving office workers' health outcome with no adverse effects on productivity and musculoskeletal disorder.

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by
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SEDENTARINESS, PRODUCTIVITY, PERCEPTION AND LONG TERM HEALTH EFFECTS OF SIT-STAND WORKSTATION AT WORK: A LITERATURE REVIEW

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I dedicate this thesis to my family, in recognition of your support, love and continued reminders to believe in myself and strive for excellence.

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CHAPTER 1

INTRODUCTION

Sedentary behavior has been increasingly identified as a contributor to poor health outcomes (Bertrais et al., 2005; Patel et al., 2010) and musculoskeletal complaints (Norman et al., 2004). Pain and discomfort may occur when workers have static postures such as sitting for long periods of time (Konz & Johnson, 2007). As early as 1953 there has been interest in investigating sedentary work versus heavy work and the impact on workers (Morris & Heady, 1953). Their analysis of epidemiological studies indicated that coronary heart disease is more common in men who completed sedentary versus heavy work**.** Coronary heart disease was one of seven conditions identified to have greater mortality in workers who completed light versus heavy jobs. Sedentary work can be defined as work that is primarily completed in a seated posture for long periods.

Today many people have more sedentary lifestyles and jobs compared with those in the past (Hill et al., 2003). Technological advancement has had a global impact on occupational sedentariness which has increased steadily in the past five decades (Ng & Popkin, 2012). Adverse health effects, such as obesity, are at high proportions with a great influence from individual's environment which includes jobs that require less physical labor and increased time spent on sedentary activities (Hill et al., 2003). There has been increasing interest to determine whether sedentary work has a negative impact on workers' health. Researchers have found strong evidence of a correlation between increased sedentary behaviors and cardiovascular disease (Proper et al., 2012) and type II diabetes (Proper et al., 2012; van Uffelen et al., 2010; Wilmot et al., 2012).

Additional research has shown a likely causal relationship between increased sitting time and all-cause (premature) mortality (Proper et al., 2012; Patel et al., 2010; Biddle et al., 2016; Chau et al., 2013).

Patel et al.'s (2010) study investigated leisure time sitting, physical activity and their relationship to mortality. Participants had a baseline assessment and physical activity was assessed over a 14-year period. They found strong associations between sitting time and total mortality regardless of the participants' physical activity levels. Although the study did not obtain data on occupational sitting and participants were primarily retired, the increase in sitting time at work needs further investigation to determine if these results are applicable to the working population.

With increasing use of computers in the workplace, employees are sitting for longer periods of time and with fewer breaks (Pronk et al., 2012; Parry & Straker 2013). This coupled with the fact that sedentary work has a negative impact on health has prompted increased attention to the implementation of sit-stand workstations (SSW) in office settings. A sit-stand workstation is one that will enable a worker to perform job tasks from either a seated or standing position. The table can be raised or lowered to an appropriate height depending on the workers' posture.

Several literature reviews on the subject have been published (Karol & Robertson 2015; Agarwal et al. 2018; Shrestha 2018). The literature review from 1995 to 2013 was completed by Karol & Robertson (2015) to examine the association between sit-stand workstations and musculoskeletal and visual discomfort and productivity. Karol & Robertson (2015) included several outcomes but did not include long term health effects from SSW use. Several studies on long term effects of SSW have been published after the above surveys. Some literature surveys (Agarwal et al., 2018; Shrestha 2018) specifically looked at the effect on SSW on back pain and sedentariness.

The purpose of this research is to expand upon prior reviews completed and explore the impact of sit-stand workstations on sedentary employees. This thesis will review sit-stand workstations as they relate to subjective musculoskeletal complaints, sedentary behavior, users' perception after short- and long-term use, productivity and cardiometabolic markers such as blood pressure, cholesterol, and glucose levels.

CHAPTER 2

LITERATURE REVIEW

A literature search was conducted using Scopus and Science Direct data bases at NJIT's Van Houten Library. The following key words were used in the database search: occupational sitting, sit-stand, sedentary, musculoskeletal disorder, and office ergonomics. The reference lists of the articles found via Scopus and Science Direct were checked manually for additional relevant articles. To be included in the review, studies were required to include 1) adult working population, 2) sit-stand workstation intervention, 3) outcome measures of user perception, performance, cardio-metabolic biomarkers, sit-stand workstation usage, or other physiological measures. Altogether 23 studies were included in this review which met our inclusion criteria.

Among the literature, studies were conducted in workplaces that previously had sit-stand workstations or introduced them as a new intervention. A few laboratory studies were also included that measured productivity and discomfort from SSW use. In many of the field studies occupational physical activity (sitting, standing, walking, sit-to-stand transitions) were measured via an accelerometer (ActivePAL®.) This device, attached to a users' thigh, tracks physical activity over a few days or a whole week. It can measure sitting time, number of sit to stand transitions, walk time, distance etc. over an observation period. Participants responded to standardized questionnaires regarding job role, length they had a SSW, and how often it was used and in what position. They also provided their opinion regarding adaptability and ease of use, satisfaction with the desks, and perceived benefits or negative outcomes associated with use of a SSW. Studies that sought to explore SSW impact on biomarkers measured participants' blood pressure, and took saliva and blood samples to find cholesterol, glucose levels among other data points. The following sections provide details of the reviewed articles grouped under different outcomes of SSW use. At the end of each section, the results were synthesized to present the general level of development on the topic.

2.1 Sit-Stand Interventions and Sedentary Behavior

Researchers began exploring the use of sit-stand workstations to reduce potential effects of prolonged sitting at work. Sit-stand workstation research has indicated reduced sitting time can be achieved in office environments (Alkhajah et al. 2012; Healy et al. 2013; Neuhaus, et al. 2014; Graves et al. 2015; Carr et al. 2016; Tobin et al. 2016; Zhu et al. 2017; Renaud et al. 2018).

SSW were introduced to office-based university employees in Brisbane, Australia to assess short to medium length of use impact on sitting time and physical activity (Alkhajah et al., 2012). The intervention group n=18 received a SSW and were compared to a control group n=14 who did not receive any workspace modification. Participants were early to mid-30's, majority female (94.4% intervention, 85.7% comparison) with a normal BMI (22.6 intervention, 21.5 comparison). The group consisted of students (27.8% intervention, 7.1% comparison), general employees (44.4% intervention, 21.4% comparison), and academic employees (27.8% intervention, 71.4% comparison). 7-day assessments regarding physical activity in the form of sitting and standing time, steps taken and sit to stand transitions (via activPAL3) and BMI were completed at baseline, 1-week and 3-month follow-up. The intervention group saw a reduction in sitting time by 137 minutes ($p<.01$) and standing time increase by 130 minutes ($p<0.01$) per work day at 1 week which was sustained through re-evaluation at 3 months which sitting was reduced by 125 minutes ($p<0.01$) and standing increased by 124 minutes ($p<0.01$) per work day. Stepping time was increased by 6 minutes ($p<0.05$) but was not sustained at the 3-month follow-up. Similar results were seen with sit-to-stand transitions which were significant at one week but not continued through the third month. This study provides evidence that sit-stand workstations can reduce sitting and increase standing time in the workplace.

Many studies have focused on how the use of SSW can be encouraged whether by electronic reminders, ergonomic training or management advocacy. Interventions with reinforcement of active behaviors such as the stand up and move initiative with support from health coaches (Healy et al., 2013) achieved more than a 2-hour sitting reduction per work day. The 4-week intervention was based in Melbourne, Australia n=22 and consisted of an information session regarding being active at work, one on one sessions with a health coach with 3 follow up telephone calls and introduction of a SSW. The control group n=21 maintained their usual work activities. In comparison to the control group, the intervention group demonstrated a 125 minute per 8-hour workday ($p<0.01$) reduction in sitting time and 73-minute reduction in sitting longer than 30 minutes ($p<0.01$). Average standing time was increased by 127 minutes per 8-hour workday ($p<0.01$). Participants attributed the support from the employer to helping the SSW intervention have such an impact and positive reception.

