EFFECTS OF A WORKPLACE SEDENTARY BEHAVIOR INTERVENTION ON SLEEP IN OFFICE WORKERS WITH SLEEP COMPLAINTS: RESULTS FROM THE STAND AND MOVE AT WORK TRIAL

A thesis submitted to the University of Arizona College of Medicine – Phoenix
in partial fulfillment of the requirements for the Degree of Doctor of Medicine

Kelby Schaeffler
Class of 2020

Mentor: Matthew Buman, PhD

Effects of a workplace sedentary behavior intervention on sleep in office workers with sleep complaints: Results from the Stand and Move at Work Trial.

Kelby Schaeffler, BS, MSIV at The University of Arizona College of Medicine Phoenix

Matthew P Buman, PhD, College of Health Solutions, Arizona State University

Meynard J Toledo, PhD, College of Health Solutions, Arizona State University

Mark A Pereira, PhD, Division of Epidemiology and Community Health, University of Minnesota

Nathan Mitchell, MPH, Division of Epidemiology and Community Health, University of Minnesota

Miranda Larouche, BS, College of Health Solutions, Arizona State University

Sarah Mullane, PhD, College of Health Solutions, Arizona State University

Kristina Hasanaj, College of Health Solutions, Arizona State University

Sarah Rydell, Division of Epidemiology and Community Health, University of Minnesota

Junia Brito, Division of Epidemiology and Community Health, University of Minnesota

ABSTRACT

Background: Chronic inadequate sleep is associated with increased risk for cardiovascular disease, hypertension, obesity, immunosuppression and overall mortality. There is an abundance of research on the effects of exercise on sleep, but there is currently no data on the impact of sedentary interventions in the workplace on acute and long-term sleep quality/quantity.
Purpose: The purpose of this study is to determine if increased standing and/or light-intensity physical activity (LPA) at work will improve sleep quality and duration in sedentary office-workers with mild to moderate sleep complaints.
Methods: For this group randomized trial, 51 participants with mild-to-moderate sleep complaints were selected from the Stand and Move at Work Trial. Participants were randomized into two groups: *MOVE+* (a multilevel individual, social, environmental, and organizational intervention targeting increases in LPA in the workplace) and *STAND+* (*MOVE+* intervention with the addition of the installation of sit-stand workstations). Sedentary behavior/LPA and sleep were measured objectively at baseline, 3 and 12 months with the activPAL3 micro accelerometer (PAL Technologies, Glasgow, United Kingdom) and the GeneActiv (GeneActiv, Activinsight, Wimbolton, UK) wrist-worn actigraphy sensor.
Results: The sit-stand workstation intervention was effective, with the STAND+ participants sitting on average 70 minutes/day less than the MOVE+ participants at 12 months ($p<0.05$). There were no statistically significant differences between intervention groups in objectively or subjectively measured time in bed, total sleep time, sleep onset latency, wake after sleep onset, or sleep efficiency at the 3 or 12-month timepoints. On the individual level, adjusting for group assignment, there was no correlation between change in sedentary behavior and sleep measures, objective or subjective.
Conclusion: This study found no correlation between a decrease in sedentary behavior at work and changes in objective or subjective measures of sleep. Limitations of this study include underpowering due to small sample size, potential significance of difference in baseline demographics and sleep/sedentary behavior between in groups, and the nature of the intervention being low-dose.
Key Terms: sedentary behavior; sit-stand workstation; sleep; workplace; light-intensity physical activity

1. INTRODUCTION

1.1 Definition of Adequate Sleep

Sleep need varies significantly among individuals and across the lifespan[18]. The National Sleep Foundation recommends that adults age 18-64 get 7-9 hours of sleep per night, while for older adults (65+) 7-8 hours is sufficient. Most adults report sleeping six to eight hours per night, but some adults report only requiring six hours of sleep per night without the need for catch-up sleep to feel refreshed. Sleep insufficiency is therefore not necessarily defined in terms of hours, but rather as an inability to support adequate alertness, performance, and health. That being said, the American Academy of Sleep Medicine (AASM) and the Sleep Research Society recommend that adults sleep seven or more hours per night in order to maintain optimal health[24].

1.2 Prevalence of Inadequate Sleep

Insufficient sleep is a significant public health concern in our world today. In the United States, more than one-third of adults report sleeping less than seven hours per night, and nearly 30 percent report sleeping six hours or fewer[11,13]. These rates are even higher among younger adults, racial and ethnic minorities, and patients with low socioeconomic status. Population-based studies of United States workers have found an increased prevalence of short sleep duration in those with long or extended work hours, rotating or shift work, and increased job-related stress[14,19,22]. An estimated 50-70 million US adults have a diagnosed sleep disorder[7]. The prevalence of short sleep duration may also be increasing over time. A study that evaluated time diaries from eight population-based studies between 1975 and 2006 found that the prevalence of short sleep duration (<6 hours per night) increased from 7.6 percent in 1975 to 9.3 percent in 2006[10]. In this study, the odds of short sleep duration were increased in full-time workers. The Behavioral Risk Factor Surveillance System (BRFSS) survey of sleep behaviors in 2008 determined that, among 74,571 adults, 35.3% reported <7 hours of sleep regularly, 48.0% reported snoring, 37.9% reported unintentionally falling asleep during the day in the past month, and 4.7% reported nodding off or falling asleep while driving in the past month[8]. The CDC's surveillance of sleep-related behaviors has increased in previous years due to recognition of the importance of sleep to population health[1].

