EFFECTS OF SIT-STAND DESKS IN A COLLEGE CLASS

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Jeremy Michael Frost

In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Program:
Exercise Science and Nutrition

November 2016

Fargo, North Dakota

North Dakota State University
Graduate School

Title

EFFECTS OF SIT-STAND DESKS IN A COLLEGE CLASS

By

Jeremy Michael Frost

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

SUPERVISORY COMMITTEE:

Donna J. Terbizan
Chair

Won Byun

Marty Douglas

Susan Ray-Degges

Approved:

November 3, 2016
Date

Yeong Rhee
Department Chair

ABSTRACT

This disquisition examined the effects of sit-stand desks in a college classroom over the course of a semester and was split into two studies. Paper 1 determined the pattern of sit-stand desk usage over the course of a semester, the relationship to movement outside of class, and likeability of the sit-stand desks. Paper 2 determined the effect of using adjustable-height (sit-stand) desks in a college class on attention (AT), stress (ST), musculoskeletal discomfort (MD), anxiety (AN), and academic performance. Participants (total n=18; control=6) were recruited from two sections of the same course at a public university in Minnesota.

Individual daily standing time for the intervention group ranged from 0-100% of daily attendance time and the daily group average ranged from 2.1-38.4%. Weekly standing was lower ($p<.05$) in week 8 than week 5, 9, 11, 13, and 15. There was no difference in standing percentage between Wednesdays and Fridays. A third of all standing bouts were less than 0.3 min and two-thirds were less than 2 min in length. Perception Questionnaire answers were positive for using the desk and their effect on ability to work in class. The amount of daily moderate-to-vigorous physical activity (MVPA) did not differ between groups or between time points (week 7 vs. 14). All participants completed visual analogue scales (VAS) to measure AT, ST, MD, and AN from week 3-15, and took exams at week 4, 6, 8, 10, 12, 14, and 15. The main findings indicated lower MD scores for the intervention group, higher week 6 than week 11 scores for AN and ST, and more variability in AT and ST scores. Exam scores were not different between groups. There was no difference in direct observation of attention (OAT) between groups (total n=15; control=6) at week 9, 12, or 13.

The results indicate the sit-stand desks were utilized at low levels, and for short durations, for most participants, but perceptions of desk use remained positive. In addition, sit-stand desks were associated with lower MD scores and weekly fluctuations in AT, ST, and AN. Future interventions should attempt to minimize the variability in desk use.

ACKNOWLEDGEMENTS

There have been so many people that have been supportive of my decision to get a PhD. It was in the back of my mind for a few years and I am glad I had supportive people around me to help me understand that it was a good idea to just jump in and get started.

First, I would like to thank Dr. Donna Terbizan for taking me on when I needed a new advisor and helping me to finish. I don't know that I would have finished if you were not here to help me take things one step at a time and to complete all the various components of a large process like this. You have been of great help in creating a quality product that I can be proud of and I am very thankful for your positive attitude and all of the support along the way. I would also like to thank Dr. Gary Ligouri for initially taking me on as a part-time student and being fine with my slow pace of taking classes. Without your guidance I would not have felt as though I could keep making progress when the end seemed so far away. A big thanks also goes to the rest of my committee members, Dr. Wonwoo Byun, Dr. Marty Douglas, and Dr. Susan Ray-Degges for helping me get through this, and to Curt Doetkott for answering all my statistical questions.

I would also like to thank a small group of graduate students that made me feel welcome in the program, even though I was not regularly on campus: Sarah Hilgers-Gretterman, Chuck Fountaine, John Schuna Jr., and Allison Barry.

I also appreciate the support of St. Cloud State University for the Faculty Research Grant that made this project possible.