Another study that explored the impact of reinforcement (Neuhaus et al., 2014) compared traditional desks n=14 to SSW n=14 to SSW plus reinforcement (SSW-R) n=16 over a 3-month period to determine sitting time and activity levels. The study approach was the same as those previously discussed with the use of activPAL3 to monitor physical activity, questionnaire to secure demographics, musculoskeletal symptoms, productivity etc. The SSW-R and SSW group both received the sit-stand desks and instruction for use from the occupational health and safety team. The SSW-R group received additional information regarding the baseline sitting behaviors, an information session and booklet, and biweekly emails reminding them to sit less and move more. Participants average age was 42 years old, 84% female and 55% managers/professional roles and 46% clerical/service/sales. At baseline the average sitting time was 77% of the 8-hour work day (SSW 373 minutes/8 hour day, SSW-R 366 minutes/8 hour day and comparison 365 minutes/8 hour day). When compared to the traditional SSW group the group with the multi-component approach saw more significant reduction in sitting time and increase in standing time. There was an 89 min/workday reduction ($p < 0.001$) in the SSW-R group when compared to the control group. There was a 33 min/workday reduction in SSW group compared to the control group, but the results were not significant ($p=.285$).

SSW intervention impact on sitting time was investigated (Graves et al., 2015) by introducing SSW to sedentary office employees. The study consisted of 47 office employees who were 79% female with an average age of 39 years old. The intervention n=26 received a SSW and the control n=21 continued work at their usual workstation. This was an 8-week intervention with assessments at baseline, 4 and 8 weeks. Assessments were conducted for 5 days and sedentary behavior during the workday was gathered via diary in 15-minute intervals when participants answered a question about their current activity: sitting, standing, walking or other. Reminder prompts were sent at the start of the day via text or email to encourage compliance. Sitting, standing and walking time was estimated by multiplying the frequency of recording by 15. The researchers substantiated this approach under the assumption that the users would be in that posture for the entire 15-minute period. The intervention saw a significant decrease in sitting time by 80 min/workday ($p<0.05$) and increased standing time by 73 min/workday ($p<0.05$). There wasn't a significant effect on walking time.

A study was conducted in a Mid-West company (~1000 employees) that began replacing sitting desks with fully adjustable, electronic lift, SSW in 2009 (Carr et al., 2016). The study recruited n=31 participants who worked with a SSW for at least six months. The control group n=38 used sit (S) only desks. The average duration of use of the current desk types were 1.8 and 6.4 years, respectively. The SSW group was composed of participants from administrative/clerical [31%], statistical/testing [13%], management [12%], marketing [10%], research [7%], accounting [7%]) with access to electric hoist SSW for an average of 1.8 years. Participants were middle-aged (average 44 years), overweight/obese (BMI 30.5 kg/m), and female (74%). ActivPAL3 was used to record sit time, stand time, number of transitions, walk time etc. for 5 days for the participants from each group. The results showed that SSW users sat 66 minutes fewer ($p<0.05$) and stood 60 minutes more ($p<0.01$) at work compared with employees provided with sitting desks. Median sitting time for SSW and S groups were 6.2 and 7.3 hours during work, respectively. Median standing time for SSW and S groups were 2.9 and 1.9 hours during work, respectively. The result supports the fact that providing employees access to sit–stand desks reduces sitting and increases standing time. Thus, SSW represent a potentially sustainable approach for reducing occupational sedentary behavior.

Tobin et al. (2016) examined the effect SSW had on office employees' sedentary behaviors in Perth, Australia. The study was conducted in two office settings, at a nongovernment entity and a university. There were 37 participants and the group was 86% female with an average age of 34 years old. At baseline, participants wore active-PAL for 5 days which measured sitting and standing time, steps taken and sit to stand transitions and logged their hours at work. The intervention group n=18 received SSW and an ergonomic assessment at the start of week 2. The control group n=19 continued use of their regular workstation. The groups were reassessed at week 5 and sitting time had been reduced by 99.8 min/workday ($p<0.01$) while standing time was increased by 99.4 min/workday ($p<0.01$). There weren't significant differences in sit-to-stand transitions, stepping time, or steps taken. The results from this study are consistent with others regarding the benefit of SSW in reducing sitting time and increasing standing time. The lack of effect on sit-to-stand transitions and steps are also consistent.

A longer study was conducted at Arizona State University after a re-design of existing workplaces of a university building (Zhu et al., 2017). The new offices received electric hoist SS work tables. Three treadmill workstations were also installed in the common area. This group of participants were named "stand and move" group. During the first week of relocation in the new offices, they received emails from their supervisor encouraging the use of SS desks. This group received weekly "e-newsletters" for 4 months discussing sedentary behavior, goal setting, overcoming common barriers, importance of social support, and maintaining progress. University staff and faculty within the same unit but in a geographically distinct workplace were recruited to serve as a comparison arm. The offices did not receive any change from the existing sitting desks and office environment. This group was named "Energize your workday" and received similarly formatted weekly e-newsletters to promote improved office ergonomics and increased energy on workdays. Newsletter topics included creating a healthy workstation, mindful posture, postural stretches and exercises, lifting and carrying techniques, desk ergonomics, desk stretches and exercises, back basics, and injury prevention strategies.

The intervention group included 24 participants, 4 full time faculty and 20 full time staff. The control group included 12 full time staff. Participants were predominantly white (83%), middle aged (39 years average), female (75%), and had completed 4-year college education (89%). Posture assessments were conducted at baseline - prior to installation of sit-stand workstations, after 4 months - post-test; (end of active intervention), and after 18 months (follow-up).

The participants wore activPAL3c for 7 consecutive days and kept a diary of work time and non-work time, and non-work days, during each measurement day. From these recordings total sitting, total standing, total light physical activity (LPA) time, total moderate-vigorous physical activity (MVPA) time, sit-to-stand transitions (total sit-to-stand/stepping transitions/h of sitting), and time accrued in prolonged sitting (sitting bouts$\geq$30 min sitting time) for 8 working hours, and 8 non-working hours were determined. LPA and MVPA was defined as walking with cadence of$<$100 steps/min or $>$100 steps per min. There was a loss of participants and data over the posttest and follow up period. At the 4-month posttest there was no loss of participants. At the 18-month follow up, 16 participants from SSW group and 9 participants of the control were available. In each stage some participant data were missing. For missing participants and other data loss due to measurement device problems, some data were lost. These missing data were imputed using maximum likelihood parameter estimation.

In this study, both the groups received ergonomics and motivational support that were intended to improve values of all outcome variables at posttest (4 months) and at follow up (18 months) from the initial values (at t=0 month). The mean improvements from the two groups were statistically compared with from 0 months to 4 months (short term) and 0 months to 18 months (long term), using baseline adjusted analysis of covariance. None of the variables improved statistically ($p<0.05$) for the SSW group compared to the control group in short term. During this period both the groups were receiving ergonomic and motivational guidance. At the follow up (after 18 month) significant decrease in seating time ($p<0.01$), significant increase in standing time ($p<0.05$) and significant decrease in prolonged seating ($p<0.01$) were obtained for SSW group as compared to the control group.