1.3 Consequences of Inadequate Sleep

Sleep has two dimensions: duration (quantity) and depth (quality). When either of these is inadequate, daytime alertness and functioning suffer. Symptoms of inadequate sleep include irritability, decreased concentration, attention deficits, reduced vigilance, distractibility, poor motivation, fatigue, restlessness and incoordination. Cognitive impairment is the most prominent effect of acute sleep deprivation. In laboratory settings, sleeping less than seven hours per night results in cumulative deficits in alertness and attention[4]. Occupational errors are more common among individuals with sleep insufficiency. For example, studies in health care professionals have shown that individuals with 24-hour shifts make more frequent serious diagnostic errors than when they work shorter shifts[3], and experience more work-related injuries[2]. Acute sleep deprivation has also been shown to depress respirations, cause depression or anxiety, decreased libido, poor judgment, and other signs of physiologic dysfunction.

Perhaps even more importantly, chronic sleep insufficiency has been associated with a great variety of adverse health outcomes. In a 2016 statement from the American Heart Association, sleep restriction is recognized as a risk factor for adverse cardiometabolic outcomes (increased risk for hypertension, coronary artery disease, heart attack, and stroke)[20]. Chronic sleep loss is also associated with immunodeficiency and enhanced susceptibility to the common cold[4]. Sleep restriction may cause increased rate of decline in renal function[17] and negative metabolic consequences that increase risk for obesity and associated conditions such as type 2 diabetes. Finally, an association exists between chronic sleep insufficiency and all-cause mortality[12].

1.4 Physical Activity/Sedentary Behavior and Sleep

American adults spend an average of 7.5h/day sedentary[15]. Moderate-vigorous physical activity (MVPA) seems to confer the strongest benefit on health, however recent studies have suggested that replacing sedentary time with standing or other light-intensity physical activity (LPA) or movement – even when holding MVPA constant – is associated with health, longevity, and lower cardiometabolic risk[6,9,16,21]. A significant body of research has investigated the effects of physical activity on sleep. Results generally suggest that physical activity is beneficial for sleep, and that moderate physical activity seems to be more effective than vigorous activity in improving sleep[23]. A 2017 systematic review and meta-analysis found that sedentary behavior was associated with an increased risk of insomnia and sleep disturbance[25].

1.5 Rationale

The majority of studies performed to date on the effects of physical activity on sleep involve formal exercise training programs, or monitor physical activity on the basis of minutes of intentional exercise performed. The physical activity is either measured objectively for a short time period (often several weeks), or is reported subjectively as minutes spent in moderate to vigorous exercise. Many of these studies have included only “good sleepers”/fit athletes, or individuals with insomnia. Additionally, almost all previous studies on the subject have measured sleep quality and quantity subjectively, with questionnaires and self-reporting. Objective laboratory studies have been criticized for small sample sizes, differing methodology, and short time periods.

By objectively measuring both 24/7 activity levels, including postural change (standing vs. sitting) and LPA, and sleep quality and quantity intermittently over a 12-month period, our study aimed to provide new insight into the effects of daily sedentary habits on sleep health. Our intervention is practical to real-world scenarios, as we provided sit-stand workstations and some strategies and goals for decreasing sedentary behavior, but it was up to the participants themselves to implement the intervention to varying degrees. Additionally, we have included only adults with sedentary jobs and mild to moderate sleep complaints, which constitutes a large portion of the country’s population and makes the study’s possible significance profound.

2. **METHODS**

2.1 Study aims

Our primary aim was to determine whether participants in the *STAND+*, relative to the *MOVE+*, study arm had greater improvements (if present) in objective and/or subjective measures of sleep quality and duration over the 12-month intervention period. Our secondary aim was to determine whether decreased sitting time (and increased standing and/or light intensity physical activity) at work, regardless of treatment arm, was correlated to changes in objective and/or subjective measures of sleep quality and duration over the 12-month intervention period.

2.2 Study design

This is a sub-study of the ‘*Stand & Move at Work*’ two-arm group-randomized (i.e., cluster randomized) trial. The design and rationale of the larger trial has been published and can be accessed for further detail[5]. Worksites (N=24) of small to moderate size (20-50 employees enrolled, N=720 employees across 24 sites) were randomized to one of two interventions: (a) *MOVE+*, a multi-level behavioral intervention targeting increases in LPA at the worksite; or (b) *STAND+*, the multi-level *MOVE*+ intervention with the addition of installation of sit-stand workstations to allow participants to stand at their desks while working. Twenty-four worksites were enrolled in the greater Phoenix, AZ, USA and Minneapolis, MN, USA metropolitan regions. Twelve worksites were randomized in each region. Worksites of three distinct sectors were equally selected (higher education, industry/healthcare, and government). Recruitment and enrollment occurred between 2015 and 2018.

2.3 *Study eligibility*

2.3.1 Worksite eligibility criteria

Worksites in Phoenix, Arizona and Minneapolis/St. Paul, Minnesota were screened for eligibility by study questionnaires completed by leadership and followed up with interviews to verify eligibility. Worksite eligibility criteria are as follows: (a) small to moderate in size (i.e., 20–50 employees); (b) >80% of employees working full time in the office (30+ hours/week); (c) predominant worksite occupation being seated office work with little movement or walking (i.e., computer or telephone-based work); (d) not currently undergoing a wellness program aimed at reducing sitting or increasing LPA at work; (e) <10% of employees currently using a sit-stand workstation at work; (f) willing to have sit-stand workstations installed at the workplace; and (g) worksite leadership willing to be randomized to either study arm.

2.3.2 Participant eligibility criteria

For the *'Stand & Move at Work'* trial, participant eligibility criteria are as follows: (a) 18 years or older; (b) generally good health and able to safely reduce sitting and increase LPA; (c) working full-time on-site (i.e. 30+ hours and at least 4 days in the office per week); (d) not currently pregnant; (e) predominant worksite occupation being seated office work; (f) not currently using a sit-stand workstation at their primary desk location at work; (g) willing to have a sit-stand workstation installed at their desk; and (h) willing to be randomized to either study arm.