Lastly, I would like to thank my family for supporting me throughout this process. To the people I cherish the most, Annah, Eli, and Nina, I could not have done this without you. It means so much to have all of you in my life and to share this journey with you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
AMVPA	Average Moderate-to-Vigorous Physical Activity
AN	Anxiety
AT	Attention
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
LPA	Light Physical Activity
MD	Musculoskeletal Discomfort
MET	Metabolic Equivalent
MPA	Moderate Physical Activity
MVPA	Moderate-to-Vigorous Physical Activity
NEAT	Non-exercise Activity Thermogenesis
PA	Physical Activity
PSTAND	Percentage of daily attendance time spent standing
SED	Sedentary
ST	Stress
VAS	Visual Analogue Scale
VPA	Vigorous Physical Activity
WPSTAND	Percentage of weekly attendance time spent standing

INTRODUCTION

Statement of the Problem

A shift in recent years is placing more focus on the behaviors and environments that cause people to sit for long periods of time on a daily basis and the potential deleterious health consequences of accumulating large amounts of sitting time. However, previously there was more of a focus on increasing people's levels of moderate physical activity (MPA) and vigorous physical activity (VPA) as one of the major mechanisms to reduce morbidity and mortality. Physical activity (PA) recommendations from the American College of Sports Medicine (ACSM) and Centers for Disease Control and Prevention (CDC), updated in 2007, indicated "to promote and maintain health, all healthy adults aged 18 to 65 yr need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week" and "perform activities that maintain or increase muscular strength and endurance a minimum of two days each week" (Haskell et al., 2007, p. 1081). Less attention is given to daily body position or movement outside of this "exercise" time. The rest of the day provides ample opportunity to potentially accumulate sedentary time, despite possibly meeting or even exceeding the current PA guidelines, due to office, classroom, or neighborhood designs that limit movement. Sedentary time is now thought to be associated with negative health consequences independent of the level of PA (Biswas et al., 2015) or body mass index (BMI) (Thorp, Owen, Neuhaus, & Dunstan, 2011).

Born from these findings of sedentary behaviors and physical activity having independent health effects is a concept known as "inactivity physiology". Hamilton, Hamilton, and Zderic (2007) described the four tenants of inactivity physiology and summarized by Ekblom-bak, Hellénius, and Ekblom (2010, p. 834): 1) Sitting and limiting non-exercise activity may independently increase the disease risk; 2) Sedentary behavior is a distinct class of behavior with specific determinants and effects on disease risk; separate from the behavior of leisure-time exercise; 3) The molecular and physiological responses in the human body of too much sitting are not always the same as the responses that follow a bout of additional physical exercise; 4) People already insufficiently physically active will increase their risk even further by prolonged sitting time. These findings provide ample reason to further explore sedentary behaviors and its effects on the body.

The investigation into sedentary behaviors, and the comments of Ekblom-bak, Hellénius, and Ekblom (2010) that "sedentary behavior should be defined as the muscular inactivity rather than the absence of exercise" (p. 834), have brought more attention to the category of movement between sedentary (< 2.0 METS), MVPA (3.0-9.0 METS), and light physical activity (LPA; requiring 2.0-2.9 METS). Research on the potential effects of LPA on various aspects of health have increased in recent years. It has been suggested that the amount of low-intensity movements of daily living, termed non-exercise activity thermogenesis (NEAT) by Levine, was lower for obese vs. lean subjects and did not change in obese subjects who lost weight (Levine et al., 2005). The ability to accumulate NEAT over time may be more advantageous than previously thought.