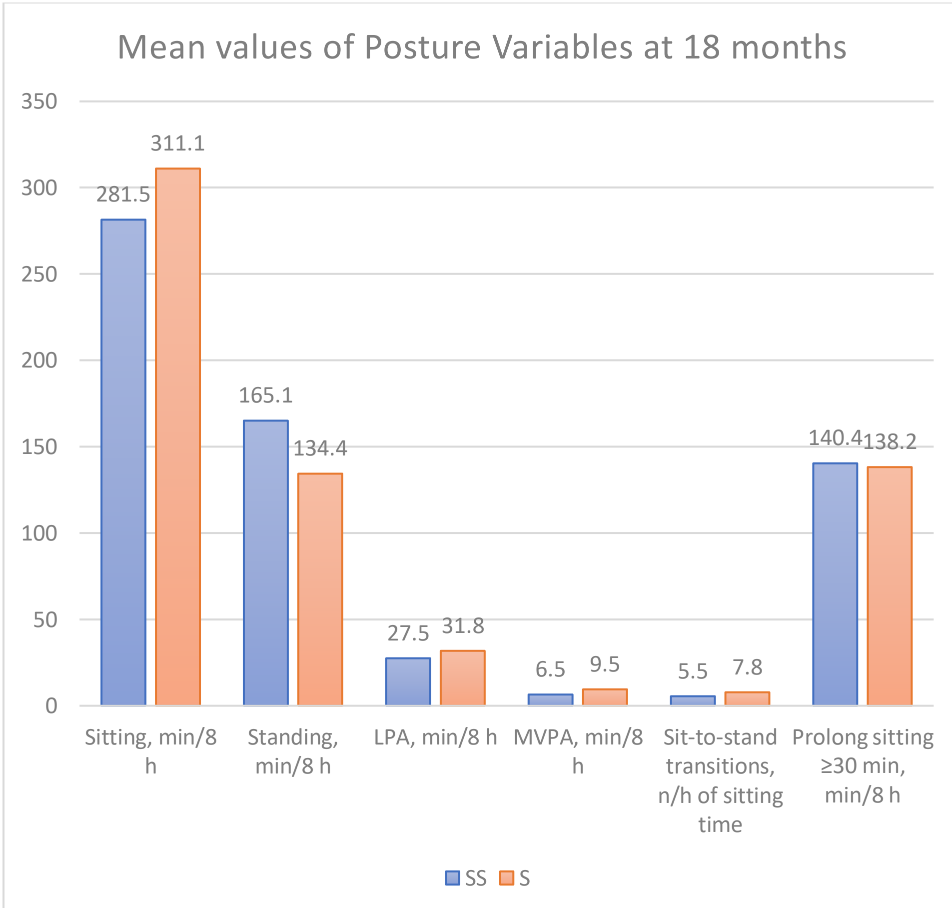

Figure 2.1 Postural Variable Outcomes for SSW and S Participants after 18 months

Source: Zhu et al., 2017

We compared the long-term postural outcomes (Figure 2.1) of SS workstation versus S workstation (Figure 2.1) from the reported average values in the article. The article did not report if these difference in means were significant. Nonetheless, average sitting time of SSW group was 30 min less compared to S group, and average standing time was 30 min more for the SSW group compared to S group, over 8 hour working period. In terms of percent of 8 working hours, the SSW group's average seating time was 59%, as opposed to 65% for S group. The corresponding values for standing time were 34% and 28%.

Based on these results, the authors concluded that SSW intervention had positive results over a long-term period in terms of postural variables.

This study examined long term use of SSW to determine user perception and how long/often the desks were used (Renaud et al., 2018). The employer had four worksites in three different European countries. The employer took measures to inform employees about proper use of the SSW and provided access to workstation ergonomic assessments. 1098 office employees were recruited and responded to surveys that addressed SSW use- how often and how long along with the users' feedback regarding the desks. Participants were middle-aged (average 46.5 years old), normal weight (24.6 kg/m) and majority male (64.6%). From the data, three types of users were assigned: non-users (less than once a month), monthly/weekly users (at least once a month to 3-4 times per week) and daily users (1+ times per day). Non-users were found to be older with higher BMI's and longer employment time. The study did not reveal reasons why non-users chose not to use the SSW. Daily and monthly/weekly users utilized the SSW for 15-30 minutes at a time 44.6% of the time. The main reasons for switching back to a seated position were related to physical discomfort or beginning a new task. Figure 2.2 are the data collected via survey. This study also found that daily users had significantly less sitting time (70%) when compared to monthly/weekly (80-90%) and non-users (90%).

OSPAQ, Occupational Sitting and Physical Activity Questionnaire; WSQ, Workforce Sitting Questionnaire. Occupational (bouts of) sitting, means of transportation to work, meeting guidelines for being physical active.

OUTCOME	Non-Users		Monthly/Weekly Users		Daily Users		Total	
OSPAQ, median (25-75 IQR)								
Sitting, percentage *	90	(85–92)	85	(80–90)	70	(60–80)	85	(75–90)
Sitting, hours/week *	36.0	(30.4–40.5)	35.2	(29.6–39.6)	30.0	(22.4–35.2)	34.0	(28–38.8)
Standing, percentage *	5	(1–5)	5	(5–10)	15	(10–30)	5	(5–12)
Standing, hours/week *	1.6	(0.4–2.5)	2.2	(1.6–4.0)	6.5	(4.0–12.6)	2.6	(1.5–5.6)
Walking, percentage *	5	(5–10)	5	(5–10)	10	(5–10)	5	(5–10)
Walking, hours/week *	2.3	(1.6–4.0)	2.2	(1.6–4.0)	3.2	(2.0–5.0)	2.5	(1.8–4.2)
WSQ, mean (SD) hours/day								
Sitting workday **	11.1	(2.1)	10.6	(2.0)	9.3	(2.4)	10.4	(2.3)
Sitting non-Workday ***	7.1	(3.2)	6.9	(3.3)	6.2	(2.7)	6.7	(3.1)
Time based at the desk on a typical work day, % (N)								
4 h or less per day	2.8	(10)	1.2	(5)	2.4	(8)	2.1	(23)
4–6 h per day	17.0	(60)	14.1	(58)	16.8	(56)	15.8	(174)
6–8 h per day	57.1	(201)	62.1	(256)	60.2	(201)	59.9	(658)
8 h or more per day	23.0	(81)	22.6	(93)	20.7	(69)	22.1	(243)
Longest period of uninterrupted time seated at the desk, % (N)								
less than 30 min	5.4	(19)	3.4	(14)	12.0	(40)	6.6	(73)
30–60 min	23.9	(84)	20.9	(86)	38.0	(127)	27.0	(297)
1–1.5 h	25.0	(88)	33.5	(138)	25.7	(86)	28.4	(312)
1.5–2 h	20.2	(71)	21.1	(87)	15.3	(51)	19.0	(209)
2 h or more	25.6	(90)	21.1	(87)	9.0	(30)	18.9	(207)
Means of transportation to go to work, % (N)								
By car	44.3	(156)	32.5	(134)	29.6	(99)	35.4	(389)
By public transportation	26.1	(92)	31.8	(131)	35.6	(119)	31.1	(342)
By bicycle	23.6	(83)	28.6	(118)	29.0	(97)	27.1	(298)
By foot	3.4	(12)	4.6	(19)	3.6	(12)	3.9	(43)
other	2.6	(9)	2.4	(10)	2.1	(7)	2.4	(26)
Being physically active for 30 min on at least 5 days per week, % (N)	29.5	(104)	30.4	(125)	34.7	(116)	31.4	(345)

* significant difference, chi square; ** significant difference between all user groups; *** significant difference between daily users and other two user groups. $p < 0.05$.

Figure 2.2 Occupational Sitting and Physical Activity Questionnaire, Workforce Sitting Questionnaire, Occupational Sitting, Means of Transportation to work, Physical Activity Guidelines

Source: Renaud et al., 2018

The results of this study support the evidence that sit-stand desks can reduce workplace sitting time.

Table 2.1 Summary of Study Characteristics, Results and Main Conclusions of the Reviewed Articles on Sedentary Behavior

Study	Participants	Length of Intervention	Dependent Variables & Outcome	Conclusion
Alkhajah et al. 2012	32 university office employees in Australia, 91% female, $\bar{x}$ 33 years old	1 week and 3 months	Sedentary behaviors: total sitting time (-125 min/day**), stepping time, standing time (+124 min/workday**), sit to stand transitions	SSW reduces sitting time at the workplace for up to three months after installation.
Healy et al. 2013	43 office employees in Australia, 56% female, $\bar{x}$ 43 years old	4 weeks	Sitting time (-125 min/workday**), prolonged sitting more than 30 min (-73 min/workday**), standing time (+127 min/workday**), sit-to-stand transitions, and movement (steps and energy expenditure)	2 hr. sitting reduction per 8 hr. workday.
Neuhaus, et al. 2014	44 university office employees in Australia, 84% female, $\bar{x}$ 43 years old	3 months	Sitting time (-89 min/workday for multi-component and -33 min/workday for SSW**)	Multi-component group saw more significant reduction in sitting time and increased standing time.
Graves et al. 2015	47 university office employees in UK, 79% female, $\bar{x}$ 39 years old	8 weeks	Sitting time (-80 min/workday*), standing time (+73 min/workday*), walking time.	SSW significantly reduced sitting time and increased standing time.

Carr et al. 2016	69 office employees in USA, 74% female, $\bar{x}$ 44 years old	5 months	Sitting time (-66 min/workday*), standing time(+60 min/workday**), sit to stand transitions, steps;	Participants with SSW sat less and stood more than their counterparts.
Tobin et al. 2016	37 office employees in Australia, 86% female, $\bar{x}$ 34 years old	5 weeks	Sedentary behaviors: Sitting time (-100 min/workday**), standing time(+100 min/workday**), sit-to-stand transitions, stepping time, steps taken;	Sitting time and standing time were significantly improved.
Zhu et al. 2017	36 university employees in USA, 75% female, $\bar{x}$ 39 years old	18 months	sitting time (-52 min/workday**), standing time (+17.7 min/workday**), productivity*,	Reduced sitting time and increased standing time.
Renaud et al. 2018	1098 office employees in 3 European countries, 65% male, $\bar{x}$ 47 years old	18 years	Sedentary behaviors: sitting time (daily users sat 108 min/workday less than non-users*), standing time, walking; frequency and length of standing.	SSW non-users sat more than the monthly/weekly and daily users. Over 30% of the participants used the SSW daily.