2.3.3 Sleep sub-study participant eligibility criteria

Of the '*Stand & Move at Work'* trial participants (N=720), 50 individuals who met the inclusion/exclusion criteria were recruited on a voluntary basis to participate in the sleep sub-study. These eligibility criteria are as follows: (a) willing to participate in all aspects of the 'Stand and Move at Work' study; (b) self-reported mild to moderate sleep complaints (trouble falling asleep, wakefulness after sleep onset, etc.); (c) never been diagnosed with a sleep-related condition; (d) do not meet criteria for high risk for obstructive sleep apnea.

2.4 *Interventions*

The *'Stand & Move at Work*' interventions were delivered over 12 months by an intervention development team composed of behavioral scientists, ergonomists, exercise scientists, and worksite wellness coordinators. The primary behavioral target of the *MOVE+* intervention was to accumulate 30 minutes or more of additional LPA each day. The primary behavioral target of the *STAND*+ intervention was, in addition to the *MOVE+* target, to increase time spent standing to 50% of desk-based time during the workday (e.g. standing for 3 hours out of 6 total desk-hours per day). A *Stand & Move at Work* "Toolkit", a manual with all intervention materials, was created and distributed to each worksite prior to the intervention start date. The Toolkit was comprised of both "required" strategies and "optional" strategies. Additional strategies to increase standing time/LPA generated by the worksite staff were encouraged. This ensured uniformity of the delivered interventions, while allowing flexibility and autonomy among worksites, in order to make the results as real-world applicable as possible. Implementation of strategies were closely monitored through quarterly worksite audits and worksite leader interviews throughout the intervention period.

2.4.1 Intervention elements

2.4.1.*1 Policy-level components*

As the primary aim of the '*Stand and Move at Work'* trial was to develop an effective intervention to decreased sedentary behavior in the workplace, the published design and rationale article provides extensive detail regarding the intervention techniques implemented in this study[5]. Each worksite identified a worksite leader and advocate whose primary role was to provide higher-level support for intervention strategies to be implemented. Organizational changes were reinforced by the distribution of four quarterly support emails sent by the worksite leader to employees. Templates were provided to include at minimum: (a) support for the program and employee participation; (b) a brief review of the previous quarter progress; (c) commendation of individuals who have shown high levels of engagement; and (d) an outline of new intervention initiatives for the upcoming quarter. Leaders also attended quarterly meetings with an experienced behavioral science research team member, whose role was to facilitate the intervention by ensuring all materials and concepts were explained fully.

2.4.1.2 Environment-level components

The primary environmental difference between the *STAND+* and *MOVE+* study arms was the installation of sit-stand workstations for the *STAND+* arm only. These workstations were installed by our trained research staff. The *Ergotron* sit-stand workstation Workfit-TL model (Ergotron, Inc., St. Paul, MN) has been selected because it is able to be retro-fitted for use with almost all workspaces, requires little or no installation as it is simply placed on the existing desk surface, is affordable relative to many alternatives, has more desk surface area then many alternatives on the market, it can be easily raised and lowered to a broad range of positions, and can accommodate one or two large computer monitors. The Workfit-TL transitions from seated to standing positions by holding two levers and providing minimal force. Other required environmental changes included a signage starter pack designed to provide information about sedentary behavior, information about the benefits of taking the stairs, encourage goal setting, provide instruction (e.g., walking routes around the office), and provide general encouragement. All participants regardless of randomization were provided with a footrest to use as a resting place for either foot while standing, as a stretching aid, and as a visual reminder regarding participation.

2.4.1.3 *Individual and social-level components*

An e-newsletter (The *Insider*) was used to deliver individual and social-level intervention content. The *Insider* was sent weekly during the first month of the intervention, and bi-weekly during months 2-12, for a total of 26 newsletters. *Insider* topics included: Desk-based ergonomics, tips to stand and move more at work, productivity and moving more, walking routes, stretching at work, goalsetting, LPA and depression, the risks of sedentary behavior, and sleep and LPA. One-on-one coaching sessions were held once for each participant for goal-setting. Participants also received instructions regarding the desk-based ergonomic set up (both *MOVE*+ and *STAND*+). The *STAND*+ arm received specific instructions (guided by an experienced ergonomist) regarding their new sit-stand workstation set up.

2.4.1.4 *Primary differences between study arms*

The primary difference between study arms was the provision of a sit-stand workstation at the start of the intervention for the *STAND*+ group only. This primary difference did require some small adaptations to other intervention strategies (see Table 1). Participant goals differed per study arm (i.e. increasing standing and LPA time for *STAND*+ group vs. increasing LPA only for *MOVE*+ group). All participants were encouraged to adhere to a "30-minute rule", meaning a goal of 30:30-minute sit to stand ratio in the *STAND*+ group, and replacing 30 minutes of sit time with an equal accumulation of moving throughout the workday in the *MOVE*+ group. Second, although the *STAND*+ and *MOVE*+ arms were provided with an identical Stand & Move Toolkit and the same level of support to implement socio-ecological changes, it is likely that the application of the Toolkit differed per arm to target the specific target intervention arm goals. Finally, in some instances, the e-newsletter topics remained the same across arms but the content was adjusted per arm to reduce contamination and ensure that information is specific to the intervention arm. For example, the ergonomically themed e-newsletter included sit-stand desk information for the *STAND*+ group, however, the *MOVE*+ content only included seated desk information.