The trend of moderate physical activity occupations being replaced with occupations requiring only sedentary or light intensities over the last 50 years (Church et al., 2011) may provide a rationale to the recent efforts to design numerous devices to address the increasingly sedentary nature of work and school environments. The standard desks and chairs used in work and school settings, unchanged for many years, have been altered to change the body position for workers and students while still allowing them to complete normal work or school tasks (i.e., typing, writing, talking on the phone, using a computer, etc.). Less expensive examples of these alterations include removing all chairs and desks to have standing meetings (Levine, 2007) or using physio balls or stools instead of chairs (Beers et al., 2008; Speck & Schmitz, 2011). More costly examples of devices created to reduce sedentary time include rigid (Wilks, Mortimer, & Nylén, 2006) or adjustable (Alkhajah et al., 2012) standing-height desks and rigid (Thompson et al., 2014) or adjustable (Ben-Ner et al., 2014) treadmill desks that incorporate walking on a treadmill at low speeds (e.g., 0.5-2.0 mph) instead of desks requiring a static, seated position, as well as pedal desks that allow a self-selected pedaling motion (Carr et al., 2012). Several workplace interventions were also considered “multicomponent” because they offered additional services to the altered desk for decreasing sedentary time. These additional services included workshops and tips sent via email (Healy et al., 2013), face-to-face coaching, email, phone calls, and a tracking tool (Neuhaus, Healy, Dunstan, Owen, & Eakin, 2014), a nurse providing lectures and motivation (Wilks, Mortimer, & Nylén, 2006), weekly counseling and accelerometer feedback (Thompson, Koepp, & Levine, 2014), and support from an interventionist at the same time the company was implementing other health campaigns in the workplace (Tudor-Locke et al., 2014).

A major focus of the numerous workplace or school interventions has been to decrease sitting time and increase standing/moving time (Lanningham-Foster et al., 2008; Schuna et al., 2014; Stephens et al., 2014). In addition, the effects of the interventions on the following physiological variables have been investigated: weight, waist and hip circumference, cholesterol, plasma glucose and triglycerides, blood pressure, hemoglobin A1c (John et al., 2011; Koepp et al., 2013), and musculoskeletal discomfort (Hedge & Ray, 2004). The research has also has focused on energy expenditure (Buckley, Mellor, Morris, & Joseph, 2014; Cox et al., 2011; Elmer & Martin, 2014), performance on common office tasks (Hasegawa, Inoue, Tsutsue, & Kumashiro, 2001; John et al., 2009), and to a lesser extent, stress, mood, and cognitive function (Pronk et al., 2013), and academic engagement (Dornhecker, Blake, Benden, Zhao, & Wendel, 2015). Lastly, whether the subjects liked the altered work desk and environment has been investigated as this can have an effect on how much a product is used (Cifuentes, Qin, Fulmer, & Bello, 2014). The knowledge of how altered work and school environments affect the body can lead to the identification of the components of a successful intervention for different populations or environments.

Much of the research addressing sedentary behaviors has focused on the work environment, with a few studies addressing the school environments of elementary-aged-students, leaving a gap in the research which addresses students in the college setting. In many respects, the college population has the same difficulty in engaging in the proper amount and intensity of physical activity as does the general population (Keating, Guan, Pinero, & Bridges, 2005). It has been reported that a large percentage of the college population does not engage in the proper amount of MVPA and they accumulate nearly 30 hours of sedentary time from studying, and computer and television use (Buckworth & Nigg, 2004). In addition, the college classroom environment is similar to the office and school environments targeted by the previously mentioned interventions in that they have utilized standard chairs and sitting-biased desks for students for many years. However, the college setting is different in that students are not often limited to sitting for a full workday, like in an office environment, but rather they are intermittently sitting in class, at work, to study, to relax, etc., with sporadic opportunities for movement as they switch between some or all of these activities each day. It is currently unknown if the wave of newly designed desks would have a positive impact on classroom sitting time, or attention, stress, anxiety, and musculoskeletal discomfort level, or academic performance of students in the college environment.

Purpose of the Study

The purpose of this investigation is to determine the effects of an adjustable-height sit-stand desk on classroom sitting time, on attention, stress, anxiety, and musculoskeletal discomfort level, on academic performance, and on movement outside of the classroom of college students over the course of a full semester.

Research Questions

1. What is the utilization pattern of a sit-stand desk over the course of a semester-long college class?
2. Does a sit-stand desk used over the course of a semester-long college class have any effect on the amount of standing time or the intensity of movement outside of the class?
3. What are the perception of use feelings related to using a sit-stand desk over the course of a semester-long college class?
4. Does a sit-stand desk used over the course of a semester-long college class have any effect on attention, stress, anxiety, or musculoskeletal discomfort level?
5. Does a sit-stand desk used over the course of a semester-long college class have any effect on academic performance (exam scores and overall course grade)?