NOTE: ** statistically significant at $p<0.01$, * statistically significant at $P<0.05$

Table 2.1 is a results summary of all the studies discussed in this section. All research was conducted among office employees (Carr et al., 2016; Healy et al., 2013; Tobin et al., 2016; Renaud et al., 2018) with some study participants who worked in university office settings (Alkhajah et al., 2012; Graves et al., 2015, Neuhaus et al., 2014; Zhu et al., 2016). 50% of the studies were conducted in Australia (Alkhajah et al., 2012; Healy et al., 2013; Neuhaus et al., 2014; Tobin et al., 2016) with representation from Europe (Graves et al., 2015; Renaud et al., 2018) and the US (Carr et al., 2016). Most of the studies were short-term (Alkhajah et al., 2012; Carr et al., 2016; Graves et al., 2015; Healy et al., 2013; Neuhaus, et al., 2014; Tobin et al., 2016) and the length of intervention varied from 1 week (Alkhajah et al., 2012) to 5 months (Carr et al., 2016) with longer studies at 18 months (Zhu et al., 2016) and 18 years (Renaud et al., 2018). When comparing length of intervention from shortest to longest we see consistent reduction in sitting time when using a SSW. All studies had significant impact on sitting time and reduction varied from 52 minutes per workday, $p<0.01$ (Zhu et al., 2017) to 125 minutes per workday, $p<0.01$ (Alkhajah et al., 2012). Similar results were seen with standing time increase of 17.7 min per workday, $p<0.01$ (Zhu et al., 2017) to 127 min per workday, $p<0.01$ (Healy et al., 2013). Of the 8 studies included in the review 100% had a significant reduction in sitting time and 75% had a significant increase in standing time. On average, SSW decreased sitting time by about 85 minutes and increased standing time by about 84 minutes per eight hour work day. These results were sustained even with long term use up to 18 years. From the data we conclude sit-stand workstations have a significant impact on sitting and standing time in the workplace. These results can be sustained with long term SSW use.

2.2 Sit-Stand Interventions and Discomfort

An anticipated benefit of sit-stand workstations is a reduction in overall body discomfort due to the relief of fixed postures by transitioning between sitting and standing. Collaboration with employees to develop a worktable suitable to users' needs with comfort in mind (Karlqvist 1997) can be beneficial. This approach may promote adoption and sustained use of a sit-stand workstation. Study participants made final recommendations of a work table that can support the arms, allows transition from sitting to standing and prevents extreme outward rotation of the shoulder. This supports the thought that users enjoy being able to vary their postures throughout the workday.

Hedge & Ray (2004) conducted a study that was conducted with subjects at a technology and an insurance company to assess the effect of electric SSW's on user sedentary behaviors, musculoskeletal complaints and discomfort throughout the workday, productivity and user opinion of the desks. 56 participants were recruited, and complete data was collected from 33 participants. The intervention group at the insurance company n=10 received a SSW and the control n=10 continued work with their usual desk. All subjects received a baseline questionnaire regarding their work patterns and any experienced musculoskeletal complaints. One month later both groups were surveyed again with modified questions for the intervention group to gather information regarding their experience using the SSW. The study at the tech company had a cross over design but had the same outcome measures. All participants received the same baseline questionnaire as the insurance company and the intervention group n=20 received the electric SSW. The control n=16 worked at their usual workstation and one month later the control and intervention groups switched types of desks and continued the study for another month to allow all participants to experience use of the SSW. Participants were then surveyed with the modified questionnaire which included questions about their experience using the SSW. The data was merged and at the end of the study they had complete data for 33 participants. There was a small, significant decrease in frequency of discomfort in left eye*, right neck**, upper back**, lower back**, left thigh**, shoulders**, right elbow*, forearms**, wrists**, left hand** and right hand* (**$p<0.01$, *$p<0.05$). There was increased right upper arm pain which is may be due to use of the dominant arm in a new posture. Participants noted significantly lower discomfort ratings with the SSW mid-morning and from early afternoon through the end of the workday when compared with seated workstations. Conversely, two studies found increased musculoskeletal complaints when using SSW (Ebara et al., 2008) and when subjects stood longer than 90 minutes (Hasegawa et al., 2001).

Workplace intervention impact on call center employees' musculoskeletal discomfort and postural changes was investigated (Davis & Kotowski, 2014). Study participants n=37 were majority female (78%), full time (48%) call center employees. This was a 1-month study that assessed both SSW and traditional desks with and without reminder software. There was a 2-week adaptation period followed by a 2-week assessment. Every 30 minutes postural change reminders prompted the employee to stand and move or adjust the workstation. They received a discomfort survey at the end of each shift during the 2-week assessment period. This study demonstrated a significant reduction in musculoskeletal complaints by employees who received SSW with reminder software when compared to those with conventional workstations with and without reminder software and SSW without software. Symptoms were reduced between 22 and 46% for shoulders ($p<0.05$), lower back ($p<0.05$) and upper back ($p<0.01$).

Other studies with SSW intervention of varied length support these findings with noted significant decrease in upper back and neck (Husemann et al., 2009; Pronk et al., 2012) and back, neck, shoulder discomfort (Vink et al., 2009). Neuhaus et al. (2014) noted no significant changes in musculoskeletal symptoms. They did note insignificant increased shoulder pain in the multi-component group but decreased neck, knee, ankle and foot musculoskeletal complaints. The control group had increased hip, thigh, buttock, back and knee pain which were also insignificant. Participants in the study by Graves et al. (2018) rated their current discomfort in the lower back, upper back, neck and shoulders via questionnaire on a Likert scale at which 0 was no discomfort and 10 was extremely uncomfortable. There were no observed significant differences between the intervention and control groups.

Table 2.2 Summary of Study Characteristics, Results and Main Conclusions of the Reviewed Articles on Discomfort

Study	Participants	Length of Intervention	Dependent Variables & Outcome	Conclusion
Hasegawa et al. 2001	16 university students in lab setting in Japan, 100% male, 19-25 years old	60 or 90 minutes	Vision changes, fatigue	Change in posture was useful to reduce feelings of fatigue compared to sitting or standing for 60 minutes
Hedge & Ray 2004	56 office employees in USA, 57% male, $\bar{x}$ 38 years old	4-6 weeks	Discomfort: decreased left eye**, right hip**, right hand** and increased right upper arm**	SSW significantly reduced discomfort mid-morning and early afternoon to end of workday, including significant decrease in left eye, right hip, right hand and increased right upper arm pain
Ebara et al. 2008	24 subjects from university and staffing agency in lab setting in	1 day: 120-minute session for each condition with 40-minute interval breaks	Discomfort	SSW resulted in higher levels of discomfort in thighs, forearms and hands.

	Japan, 50% female, $\bar{x}$ 21 years old			
Husemann et al. 2009	60 university students in lab setting in Germany, 100% male, 18-35 years old $\bar{x}$ 25 years old	4 hours a day for 1 week	Physical well being	SSW had no impact on physical well being
Vink et al. 2009	10 office employees, 60% male, $\bar{x}$ 38 years old	2 weeks	Self-reported discomfort-overall**, upper back**, arms/hands, neck/shoulders**, and lower back**, hip/leg, ankle/feet	Participants had significant reduction of discomfort in back, neck and shoulder after using SSW and following ergonomic training
Pronk et al. 2012	34 office employees in USA, 88% female, $\bar{x}$ 41 years old	7 weeks (1 week baseline, 4 weeks intervention, 2 weeks post intervention)	Discomfort: upper back and neck pain reduced by 54% and fatigue**	Participants with SSW reported less pain in neck and shoulder regions
Davis & Kotowski 2014	37 call center employees, 78% female, $\bar{x}$ 36 years old	4 weeks	Discomfort: reduced in upper back and shoulders**	Reminder software regardless of the type of desk resulted in significant short-term reduction in shoulder, upper and lower back discomfort.
Neuhaus et al. 2014	44 office employees in Australia, 64% female, $\bar{x}$ 42 years old	3 months	Discomfort	Multi-component group had insignificantly increased shoulder and decreased neck, knees, ankles and feet pain

Graves et al. 2015	47 office employees in UK, 79% female, $\bar{x}$ 39 years old	8 weeks	Discomfort: lower back, upper back, neck, and shoulders	No significant impact on musculoskeletal complaints

NOTE: ** statistically significant at p<0.01, * statistically significant at P<0.05