Table 1

Intervention strategies per study arm

	STAND+	MOVE+
Individual strategies		
Take 15 × 2-min, 10 × 3-min or 6 × 5-min move breaks throughout your workday	X	X
Progress from 5 to 30 minute standing breaks every hour	X	
Use a restroom further away	X	X
Use the stairs only	X	X
Remove the trash can from your desk	X	X
Remove the recycling can from your desk	X	X
Use a walking route once a day	X	X
Stretch for 5 minutes per day	X	X
Use face to face interaction rather than email	X	X
Use centralized printing areas	X	X
Get away from your desk for lunch	X	X
Use a smaller water bottle to fill it more frequently	X	X
Stand during phonecalls	X	X
Check your emails while standing	X	
Set reminders to stand every 30-min on your calendar	X	
Leave your sit-stand desk in the standing position at the end of the workday to encourage standing the next day	X	
Set reminders to move every 30-min on your calendar	X	X
Workplace strategies		
Implement a short break (to stand or move) during meetings > 60-min in duration	X	X
Implement walking meetings	X	X
Implement standing meetings	X	X
Implement standing challenges (e.g one person standing at all times, group standing periods)	X	
Implement moving challenges (e.g stair/walking route challenges, not using restrooms on the same floor, passing an item around the office throughout the day)	X	X
Promote standing and moving at the organizational level vi a quarterly support emails	X	X

2.5 *Measurements*

All measurements were taken at baseline, 3 and 12 months. Demographic and health history variables were also assessed at each time point.

2.5.1 Measurement of sedentary behavior and physical activity

Time spent sitting, standing, and in LPA at work were assessed with the activPAL3 micro accelerometer (PAL Technologies, Glasgow, United Kingdom) for seven consecutive days at each measurement time point. The activPAL provides a valid and reliable measure of posture (sitting vs. standing) for free-living settings and uses a transducer suitable for detecting lower intensity movements. The activPAL was waterproofed using medical grade adhesive covering and attached to the midline of the thigh using a breathable, hypoallergenic tape. This method allows for the monitor to be worn continuously for seven consecutive days without removing for bathing or other water-based activities (a valuable feature that reduces missing data). Additional adhesive dressing was given to all participants for re-application as necessary. The primary output of the activPAL used for this sub-study was time spent sitting, as our question was regarding the effect of decreased sedentary behavior on sleep. Participants concurrently completed an online daily log where they reported their sleep/wake schedule and time arriving and departing their workplace. The daily logs were used to filter time spent sitting and LPA during work hours. In addition, any uninterrupted sedentary bouts of more than six hours that occur within reported wake times were considered non-wear times and treated as missing data. Days with <10h of monitor wear data or <80% of reported work time as monitor wear data were excluded from analyses. Outcomes are reported as a standardized 8h workday to account for differences in total work time.

2.5.2 Measurement of sleep

Sleep data was also measured for seven consecutive days at each timepoint using the GeneActiv (GeneActiv, Activinsight, Wimbolton, UK), a wrist-worn actigraphy sensor. Participants also filled out a daily sleep log during these time periods. We used the same five primary outcomes from the objective (GeneActiv) data and the subjective (sleep log) data: time in bed (TIB), total sleep time (TST), sleep onset latency, wake after sleep onset (WASO), and sleep efficiency. Sleep efficiency is presented as a percentage of one-hundred and is automatically calculated on the GeneActiv. Subjective sleep efficiency was calculated using the following formula (with sleep log data): (TST/TIB) x 100.

2.6 *Data Analysis*

A group-randomized trial is being conducted, given that threats to internal validity (e.g. contamination, envy) preclude randomization of individuals within the same worksite. Twelve worksites were enrolled in the Phoenix area and 12 in the Minneapolis area, and the randomization scheme was stratified by geographical location so as to not have any confounding based on geography (AZ vs. MN). Six pairs of worksites in AZ and six pairs in MN were identified, with the pair members having the same sector (academia, government, or healthcare/industry). Each pair was randomized so that one worksite in each pair is assigned to the *MOVE*+ intervention and the other to the *STAND*+ intervention. Since the sleep sub-study participants were recruited after initial worksite randomization, worksite and demographic are not evenly split between study arms in this sub-study. See Table 2 for demographic information for participants in this sleep sub-study.

Sleep parameters were derived from the GeneActiv using GGIR software and were matched with the corresponding sedentary and physical activity behavior data from the ActivPAL device. All variables were summarized by timepoint and expressed as daily averages. We also explored intra-individual variability in objective and self-reported sleep measures. Continuous variables were examined for any deviation from normal distribution and were transformed accordingly. Furthermore, continuous variables were expressed in means and standard deviations and categorical variables were expressed as percentages. Multilevel models (SAS PROC Mixed) were created to evaluate the research questions. All models were adjusted for baseline sitting time, age, sex and race.

2.6.1 Primary aim analysis

Our primary aim was to determine whether individuals in the the STAND+ study arm, relative to individuals in the MOVE+ study arm, had greater improvements in their objective and subjective sleep duration and quality at 3 and 12-month timepoints. Independent variables: timepoint, group assignment, and group x time. Dependent variables: acc_TIB, acc_TST, acc_Latency, acc_WASO, acc_Efficiency, sl_TIB, sl_TST, sl_Latency, sl_WASO, sl_Efficiency. Means and standard deviations of each outcome by group at each timepoint were examined for any differences. Multilevel modeling was also used to model these changes over time between the two groups. The final model includes group, time, and group x time interaction as predictors. The beta of the group x time interaction was then evaluated to determine if there were any significant differences in the change in outcome between the two groups at the 3 and 12-month timepoints.