Limitations of the Study

There are several limitations to this research. The students who chose to participate in the study may be more interested in using sit-stand desks and therefore may not accurately represent the usage of all students. In addition, the use of video to capture standing time may affect the participants' use of the sit-stand desks (specifically, they may use them more because they know they are being recorded). The visual-analogue-scale (VAS) used to capture subjective attention, stress, anxiety, and musculoskeletal discomfort level are easy and quick to administer but do not capture specific reasons for the responses (i.e., it does not indicate why a participant responded with a low or high score). Therefore, fluctuations in these measures may be attributed to variables not measured in this study (e.g., sleep patterns, amount of physical activity, personal relationships, working while taking classes, etc.). Another limitation is the use of exam scores as our measure of academic performance. Similar to VAS questionnaires, fluctuations in exam scores may be attributed to variables not measured in this study (e.g., previous experience with the course material, amount of studying, ability to memorize information, etc.). Lastly, using accelerometers to measure movement during only two weeks of the study may not give an accurate measure of the participants' movement during other points in the semester or how much they would move at other points during the year.

Definitions

Non-exercise Activity Thermogenesis (NEAT): The expenditure of energy associated with "activities of daily living, fidgeting, spontaneous muscle contraction, and maintain posture when not recumbent" (Levine, Eberhardt, & Jensen, 1999).

Visual Analogue Scale (VAS): A visual analogue scale (VAS) consists of a single horizontal line, 100 mm in length, which allows the respondent to quickly indicate their answer to a question by drawing a vertical mark somewhere on the line. A numerical value is calculated by measuring from the left end of the horizontal line to the vertical line the participant drew. It may also consist of Likert Scale values from 1-5 (or 1-10), which allows the participant to circle a value that represents their answer. (Davey, Barratt, Butow, & Deeks, 2007)

Postprandial glucose: Blood glucose levels after consuming food (Bailey & Locke, 2014).

Inactivity Physiology: A term used to represent the effects of inactivity on the body (Hamilton, Hamilton, & Zderic, 2004).

Metabolic Equivalent (MET): A metabolic equivalent (MET) represents activity intensity and energy expenditure. One MET represents resting energy expenditure (Haskell et al., 2007).

Sedentary Behavior: Encompasses activities (i.e., sleeping or sitting) with an energy cost of 1.0-1.5 METs. (Pate, O'Neill, Lobelo, 2008).

Light Physical Activity (LPA): Encompasses physical activities with an energy cost of less than 3.0 METs (Haskell et al., 2007).

Moderate Physical Activity (MPA): Encompasses physical activities with an energy cost of 3.0 – 6.0 METs. (Haskell et al., 2007)

Vigorous Physical Activity (VPA): Encompasses physical activities with an energy cost of more than 6.0 METs (Haskell et al., 2007)

Moderate-to-Vigorous Physical Activity (MVPA): Encompasses physical activities in a combination of moderate and vigorous intensity categories (Haskell et al., 2007); or ≥ 4.0 METs. (Healy et al., 2013)

REVIEW OF LITERATURE

What Is Sedentary Behavior and Inactivity Physiology?