Table 2.2 is a results summary of all the studies that had discomfort or musculoskeletal complaints as an outcome measure. Research was conducted among office employees (Graves et al., 2015; Hedge & Ray 2004; Neuhaus et al., 2014; Pronk et al., 2012; Vink et al., 2009) with one study in a call center setting (Davis & Kotowski 2014). A few studies were conducted among university students and/or staff in a lab setting (Hasegawa et al., 2001; Husemann et al., 2009) with additional recruiting from a staffing agency (Ebara et al., 2008) to vary the age of the participants. The location of the studies was varied and occurred in Japan (Ebara et al., 2008; Hasegawa et al., 2001), United States (Hedge & Ray 2004; Pronk et al., 2012), European Union (Graves et al., 2015; Husemann et al., 2009), and Australia (Neuhaus et al., 2014). Measurement of discomfort is subjective in nature and was obtained via questionnaire or survey in all the studies. Subjects rated the severity and frequency of musculoskeletal discomfort in specific body parts (Hedge & Ray 2004) and how that discomfort changed throughout the day when using SSW. Other studies assessed discomfort on a Likert scale of 0 (no discomfort) to 10 (extreme discomfort) (Davis & Kotowski 2014; Graves et al., 2015; Vink et al., 2009) or 0 (no complaints) to 4 (severe complaints) (Husemann et al., 2009). Some studies had participants rate their overall feeling of fatigue (Hasegawa et al., 2001) and tiredness in specific body parts (Ebara et al., 2008). The length of studies with significant results varied from 2 weeks (Vink et al., 2009), 4 weeks (Davis & Kotowski 2014), 6 weeks

(Hedge & Ray 2004) to 7 weeks (Pronk et al., 2012). Vink et al.'s (2009) participants had significant ($p<0.01$) reduction of discomfort in upper and lower back, neck and shoulder after using SSW and following ergonomic training. Davis & Kotowski (2014) concluded that use of software reminding users to get up and move regardless of the type of desk (S or SSW) resulted in significant ($p<.01$) reduction in shoulder and upper back discomfort. Hedge & Ray's (2004) study saw significantly reduced discomfort in participants' left eye, right hip, right hand specifically mid-morning and early afternoon to end of workday. They did note a significant increase in right upper arm pain. Other studies saw a reduction in overall feelings of fatigue ($p<0.01$) (Pronk et al., 2012). Positive data was still found in studies that did not have significant results. Hasegawa et al. (2001) noted change in posture was useful to reduce feelings of fatigue compared to sitting or standing. Subjects in Husemann et al. (2009) and Graves et al.'s (2015) studies had neither positive nor negative impact on musculoskeletal complaints. Ebara et al.'s (2008) results showed higher levels of discomfort in thighs, forearms and hands during SSW use. This study was conducted in a lab study with a short duration which may have had an impact since there wasn't a period to become accustomed to the desks. The multi-component group in Neuhaus et al.'s (2014) study had insignificantly increased shoulder and insignificantly decreased neck, knees, ankles and feet pain. Out of the nine studies reviewed those that found significant reduction of musculoskeletal discomfort were in hips, hands, upper and lower back, neck and shoulders and one had significant reduction in overall fatigue. Even with studies that had insignificant findings subjects had reduced fatigue and less discomfort in the neck/shoulders, knees, ankles and feet. There was insignificant increase in shoulder, thighs, forearms and hands. Two of the studies found no impact on subjects' well-being or discomfort. Many of the studies saw a positive impact on the users' discomfort but the average participant group size was 31 subjects and the longest intervention period was 3 months. Based on the data there is potential for SSW to reduce discomfort up to 3 months of use but long term longitudinal studies are needed to confirm the results we see in this review.

2.3 Sit-stand Interventions and Productivity

Workers and employers have expressed concern regarding the use of sit-stand desks and the effect they may have on worker productivity. Productivity can be subjective, and researchers have approached this assessment in different ways.

A review was completed specifically on the relationship between SSW, reduction of worker discomfort and effect on productivity (Karakolis and Callaghan, 2014). They located eight studies in which three (Dainoff, et al. 1999 and Hedge and Ray, 2004 showed increased productivity when comparing SSW to sit only. Ebara et al. (2008) indicated a small, insignificant trend of declined performance. Participants in the Hedge & Ray (2004) study completed baseline and post intervention questionnaires where the SSW users rated productivity higher (57.5%) when compared to the control group (20%) and an overall preference for the SSW 82.4% vs. 64.7% (control).

Call center employees in Sydney, Australia participated in a 5-month study (Chau et al., 2016) and it was determined that sit stand desks can reduce sitting time while still maintaining productivity in the workplace. The participant group was majority male (55%) with an average age of 33 years. The intervention group n=16 received SSW, brief training and daily reminders to stand up and move for 2 weeks post-installation. The comparison group n=15 performed work tasks at their regular workstations. Productivity was measured based on metrics set forth by the employer which included call handling time, hold time, talking time and presenteeism along with user subjective responses. Subjective productivity was assessed by asking users to respond to statements using a Likert scale where 1 was strongly disagree and 5 was strongly agree. The statements specific to productivity asked the user if they were able to sustain energy throughout the day, feel positive at work and whether there were obstacles impeding ability to complete job tasks. This data was gathered at baseline, weeks 4 and 19. There were no significant changes in the productivity outcome measures from baseline to the completion of the study. Both the intervention and control groups had positive views of energy and ability to complete work tasks. This study indicates SSW do not have impact on productivity whether negative or positive. Pronk et al. (2012) had subjective measures of productivity. In response to a questionnaire 66% of the intervention participants felt more productive with the SSW at the posttest survey.

SSW impact on physical and psychological complaints and data entry efficiency was investigated by Husemann et al. (2009). 60 male students were assigned randomly to either an intervention or control group to complete data entry for 4 hours on 5 consecutive days. Work parameters were assigned based on the type of desk. The SSW group completed the task sitting for 30 minutes, standing 15 minutes, 10 minutes other tasks and a 5 minute break. The control group completed data entry seated for 45 minutes, 10 minutes other tasks and a 5 minute break. A computer program was used to capture the data entry quantity and quality which was compared SSW to the control. There weren't any significant differences between the groups but they note a trend for a small, insignificant decrease in efficiency when standing.

Dutta et al. (2014) conducted a study of office workers n=28 to assess SSW effect on sedentary behavior with secondary outcomes which included productivity. The study involved a 4-week period of SSW use, a 2-week period where seated work was completed with no measurements taken, and then a 4-week control period where subjects completed their work regular seated positions. Participants received ergonomics assessments prior to SSW use and weekly email reminders reiterating the goal of replacing 50% of seated work time with standing. Physical activity was measured by accelerometer which was obtained on two randomly assigned days of the week which included weekends and self-reported questionnaire. Participants also responded to questionnaires to obtain information regarding productivity. In addition to a significant reduction in sitting time during work-hours (-21%, $p<0.05$) and the entire day (-14%, $p<0.05$), the subjects noted no impact (positive or negative) on their productivity. Dutta et al. (2015) later went on to conduct focus groups and individual interviews with the same subjects n=28 from the 2014 study where they reiterated they had no change in productivity when using the SSW.

Zhu et al. (2017) measured productivity and presenteeism using a standardized questionnaire. Participants were asked to recall their past working week and answer questions using a 5-point Likert scale. All items were summed to provide one score per participant ranging from 0 (high productivity) to 100 (low productivity). For presenteeism, participants were asked to recall the last month and rate their ability to accomplish tasks and focus despite health impairment using a 5-point Likert scale. All items were summed to provide one score per participant ranging from 6 (low presenteeism) to 30 (high presenteeism). All these measurements were performed at the beginning, after 4 months of intervention and after 18 months follow up. Posttest (after 4 months) interviews were conducted for the participants of the intervention group with questions asked were broadly about their experiences with the sit-stand workstations, walking workstations, and associated motivational content distributed.