2.6.2 Secondary aim analysis

Our secondary aim was to determine whether increases in standing time and decreases in sedentary time, regardless of assigned study arm, are associated with improvements in objective and subjective sleep duration and quality at 3 and 12-month timepoints. Independent variables: sP5_sit, timepoint, study arm. Dependent variables: sP5_sit, acc_TIB, acc_TST, acc_Latency, acc_WASO, acc_Efficiency, sl_TIB, sl_TST, sl_Latency, sl_WASO, sl_Efficiency.

Table 2.
Baseline participant characteristics

				MOVE+		STAND+	
		N	%				
Treatment	Move+	24	47.06				
	Stand+	27	52.94				
		N	%	N	%	N	%
State	Arizona	24	47.06	13	54.17	11	40.74
	Minnesota	27	52.94	11	45.83	16	59.26
		N	%	N	%	N	%
White non-Hisp	No	18	35.29	6	25	12	44.44
	Yes	33	64.71	18	75	15	55.56
		N	%	N	%	N	%
Sex	Female	41	80.39	17	70.83	24	88.89
	Male	10	19.61	7	29.17	3	11.11
		N	%	N	%	N	%
Education	Unknown	2	3.92			2	7.41
	Less than high school	2	3.92	1	4.17	1	3.7
	Obtained GED	29	56.86	12	50	17	62.96
	High school graduate (Diploma)	18	35.29	11	45.83	7	25.93
		N	%	N	%	N	%
Sector	Education	24	47.06	12	50	12	44.44
	Industry	10	19.61	2	8.33	8	29.63
	Government	17	33.33	10	41.67	7	25.93

Table 3.
Baseline measures

Variable	All participants N	All participants Mean	All participants Std Dev	MOVE+ N	MOVE+ Mean	MOVE+ Std Dev	STAND+ N	STAND+ Mean	STAND+ Std Dev
Age	51	43.19	10.8	24	41.26	9.25	27	44.9	11.93
acc_TIB	51	454.25	52.67	24	454.08	32.58	27	454.41	66.31
acc_TST	51	371.69	55.08	24	381.65	37.22	27	362.83	66.61
acc_Latency*	51	3.42	6.11	24	3.28	4.18	27	3.55	7.5
acc_WASO	51	79.14	49.95	24	69.15	44.85	27	88.03	53.33
acc_Efficiency	51	82.17	10.21	24	84.48	8.97	27	80.12	10.96
sl_TIB	48	463.72	49.79	23	457.87	42.55	25	469.09	55.98
sl_TST	48	427.45	50.27	23	419.68	41.06	25	434.61	57.37
sl_Latency	50	14.33	11.23	24	15.44	13.34	26	13.31	9.01
sl_WASO*	50	9.3	9.03	24	8.64	9.89	26	9.92	8.31
sl_Efficiency	48	0.92	0.04	23	0.92	0.04	25	0.92	0.04
Valid_P5	51	7.04	0.8	24	7.17	0.56	27	6.93	0.96
P5_min	51	922.01	43.22	24	930.56	28.88	27	914.42	52.23
sP5_Sit	51	604.83	95.91	24	616.61	95.14	27	594.36	97.17
sP5_Stand	51	252.31	81.95	24	244.11	81.49	27	259.59	83.21
sP5_LPA	51	84.68	28.29	24	82.7	27.01	27	86.44	29.79
P5_Sitstand	51	55.12	13.49	24	55.23	15.11	27	55.02	12.17
P5_long_sitbout_ct	51	5.17	1.56	24	5.39	1.77	27	4.97	1.36
sP5_long_sitbout_dur	51	302.56	100.23	24	308.98	114.05	27	296.86	88
P5_step_min	51	98.7	30.78	24	96.2	29.24	27	100.92	32.48

*Acc_= accelerometer-measured variable; sl_= sleep log-measured variable; TIB = time in bed; TST = total sleep time; WASO = wake after sleep onset; valid_P5 = number of valid days of measurement per 7-day period; P5_min = minutes wearing accelerometer per day; sP5_Sit = minutes sitting per day; sP5_Stand = minutes standing per day; sP5_LPA = minutes spent in light-intensity physical activity per day; P5_Sitstand = number of sit-stand transitions per day; P5_long_sitbout_ct = number of sit bouts >30 minutes per day; sP5_long_sitbout_dur = minutes in sitbouts >30 minutes per day; P5_step_min = minutes walking per day

3. RESULTS

3.1 Baseline data and participant attrition

Participant (N=51) characteristics are described in Table 2 and baseline GeneActiv and sleep log data are described in Table 3. Participants were on average 43 years old and predominantly female (41%). On average at baseline, participants spent 7.6 hours in bed and 6.2 hours sleeping, which equates to 82.2% sleep efficiency (GeneActiv-measured). The MOVE+ group had slightly greater GeneActiv-measured sleep efficiency at baseline than the STAND+ group (84.5% vs. 80.1%). Subjective sleep log data differed from GeneActiv data, as seen in Table 3. Participants reported on average 7.7 hours in bed and 7.1 hours sleeping, for a 92.0% sleep efficiency. Baseline sedentary data differed slightly between groups as well. At baseline, the MOVE+ participants spent on average 10.3 hours sitting/day (compared to 9.9 hr/day STAND+), 4.1 hours standing/day (vs. 4.3 hrs/day STAND+), and 1.41 hours in light-intensity physical activity (LPA)/day (vs. 1.43 hr/day STAND+). In summary, the STAND+ participants appeared to be slightly more active and less sedentary at baseline than the MOVE+ participants.

51 participants enrolled and met exclusion and inclusion criteria, and 37 participants completed data collection at the 12-month time point and these results were analyzed (see CONSORT diagram). Reasons for non-participation included participants leaving their job, changing jobs within the company such that their desk was not within the geographic area of the office participating with the study.