The potential for movement, or not moving, exists for each person as they go about their daily activities. This encompasses work or school time and free/recreational time. Past recommendations often focused on increasing the amount and intensity of purposeful physical activity (i.e., exercise). However, there is a growing emphasis being placed on sedentary behaviors and the independent effects of these behaviors on health and wellness. In a review of longitudinal studies from 1996-2011, Thorp, Owen, Neuhaus, and Dunstan (2011) concluded that "time spent in sedentary activities has been shown to be consistently associated with increased risk for all-cause, CVD-related, and all-other-causes mortality in both men and women independent of BMI and physical activity" (p. 209). Van der ploeg, Chey, Korda, Banks, and Bauman (2012) also found that the amount of PA did not change the association between sitting and all-cause mortality in a study of 222,497 subjects that were 45 years or older in Australia. Therefore, even those with high levels of physical activity had higher mortality rates if they sat for longer periods each day. However, not all research supports these views. A review of studies on occupational sitting and health risks by Van Uffelen et al. (2010) utilized the World Cancer Research Fund /American Institute for Cancer research (WCRF/AICR) criteria to evaluate the effects of behavior on health risks. In contrast to the results of Thorp et al. and Van der ploeg et al., Van Uffelen et al. concluded that "using the WCRF/AICH criteria for judging causal relationships, there is at this time only limited evidence in support of a positive relationship between occupational sitting and health risks" (p. 386). One reason for this lack of association between sitting and health risks may have been that some studies did not provide a quantification of sitting time and therefore a dose-response relationship between sitting and health risk could not be fully determined.

Born from these findings of sedentary behaviors and physical activity having independent health effects is a concept known as “inactivity physiology”. The following authors have utilized this concept as the framework of their published articles. A review by Hamilton, Hamilton, and Zderic (2004) investigated the role of movement and lack of movement (immobilization) on lipoprotein lipase (LPL) activity. They concluded that more contractile activity, in the context of an active lifestyle, could have positive metabolic effects and, therefore, slow or prevent the onset of chronic diseases. A short communication by Chia and Suppiah (2013) described an ongoing pilot intervention to determine the effects of a seat cycle to increase low-intensity activity while seated. In addition, Ekblom-bak, Hellénius, and Ekblom (2010) suggested that “sedentary behavior should be defined as the muscular inactivity rather than the absence of exercise” (p. 834). Hamilton, Hamilton, and Zderic (2007) described the four tenants of inactivity physiology and they are summarized by Ekblom-bak et al. (p. 834):

1) Sitting and limiting non-exercise activity may independently increase the disease risk.
2) Sedentary behavior is a distinct class of behavior with specific determinants and effects on disease risk, separate from the behavior of leisure-time exercise
3) The molecular and physiological responses in the human body of too much sitting are not always the same as the responses that follow a bout of additional physical exercise
4) People already insufficiently physically active will increase their risk even further by prolonged sitting time.

There have been numerous devices created or modified for the purpose of gaining health benefits during what has always been or has evolved into a sedentary activity. For instance, standard desks are now height-adjustable so a person can stand for a portion of their time at work. Also, standard treadmills have been converted into treadmills with a work surface at the top instead of the standard control panel (a Treadmill desk). These treadmill desks are run at low speeds (0.5 – 2.0 mph) to balance movement with the ability to do quality work and are sometimes height-adjustable to allow changing of positions.

The most important question that remains, and perhaps the most difficult to answer, is whether all of these modifications and the expense that goes into them provides any benefit during work, school, or free time. There are opposing viewpoints as to whether we should exert the effort or resources to champion their use. For instance, in a letter to the editor, Feld (2009) said "with payers' scrutiny of rising imaging costs, the idea of spending several thousand dollars to add a treadmill to the reading station to rescue slothful radiologists is wonderfully ironic" (p. 213). In this case, it appears the thought is that we could be more effective if we focus on increasing our movements without expensive equipment. In contrast to this opinion, some researchers have embraced the idea of integrating technology into the work day. For example, Levine (2007) has focused some of his research on creating a variety of products, as well as designing a variety of altered work or school environments, in an effort to get people to sit less during the day. Levine's review article on increasing non-exercise activity thermogenesis (NEAT) on a personal scale, as well as a large scale, shows examples of some of these products. In this case, there appears to be a more purposeful use and reliance on technology and equipment that has an additional cost to the user. In some cases the cost is small and in some cases much larger (e.g., treadmill desks or redesigning workplace or school space), but there is some emphasis on getting products produced on a larger scale and into the hands of the public.