Table 2.3 Summary of Study Characteristics, Results and Main Conclusions of the Reviewed Articles on Productivity

Study	**Participants**	**Length of Intervention**	**Dependent Variables & Outcome**	**Conclusion**
Hedge & Ray 2004	56 office employees in USA, 57% male, $\bar{x}$ 38 years old	4-6 weeks	Productivity**	SSW significantly increased subjective productivity
Ebara et al. 2008	24 subjects from university and staffing agency in lab setting in Japan, 50% female, $\bar{x}$ 21 years old	1 day:120-minute session for each condition with 40-minute interval breaks	Performance and sleepiness	There was a tendency for increased productivity while standing
Husemann et al. 2009	60 university students in lab setting in Germany, 100% male, 18-35 years old $\bar{x}$ 25 years old	4 hours a day for 1 week	Performance-data entry efficiency	Small, insignificant decrease in efficiency when standing
Pronk et al. 2012	34 office employees in USA, 88% female, $\bar{x}$ 41 years old	7 weeks (1-week baseline, 4 weeks intervention, 2 weeks post intervention)	Productivity	66% of the intervention participants felt more productive with SSW

Dutta et al. 2014	28 office employees in USA, 68% female, $\bar{x}$ 40 years old	4-week intervention, 2 rest, 4-week control	Productivity	Participants noted an increased sense of well-being and energy with no impact on productivity.
Chau et al. 2016	31 call center employees in Australia, 45% female, $\bar{x}$ 33 years old	5 months	Productivity	Participants with SSW stood more with no observed reduction in productivity
Zhu et al. 2017	36 university employees in USA, 75% female, $\bar{x}$ 39 years old	18 months	Productivity	There was no significant impact on productivity.

NOTE: ** statistically significant at $p<0.01$, * statistically significant at $P<0.05$

Table 2.3 is a results summary of all the studies that had productivity as an outcome measure. Previously discussed studies involving office employees in the US (Hedge & Ray 2004; Pronk et al., 2012) were reviewed in addition to another US study (Dutta et al., 2014). Studies conducted within a lab setting involving university students and staff (Ebara et al., 2008; Husemann et al., 2009; Zhu et al., 2017) were also included. A new study was identified (Chau et al., 2016) that took place in Australia with call center employees. Users had a SSW for 5 months which was long term when compared to Husemann et al.'s (2009) 1 week, Hedge & Ray's (2004) 6 weeks and Pronk et al.'s (2012) 7 weeks. Productivity is also subjective in nature and assessed via questionnaire (Chau et al., 2016; Dutta et al., 2014; Hedge & Ray 2004; Pronk et al., 2012; Zhu et al., 2017). Husemann et al. (2009) took another approach and used a computer program to capture the users' data entry quantity and quality and compared SSW to the control. They noted an insignificant decrease in efficiency when standing. The only study that had significant impact on productivity was Hedge and Ray (2004). Participants rated SSW productivity higher when compared to the control (57.5%) vs. 20%, $p<0.01$)and an overall preference for the SSW 82.4% vs. 64.7%. Out of the 7 studies reviewed, one study saw a significant increase in productivity, two had positive but insignificant increase in productivity, three had no impact on productivity and one had an insignificant decrease in productivity. The study that found a small decrease in productivity was a 1 week intervention conducted in a lab setting with university students completing data entry to simulate a work environment. Unfamiliarity with data entry and the short intervention period may have had an impact on the productivity as well. All the other studies had either a significant positive impact or no impact (neither positive nor negative) on productivity. Overall the data indicates SSW's have no impact on productivity whether negative or positive.

2.4 Sit-Stand Interventions and User Perception

Perceived benefits and use are topics of interest as it is important to obtain user feedback to determine if long term use is sustainable. One study examined employees' reasons for SSW utilization and compliance with the use of the desks (Wilks et al., 2006). Four companies had introduced either electric operated SSW (85%) or manually operated SSW (15%). Participants n=165 were majority female (66%) aged 36-50 years and many reported pain in the neck/shoulder or back (70% women, 54% men). 80% of the participants had the SSW for more than a year. 60% used the SSWS once a month or less and 20% used them daily. The top two reasons employees gave for lack of use were they did not bother to use it and the part of the table that could be raised was too small (Figure 2.3).

Reasons for a low degree of utilisation of the sit–stand function, men ($n = 33$) and women ($n = 65$)

Reasons for low utilisation (sit–stand alternation once a month or less)	Men ($n = 33$)	Women ($n = 65$)	Total ($n = 98$)
Do not bother to use the function	21 (64%)	41 (63%)	62 (63%)
Table surface too small when standing	6 (18%)	25 (38%)	31 (32%)
Get sufficient variation of posture and movement	9 (27%)	8 (12%)	17 (17%)
Other reason than alternatives in questionnaire	7 (21%)	10 (15%)	17 (17%)
Difficult to find acceptable working posture	6 (18%)	10 (15%)	16 (16%)
Get pain when standing and working	1 (3%)	4 (6%)	5 (5%)
Embarrassing to stand when others are sitting	2 (6%)	2 (3%)	4 (4%)
Vision not good when standing	1 (3%)	0 (0%)	1 (1%)

Figure 2.3 User Reasons for Low Sit-Stand Utilization
Source: Wilks et al., 2006

The researchers attributed the low compliance in that the introduction of the desks was part of a workplace reorganization versus employees seeking them out or receiving motivational reasons, such as health impact, to use the desks. Half of the participants received instruction from a physiotherapist, and they were more likely to utilize the SSW. Participants were not asked whether the change in posture lessened musculoskeletal pain.

Another study assessed the use and perception of the desks (Grunseit et al., 2013) by administering pre and post (3-month) intervention surveys. 58% of the office staff completed baseline surveys and 72% of those participants completed the follow up survey 3 months later. The median proportion of sitting time at baseline was 85% vs 60% at 3 months follow up. They determined that SSW can reduce sitting time which was also affected by users' anticipation of positive health benefits, use of external prompting and perceived productivity which can influence users to switch to SSW. There is evidence of improvement in self-reported mood (Pronk et al., 2012) and increased energy and alertness at work (Dutta et al., 2014).

Tobin et al. (2016) examined the effect SSW had on psychological stress, self-perceived physical and mental health, work ability and perceived benefits of alternating between sitting and standing. These measures were assessed at baseline and at week 5. Work ability had a specific questionnaire that asked the users' opinion regarding current ability to complete work compared to their lifetime best and in relation to the demands of the job. They answered questions about their physical and mental health which was rated on a 6-point Likert scale with 1 being very poor and 6 excellent. User perception regarding the benefits of alternating between sitting and standing was assessed by asking if they got any benefits regarding stress, comfort, productivity, focus, happiness, energy or health. There was no significant difference in self-reported physical or mental health. There was a small, significant decrease in self-reported current work ability ($p<0.01$). At week 5, 61% of intervention group felt more energized and 56% felt more comfortable in their workstation.

Prolonged workplace sitting was targeted during a 12-month trial in which employees n=136 received SSW, individual health coaching and organization support of desk usage (Dunstan et al., 2013). This study (Hadgraft et al., 2017) conducted interviews n=27 and focus groups n=7 with voluntary participants following that 12-month intervention. The participants were middle-aged (47 years) and majority women, 57% in the interview group and 86% in the focus groups. Questions posed to the participants addressed whether the SSW was used, overall impact on the participant, obstacles to reducing workplace sitting and user perception regarding impact on productivity and workplace culture. The participants noted that some of their job tasks were not suitable to completion while standing which was a barrier to use of the SSW. The authors concluded that support from management and other users helped facilitate a change toward consistent use of the SSW.

Another study regarding user perception was conducted at an Australian university where SSW current and past users were surveyed to investigate the adoption, sustainability or cessation of SSW use (Henderson et al., 2018). The participants were between the ages of 18 and 65 years old and consisted of staff and student researchers and administrators with varied tasks throughout the day. To participate in the study the user must have continuously used a SSW for at least 3 months (current user) or had previously used a SSW in their current role and decided to stop using it (ceased user). The study consisted of 24 participants (n= 16 current and n= 6 ceased) along with employees who oversaw implementation, ergonomics and safety related to the SSW introduction n=2. Current users had a median use length of 21 months while the ceased users median use length was 15 months. Participants were asked questions regarding their reasons for using the workstation, knowledge of ergonomics, usability and comfort of the SSW. The two employees were asked these same questions and additionally about policies/procedures, cost benefit analysis, SSW installation, and understanding occupational safety and health and musculoskeletal disorder risk. Both user groups' responses indicate that use of the desk was associated with the task type that was being completed. Many users utilized the SSW earlier in the day and when completing less complex tasks. Users noted dissatisfaction with loss of space when using the new desks. Participants who stood for 50% of their day noted they had to work up to these longer periods of standing. The study indicates that sustained use of SSW is possible if users adapt to the new workstation and adjust based on their needs such as standing when completing certain tasks or increasing length of standing over an introductory period. Providing education to the users on the SSW set up, use and benefits when introducing them into the workplace can support sustained use.