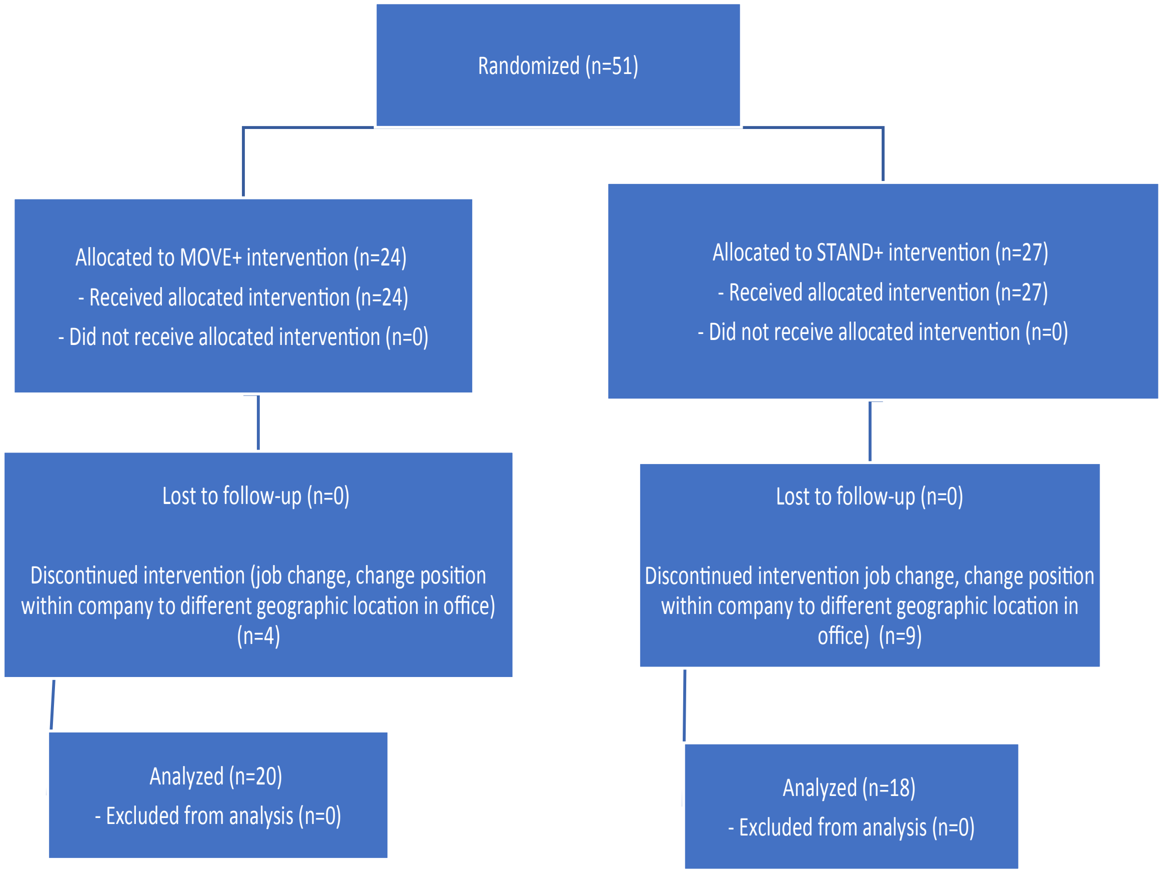


Table 4.
Change from baseline at 3 months.

	Move+ estimate(CI)	Stand+ estimate(CI)	Effect estimate (CI)	ICC	D.F	T	p value
ActivPAL							
sP5_sit	57.9 (9, 106.8)	-39.6 (-81.3, 2.2)	-97.4 (-163.2, -31.7)	0.2	17	-3.13	0.0061
GeneActiv (min)							
acc_TIB	8.4 (-17.7, 34.6)	22.9 (1.9, 44)	14.5 (-20.3, 49.3)	0	17	0.88	0.391
acc_TST	6.9 (-21.7, 35.5)	17.2 (-5.9, 40.3)	10.3 (-27.6, 48.1)	0	17	0.57	0.5741
acc_Latency	1.7 (-6.6, 10)	3.2 (-3.8, 10.2)	1.5 (-9.6, 12.6)	0.16	17	0.29	0.7782
acc_WASO	-3.7 (-30, 22.7)	-1.4 (-24.7, 21.9)	2.3 (-33.6, 38.2)	0.46	17	0.13	0.895
acc_Efficien	1.1 (-5.3, 7.4)	-0.1 (-5.8, 5.6)	-1.1 (-9.8, 7.5)	0.58	17	-0.28	0.7843
Sleep log							
sl_TIB	-0.4 (-35.3, 34.4)	-2 (-29.8, 25.7)	-1.6 (-47.8, 44.7)	0.21	16	-0.07	0.943
sl_TST	-0.9 (-26.5, 24.7)	-6.1 (-24.9, 12.8)	-5.2 (-38.2, 27.9)	0	16	-0.33	0.7448
sl_Latency	-1.1 (-5.8, 3.7)	-1.2 (-4.8, 2.4)	-0.1 (-6.3, 6)	0.12	16	-0.05	0.9598
sl_WASO	-6.4 (-13.2, 0.4)	-4.3 (-9.2, 0.6)	2.1 (-6.6, 10.7)	0	16	0.51	0.6194
sl_Efficienc	0 (0, 0)	0 (0, 0)	0 (0, 0)	0	16	-0.59	0.5615

Table 5.
Change from baseline at 12 months.