The purpose of this review is to take a comprehensive look at the research that is attempting to get people to stand or move more at work or school, and the potential effects on health, wellness, and work or school performance that may result from sitting less and standing or moving more.

What Does the Work/School Day Look Like and Why Do People Sit or Stand?

To understand why we might need to modify equipment normally used for physical activity and bring it into the work or school environment it is important to understand the amount of sitting, standing, and moving at various intensities that people engage in during the work day. Using data from the U.S. Bureau of Labor Statistics and the U.S. National Health and Nutritional Examination Survey (NHANES), Church et al. (2011) looked at the trends in occupation-related PA. Over a nearly 50-year time span, 1960 to 2008, there was a 28% reduction in the amount of jobs requiring moderate physical activity (a drop from 48% to 20%). The moderate physical activity (MPA) occupations have been replaced with occupations requiring only sedentary (< 2 METS) or Light (2.0 to 2.9 METS) intensities. Coinciding with the reduction in intensity of movements during work is a reduction in energy expenditure of 140 and 124 kcals per day for men and women, respectively. Levine and Miller’s (2007) findings reinforce this concept of occupation as a predictor of NEAT due to the findings that office workers were able to expend an additional 119±25 kcal/h while walking and working as compared to sitting during work. In addition, those who are obese engage in less NEAT throughout the day as compared to lean individuals, and do not change this postural allocation if they lose weight (Levine et al., 2005). In a review of three studies conducted in the United Kingdom, Dall & Kerr (2010) examined sit-to-stand (STS) movements during waking hours and found that workers most often had zero STS movements with a median of three STS movements. There was one hour in the morning, 9-10 am, in which individuals who performed a lot of STS movements in a single hour typically performed many of these movements. It is possible that increasing STS movements, or maintaining the high number seen in the 9-10 am time frame, throughout the day could lead to greater NEAT.

The amount of sitting and movement time for children has also been investigated in a school setting. A study of 8-11 year olds in Canada found that girls engaged in more sedentary time, and less light physical activity (LPA) and moderate to vigorous physical activity (MVPA), in the classroom than boys (Nettlefold et al., 2011). The authors suggested developing interventions for the classroom to increase PA for all students. At present, data from college students does not exist, perhaps due to the intermittent nature of class schedules from day to day.

Does Standing, Walking, or Pedaling at a Desk Increase Energy Expenditure?

Standing

The simplest, and perhaps cheapest, method of reducing sitting time at work or school is the use of a standing desk. However, will subjects expend more calories if they stand during work or school hours? The results are mixed (Table 1). A pilot study by Speck and Schmitz (2011) measured energy expenditure (EE) via indirect calorimetry for seven minutes for each of the three working conditions: sitting, sitting on a ball, and standing. There was no significant difference in kcal/min or metabolic equivalents (METs) between the conditions. A similar study by Beers, Roemmich, Epstein, and Horvath (2008) also examined potential EE differences in sitting, sitting on a ball, and standing positions. Heart rate was found to be higher in the standing condition and EE was increased by 4.1 kcal/h in the sitting on a ball and standing conditions.

Standing desks also increased EE over sitting by 0.18 kcal/min (a 17% increase) in first-grade students participating in a full school year intervention (Benden, Blake, Wendel, & Huber, 2011) and by 0.34 ±0.14 kcal/min in college-aged students, as compared to sitting (Reiff, Marlatt, & Dengel, 2012). A similar increase in energy expenditure of 9 kcal/hr was measured in acute standing as compared to sitting (Creasy, Rogers, Byard, Kowalsky, & Jakicic, 2016), while the largest increase in EE was found in office workers maintaining a standing position for a longer time period (210 minutes) increased EE by 0.83 kcal/min, which totaled 174 ± 66 kcal for the 210 min session, compared to the sitting condition (Buckley, Mellor, Morris, & Joseph, 2014). Another workplace study found an elevated Heart Rate (HR) for standing and walking workstations as compared to sitting, as well as an increased oxygen cost (VO2) for standing compared to sitting, and walking compared standing (Cox et al., 2011). As expected, the largest increase in oxygen cost was between the standing and walking conditions (4.0±0.18 vs. 7.4±033 ml/kg/min, respectively).