Renaud et al. (2018) had the longest intervention period at 18 years of SSW use. Participants were asked questions regarding positive and negative perceptions of the SSW with the non-user group used as a reference. When asked if standing can reduce the risk of developing chronic diseases 64% of the daily users agreed while monthly/weekly and non-users responded with 54.8% and 43.4% respectively. Whether standing can reduce the risk of musculoskeletal discomfort 83.8% of daily, 68.9% monthly/weekly, and 54.4% non-users agreed. Daily users were more likely to feel healthy (91%) and energetic (55.1%) versus monthly/weekly (76.5%, 31.3%) and non-users (50.6%, 11.4%). Non-users were more agreeable to the negative perception responses such as forgetting to use the standing option (79.9%), standing option causes physical discomfort (77.3%) and they exercise enough in leisure time so standing at work is not necessary (61.5%). Daily users were less in agreement although monthly/weekly users agreed that they forgot to use the standing option (88%).

Users were asked about interventions that would increase the use of the SSW. There weren't high responses for any of the interventions although each of the three groups agreed digital reminders and a health promotion training program may assist. The results indicate that even with a large population of users within a workplace supported by management and ergonomists use of the SSW is still dependent on a users' preference.

Table 2.4 Summary of Study Characteristics, Results and Main Conclusions of the Reviewed Articles on User Perception

Study	**Participants**	**Length of Intervention**	**Dependent Variables & Outcome**	**Conclusion**
Wilks et al. 2006	165 office employees, 66% female, Majority aged 36-50 years old	N/A	SSW use compliance	Participants show positive sentiment toward SSW but showed poor compliance
Pronk et al. 2012	34 office employees in USA, 88% female, $\bar{x}$ 41 years old	7 weeks (1-week baseline, 4 weeks intervention, 2 weeks post intervention)	Mood state: vigor**, anger, tension*, self-esteem, confusion*, depression*, and total mood disturbance**, fatigue**	Participants noted improved mood with use of SSW
Grunseit et al. 2013	18 office employees in Australia, 53% female, median 46 years old	3 months	Usability, acceptability	Anticipated health benefits, external prompting and perceived productivity can influence users to switch to SSW
Dutta et al. 2014	28 office employees in USA, 68% female, $\bar{x}$ 40 years old	4-week intervention, 2 rest, 4-week control	Psychological measures: relaxed**, energy*, fatigue*, appetite	Participants noted an increased sense of well-being and energy with no impact on productivity.
Tobin et al. 2016	37 university employees in Australia, 86% female, $\bar{x}$ 34 years old	5 weeks	Work ability**, self-reported mental and physical health outcomes	No significant difference in self-reported physical/mental health; significant decrease in self-reported current work ability (<0.01)
Hadgraft et al. 2017	28 office employees in Australia, 64% female,	1 year	Workplace culture and perceived health benefits	Job task was a barrier to use of the SSW. Management support helps

	$\bar{x}$ 47 years old			facilitate use of the SSW
Renaud et al. 2018	1098 office employees in 3 European countries, 65% male, $\bar{x}$ 47 years old	18 years	User perception and feedback to facilitate use	Daily users perceived the SSW as healthier and more appealing. Users recommended digital reminders, health promotion training and change in office environment to promote use.

NOTE: ** statistically significant at $p<0.01$, * statistically significant at $P<0.05$

Table 2.4 is a results summary of all the studies that had user perception as an outcome measure. User disposition toward SSW was assessed via questionnaire (Dutta et al., 2014; Pronk et al., 2012; Renaud et al. 2018; Tobin et al. 2016) and focus groups and interviews (Grunseit et al., 2013; Hadgraft et al. 2017). Some study participants in the US noted improved mood (Pronk et al., 2012, $p<0.01$) and sense of well-being and energy (Dutta et al., 2014, $p<0.05$). While others in Australia felt SSW's had no effect on physical and mental health but saw a significant decrease in current work ability (Tobin et al., 2016). Wilks et al.'s (2006) subjects reported liking the SSW but the usage was low. Renaud et al. (2018) office employees stated the job task being completed sometimes impeded use of the SSW. Of the 7 studies that had user perception as an outcome three had significant positive results regarding users' mood, fatigue/energy levels, and ability to complete work tasks. Subjects in three of the studies had positive views of the SSW and gave feedback on ways to improve use. Users recommended digital reminders, health promotion training and management support to help facilitate use of the SSW. One of the studies showed positive sentiment toward SSW's but subjects had poor compliance. The study length's varied from 5 weeks to 18 years and generally, the studies reviewed indicate positive user disposition toward SSW's.

2.5 Sit-Stand Interventions and Cardiometabolic Biomarkers

The perception that SSW may positively impact biomarkers related to obesity and cardiovascular disease is another factor that influences their use and introduction in occupational settings.

Alkhajah et al. (2012) investigated the relationship between excessive sitting and cardiovascular disease mortality by introducing SSW and assessing cardiometabolic outcomes. Fasting blood lipids and glucose were measured at baseline and at the 3-month follow-up. HDL cholesterol increased in the intervention group by an average of 0.26 mmol/L (p=0.003) but there were no significant differences in other measures. Healy et al. (2013) took a similar approach and completed assessments at baseline and 4 weeks to gather BMI, lipids, glucose and self-reported health outcomes. There was significant glucose improvement in the intervention group, but no significant changes were observed regarding other anthropometric and cardio-metabolic health outcomes. Graves et al. (2015) also explored this relationship in their study. Assessments were completed at baseline, weeks 4 and 8. Participants had their fasting blood drawn to test cholesterol, glucose and triglycerides. Vascular outcomes were measured via blood pressure, brachial artery and carotid artery intima media thickness ultrasound imaging to assess for early subclinical markers of structural atherosclerosis. There were no significant differences between the intervention and control related to vascular outcomes. There was a positive reduction in total cholesterol (-0.40 mmol/L, p,0.05). No significant effects on glucose levels or triglycerides were observed.

During the 5-month intervention study by Carr et al. (2016) cardio-metabolic health indicators (blood pressure, heart rate, fat mass, lean mass, body composition, waist circumference, and cardiorespiratory fitness) within the intervention and control groups were not different. These results indicate that providing access to sit-stand desks may not be enough to elicit improvements in the measured cardio-metabolic risk factors.

Zhu et al. (2017) had a much longer intervention period of 18 months. The posture and cardiometabolic assessments were conducted at baseline - prior to installation of sit-stand workstations, after 4 months - post-test; (end of active intervention), and after 18 months (follow-up). BMI and blood pressure were measured in laboratory, and blood samples were collected and cholesterol, HDL cholesterol, LDL cholesterol, triglyceride, fasting insulin, fasting glucose and C reactive protein was measured. Among the other variables, statistically significant positive improvement at 18 months in favor of SS workstations were found in total cholesterol ($p<0.01$), LDL cholesterol ($p<0.05$), C reactive protein ($p<0.01$) and productivity ($p<0.05$). However, for fasting insulin SSW group showed significant negative improvement ($p<0.05$) compared to S group at the follow up tests. Based on these results, the authors concluded that SSW intervention had positive results over a long-term period in terms of some cardio-metabolic variables.