	Move+ estimate(CI)	Stand+ estimate(CI)	Effect estimate (CI)	ICC	D.F	T	p value
ActivPAL							
sP5_sit	34.3 (-9.7, 78.3)	-36.2 (-83, 10.6)	70.5 (1.6, 139.4)	0	17	2.16	0.0455
GeneActiv							
acc_TIB	23.8 (3.4, 44.3)	22.2 (0.5, 43.9)	1.6 (-30.1, 33.4)	0	17	0.11	0.914
acc_TST	20.4 (3, 37.8)	19.2 (0.7, 37.7)	1.2 (-25.9, 28.3)	0	17	0.09	0.9288
acc_Latency	-0.3 (-5.5, 4.8)	-0.1 (-5.5, 5.3)	-0.3 (-7.8, 7.3)	0.79	17	-0.07	0.9449
acc_WASO	5.9 (-10.9, 22.6)	0.4 (-17.5, 18.2)	5.5 (-21.2, 32.2)	0	17	0.43	0.6691
acc_Efficien	0.1 (-2.9, 3.2)	0.2 (-3, 3.5)	-0.1 (-4.9, 4.7)	0	17	-0.05	0.9642
Sleep log							
sl_TIB	15 (-12.9, 42.9)	-2.7 (-28.9, 23.5)	-17.7 (-58.3, 22.8)	0.02	16	-0.93	0.3673
sl_TST	11.4 (-16.4, 39.2)	-2.5 (-28.5, 23.6)	-13.8 (-54.3, 26.6)	0	16	-0.73	0.4786
sl_Latency	-3.4 (-8.3, 1.5)	-1.7 (-6.3, 2.9)	1.7 (-5.5, 8.9)	0	16	0.5	0.6208
sl_WASO	-4 (-16.8, 8.9)	10 (-2, 22.1)	14 (-4.8, 32.8)	0	16	1.58	0.1346
sl_Efficienc	0 (0, 0)	0 (0, 0)	0 (0, 0.1)	0.32	16	0.64	0.5315

*All models adjust for age, sex, race, and baseline value.

Table 6.
Difference in values between groups (MOVE+ relative to STAND+).

3 MONTH Differences (adju	Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
sP5_sit_change	Trt	-97.4426	31.1676	17	-3.13	0.0061	0.05	-163.2	-31.6848
acc_TIB change	Trt	14.5273	16.5047	17	0.88	0.391	0.05	-20.2946	49.3491
acc_tst change	Trt	10.2805	17.9411	17	0.57	0.5741	0.05	-27.5719	48.1329
acc_latency change	Trt	1.5064	5.2638	17	0.29	0.7782	0.05	-9.5993	12.6121
acc_WASO change	Trt	2.2807	17.0283	17	0.13	0.895	0.05	-33.646	38.2073
acc_efficiency change	Trt	-1.1412	4.1045	17	-0.28	0.7843	0.05	-9.801	7.5186
sl_tib	Trt	-1.5844	21.8168	16	-0.07	0.943	0.05	-47.834	44.6653
sl_tst	Trt	-5.1662	15.5992	16	-0.33	0.7448	0.05	-38.2349	27.9026
sl_latency	Trt	-0.149	2.908	16	-0.05	0.9598	0.05	-6.3138	6.0158
sl_waso	Trt	2.0623	4.0717	16	0.51	0.6194	0.05	-6.5693	10.694
sl_efficiency	Trt	-0.01028	0.01734	16	-0.59	0.5615	0.05	-0.04704	0.02648
12 MONTH Differences (adjusted for age, sex, race, baseline value)									
sP5_sit_change	Trt	-70.5095	32.6706	17	2.16	0.0455	0.05	1.5805	139.44
acc_TIB change	Trt	1.648	15.0416	17	0.11	0.914	0.05	-30.0871	33.383
acc_tst change	Trt	1.1654	12.8503	17	0.09	0.9288	0.05	-25.9465	28.2772
acc_latency change	Trt	-0.2516	3.5839	17	-0.07	0.9449	0.05	-7.8129	7.3097
acc_WASO change	Trt	5.5062	12.6624	17	0.43	0.6691	0.05	-21.2091	32.2214
acc_efficiency change	Trt	-0.1045	2.2965	17	-0.05	0.9642	0.05	-4.9496	4.7406
sl_tib	Trt	-17.7479	19.1307	16	-0.93	0.3673	0.05	-58.3032	22.8074
sl_tst	Trt	-13.837	19.0725	16	-0.73	0.4786	0.05	-54.2688	26.5949
sl_latency	Trt	1.7099	3.3897	16	0.5	0.6208	0.05	-5.4761	8.8958
sl_waso	Trt	13.9878	8.8759	16	1.58	0.1346	0.05	-4.8282	32.8038
sl_efficiency	Trt	0.01493	0.02335	16	0.64	0.5315	0.05	-0.03457	0.06443

The STAND+ group decreased their sitting time at 3 months, with a sustained lower average sit time at 12 months (39.6 and 36.2 minutes less than baseline respectively, $p<0.05$; see Tables 4 and 5). The MOVE+ group, however, had higher sitting times than baseline at 3 months, with a slight down-trend though still increased from baseline at 12 months (57.9 and 34.4 minutes more than baseline respectively, $p<0.05$). Therefore, the intervention was effective, with the STAND+ participants sitting on average 70 minutes/day less than the MOVE+ participants at 12 months (See Table 6).
There was no statistically significant difference in any of the objective sleep measures in either group at 3 months or 12 months. There was also no statistically significant difference in any of the subjective sleep log measures in either group or between groups at 3 or 12 months.

3.3 Aim 2

Table 7.
Estimated effect of sP5_Sit in model adjusted for baseline, age, sex, and race in Pearson coefficients.

		Estimate	Standard Error	DF	t Value	Pr > |t|
M3	acc_TIB0	-0.02866	0.07632	36	-0.38	0.7095
	acc_TST0	0.003912	0.08452	36	0.05	0.9633
	acc_Latency0	-0.01372	0.02266	36	-0.61	0.5486
	acc_WASO0	-0.00747	0.06193	36	-0.12	0.9046
	acc_Efficiency0	0.009658	0.01377	36	0.7	0.4876
	sl_TIB0	0.05263	0.08607	28	0.61	0.5458
	sl_TST0	0.007523	0.06941	28	0.11	0.9145
	sl_Latency0	0.006051	0.01213	29	0.5	0.6216
	sl_WASO0	-0.02421	0.01801	29	-1.34	0.1892
	sl_Efficiency0	-0.00003	0.000078	28	-0.4	0.6887
M12		Estimate	Standard Error	DF	t Value	Pr > |t|
	acc_TIB0	-0.04331	0.07521	29	-0.58	0.5691
	acc_TST0	-0.04824	0.06384	29	-0.76	0.456
	acc_Latency0	-0.00337	0.01256	29	-0.27	0.7902
	acc_WASO0	-0.00817	0.05961	29	-0.14	0.892
	acc_Efficiency0	0.001487	0.01079	29	0.14	0.8914
	sl_TIB0	-0.03039	0.1026	25	-0.3	0.7695
	sl_TST0	-0.02616	0.09939	25	-0.26	0.7946
	sl_Latency0	-0.02674	0.01754	25	-1.52	0.14
	sl_WASO0	-0.03602	0.0471	25	-0.76	0.4516
	sl_Efficiency0	0.000029	0.000107	25	0.27	0.7876

Figure 1.
Individual change in accelerometer-measured sleep efficiency vs. change in sitting time at 12 months (r=.002)

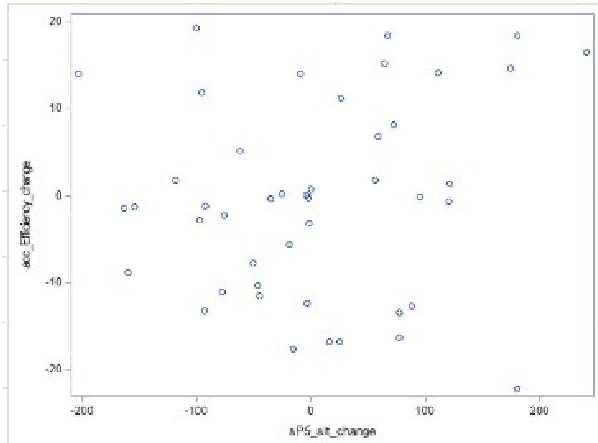
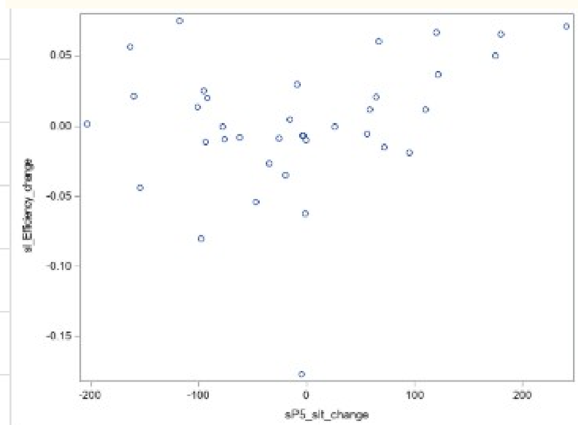


Figure 2.
Individual change in sleep log-reported sleep efficiency vs. change in sitting time at 12 months (r=.00003)



On an individual level, adjusting for group assignment, there was no statistically significant correlation between sitting time and objective or subjective sleep measures at 3 or 12 months (See Table 7). As seen in Figures 1 and 2, the Pearson coefficients for change in sleep efficiency (subjective and objective) vs. change in sitting time are non-significant (r=.002 objective, r=.00003 subjective).

4. **DISCUSSION**

The main aim of our study was to explore whether decreased sedentary behavior and increased light-intensity physical activity, namely through a sit-stand workstation intervention, has an effect on sleep quality and duration in adults with mild-to-moderate sleep complaints. We found no statistically significant difference between the MOVE+ and STAND+ intervention arms in the sleep variables examined, either accelerometer-measured or reported by sleep log. We also did not find any apparent correlation on the individual level between decreased sedentary time and changes in sleep quality or quantity. This may be due to our study being underpowered due to small sample size.

Limitations of this study include small sample size, and potential significance of differences in baseline demographics and sleep/sedentary behavior between groups and between individuals. Given what is known about the positive impact of physical activity on sleep, it is possible that though our results are null, a positive effect may be present. If this effect is present it is likely very small, and would therefore require a much larger sample size to be detected. Additionally, if the effect is present but too small for our study to have detected as statistically significant, we suspect that the effect may not be clinically significant. Likely a difference in sleep efficiency of less than one percent for example does not have a tangible impact on a person's health.

Sleep insufficiency is a significant problem that affects at least 30 percent of adults in the US, and practical solutions are needed to help combat this epidemic. The consequences of acute and chronic sleep inadequacy are serious and damaging, including adverse health conditions and decreased work performance. The current literature shows a relationship between physical activity/exercise programs and sleep improvement. This study was the first of its kind to examine the impact of sit-stand workstations on sleep quality and quantity. This type of solution is simple, cost-effective, and convenient. Many US adults do not subscribe to daily workout plans and would find it daunting and impractical to take on a goal of that size. Additionally, many of these sleep-deprived adults work long hours at a desk and do not always have time to go to the gym after work. Adding standing time to an otherwise sedentary workday is a practical solution, with desktop sit-stand workstations costing as low as $200 USD. Though our results do not show a statistically significant effect, we believe further studies are needed before it can be said that this type of intervention is not effective.

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