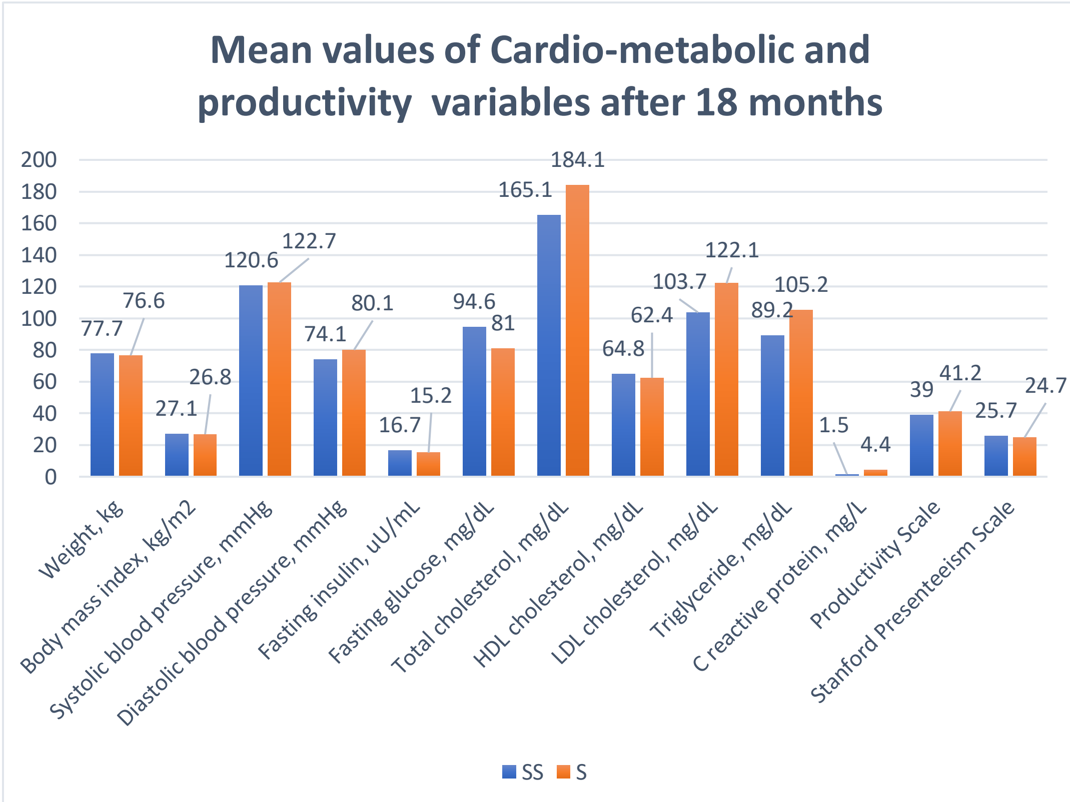

Figure 2.4 Cardio-metabolic and Productivity Variable Outcomes for SSW and S Participants after 18 months

Source: Zhu et al., 2017

Figure 2.4 compares the reported average cardio-metabolic and productivity outcomes (Figure 2.4) measured after 18 months. The SSW group had better outcomes than the S group for diastolic blood pressure (74.1, 80.1), total cholesterol (165.1, 184.1), HDL cholesterol (64.2, 62.4), LDL cholesterol (103.7, 122.1) and triglyceride (89.2, 105.2). The SSW group however, had worse outcomes in fasting glucose (94.6, 81) and fasting insulin (16.7, 15.2). Although there is some improvement in cardio-metabolic indicators for the

SSW group, the differences are small and are significant. In addition, there were only 13 and 7 participants in SSW and S group in the 18-month measurement.

Long term longitudinal studies have found some improvements in the biomarkers related to obesity and cardiovascular diseases of the SSW user group, however, not all test results are significant.

Table 2.5 Summary of Study Characteristics, Results and Main Conclusions of the Reviewed Articles on Cardio-Metabolic Biomarkers

Study	**Participants**	**Length of Intervention**	**Dependent Variables & Outcome**	**Conclusion**
Alkhajah et al. 2012	32 university employees in Australia, 91% female, $\bar{x}$ 33 years old	1 week and 3 months	Cardiometabolic biomarkers-BMI, fasting total cholesterol, HDL cholesterol**, triglycerides and glucose levels	Intervention saw increased HDL cholesterol by an average of 0.26 mmol/L. Other biomarkers were not significantly affected
Healy et al. 2013	43 office employees in Australia, 56% female, $\bar{x}$ 43 years old	4 weeks	Cardiometabolic biomarkers: BMI, blood pressure, fasting glucose*, cholesterol, and triglycerides	Significant glucose improvement in intervention group, other biomarkers were not significantly affected
Graves et al. 2015	47 office employees in UK, 79% female, $\bar{x}$ 39 years old	8 weeks	Cardiometabolic biomarkers: blood pressure, fasting total cholesterol (-0.40 mmol/L*) and glucose levels	Positive reduction in total cholesterol observed.
Carr et al. 2016	69 office employees in USA, 74% female, $\bar{x}$ 44 years old	5 months	Cardiometabolic biomarkers-resting heart rate, blood pressure, BMI, estimated peak VO2	There was no observed correlation between sitting/standing time and cardiometabolic markers

Zhu et al. 2017	36 university employees in USA, 75% female, $\bar{x}$ 39 years old	18 months	Cardiometabolic biomarkers: total cholesterol** LDL cholesterol* C reactive protein**, and fasting insulin	Significant effects were noted related to total cholesterol, LDL cholesterol, and C reactive protein.

NOTE: ** statistically significant at $p<0.01$, * statistically significant at $P<0.05$

Table 2.5 is a results summary of all the studies that had cardio-metabolic markers as an outcome measure. Studies with known origin were conducted in Australia (Alkhajah et al., 2012; Healy et al., 2013), UK (Graves et al., 2015) and US (Carr et al., 2016; Zhu et al., 2017). Study length varied from 3 months (Alkhajah et al., 2012) to 18 months (Zhu et al., 2017) with an average participant pool of 45 subjects. The cardio-metabolic markers that were measured were BMI (Alkhajah et al., 2012; Carr et al., 2016; Healy et al., 2013), cholesterol (Alkhajah et al., 2012; Graves et al., 2015; Healy et al., 2013; Zhu et al., 2017), Triglycerides (Alkhajah et al., 2012; Healy et al., 2013), Glucose (Alkhajah et al., 2012; Graves et al., 2015; Healy et al., 2013; Zhu et al., 2017) and blood pressure (Carr et al. 2016; Graves et al., 2015; Healy et al., 2013). Carr et al. (2016) obtained participants' resting heart rate and estimated peak VO2 and Zhu et al. (2017) had blood drawn to assess C reactive protein. The results show positive reduction in total cholesterol (Graves et al., 2015 $p<0.05$; Zhu et al., 2017 $p<0.01$), HDL (Alkhajah et al., 2012 $p<0.01$) and LDL (Zhu et al., 2017 $p<0.05$) cholesterol, glucose (Healy et al., 2013 $p<0.05$) and C reactive protein (Zhu et al., 2017 $p<0.01$). Carr et al. (2016) found no correlation between sitting/standing time and cardiometabolic markers. The longer term studies that were conducted for 3 months and more (Alkhajah et al., 2012; Carr et al., 2016; Zhu et al., 2017) did show improvements in some biomarkers related to obesity and cardiovascular diseases except for Carr et al. (2016). The studies reviewed indicate SSW have an impact on cardiometabolic makers such as cholesterol, glucose, and C reactive protein. The results from these studies indicate another benefit of SSW use is potential positive impact on biomarkers that cause obesity and cardiovascular disease.

CHAPTER 3

CONCLUSION

Increased office work at desks in the workplace has prompted the introduction of sit-stand workstations in attempt to reduce the negative health effects associated with sedentary behavior. This thesis provided a review of literature that studied sit-stand workstations in occupational settings and their impact on sedentary behavior, discomfort, physical activity, productivity, user perception, and cardio-metabolic biomarkers.

Based on the review, there is enough evidence to conclude sit-stand workstations can decrease sitting time and increase standing time by about 1.5 hours per 8 hour workday. The literature included an occupational setting that had SSW's for 18 years with continued use by employees. The anticipated benefit of changing posture throughout the day to alleviate static posture and potentially reduce discomfort is a reason why SSW's have been introduced. The studies reviewed show both significant and insignificant positive reduction in fatigue and overall body discomfort in employees who utilized SSW's up to 3 months. There were multiple studies that had a reduction in neck and shoulder complaints but there is some evidence that SSW may cause an increase in upper extremity discomfort. Additional studies are needed with interventions of a longer length of SSW use to address contradictory data found in the research. One of the concerns with completing job tasks while standing was that productivity would be negatively impacted. The research strongly suggests there may be a subjective improvement in productivity with no negative impact.

Another primary concern with sedentary behavior is the potential adverse impact on an individual's health. Some of the studies found significant positive impact on C reactive protein, fasting glucose, HDL, LDL and total cholesterol which are related to obesity and cardiovascular diseases. Other outcomes that were measured such as BMI and blood pressure were not significantly affected by SSW use. Since the average intervention length was less than six months, additional long term longitudinal studies are necessary to determine if other biomarkers would be impacted by longer term use of the desks and change in sedentary behaviors.

Many of the studies were conducted in an office setting with obese, middle-aged female participants. More diverse test subjects are needed to determine if the results we see in this review are all encompassing or only applicable to certain type of user. Overall the literature indicates SSW are generally well received by employees. Company (employer) support and ergonomics training appear to have a positive impact on the reception and use of sit-stand workstations. Participants attributed support from their employer and coaches to helping the SSW intervention being well received. The literature discussed employee support but did not address SSW usage and how to user should split their time between sitting and standing. Further research is needed regarding sit-stand time ratios to provide a guide and training on the use of sit-stand workstations.

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