Botter et al. (2013) found that a standing desk had a higher EE than sitting, but a lower EE than a treadmill desk or a Lifebalance Station. However, significance testing on the results was not reported so it is not known if the conditions were statistically different from one another. Schofield, Kilding, Freese, Alison, and White (2009) also found an increase in EE with standing and typing (+13%) as compared to sitting and typing. Again, statistical significance was not reported, nor was sample size for this part of the study, making comparison of these results to other studies difficult.

The increases in EE reported above may be small and negligible while sitting on a ball or standing for short durations but may accumulate to levels of practical significance during longer sessions and during longer interventions. However, the difference in methods used to calculate energy expenditure, the small sample sizes of some studies, and the different aged populations may make comparison of the results to one another more tenuous.

Table 1

Do Standing/Treadmill/Pedal/Stepping Desks Increase Energy Expenditure (EE)?

Source	Change in EE?	Mode	Measurement method	Duration
Speck & Schmitz, 2011	No change	sit/stand/ball	indirect calorimetry	7 min
Beers et al., 2008	+0.07 kcal/min	ball, stand	indirect calorimetry	20 min
Benden et al., 2011	+0.18 kcal/min	stand	BodyBugg armband	120 min
Reiff et al., 2012	+0.34 kcal/min	stand caloric	equivalents from VO2	30 min
Buckley et al., 2014	+0.83 kcal/min	stand	ind. regress eq. of HR vs. VO2	210 min
Cox et al., 2011	+0.8 ml/kg/min	stand	calculated from VO2	5 min
Creasy et al., 2016	+9 kcal/hr	stand	indirect calorimetry	15 min
Cox et al., 2011	+4.2 ml/kg/min	TM	calculated from VO2	5 min
Ben-Ner et al., 2014	+74 kcal/day	TM	accelerometer	full day
Thompson/Levine, ’07	+100 kcal/h	TM	accelerometer	15 min
Levine & Miller, 2007	+119 kcal/h	TM	mobile indirect calorimetry	15 min
Elmer & Martin, 2014	+155 kcal/h	pedal	regress eq.-Zunst-VO2 & RER	10 min
McAlpine et al., 2007	+289±102 kcal/h	step	mobile indirect calorimetry	15min

Walking-Stepping

Treadmills and under-desk stepping devices provide the opportunity to increase EE over standing. For example, Levine and Miller (2007) measured energy expenditure for 15-20 minute time periods in the following conditions: lying motionless, office-chair sitting, standing motionless, walking at 1 mph, 2 mph, and 3 mph, and using a walk-and-work desk (a desk that slides over a treadmill) at a self-selected pace (1.1±0.4 mph). EE significantly increased from typing while sitting in an office-chair to typing while on the walk-and-work desk (72±10 vs.

191±29 kcal/h, respectively). A similar study by McAlpine, Manohar, McCrady, Hensrud, and Levine (2007) measured energy expenditure for 15-20 minute time periods in a mixture of lean and obese subjects in the following conditions: lying motionless, office-chair sitting, standing motionless, treadmill walking at 0.5, 1, 1.5, 2, 2.5, and 3 mph, and using an under-desk stepper at a self-selected pace (39±ll steps for lean subjects and 40±12 steps for obese). The stepping device increased EE by 289±102 kcal/hour as compared to sitting in an office chair and was higher than the EE at the self-selected treadmill walking speed (2.6±0.5 mph for lean and 2.9±0.3 for obese). However, the self-selected treadmill speed was chosen based on the instructions to find a “pleasurable, exercise walking” speed and the participants were not simulating office work while measurements were collected. It is possible that a reduction in intensity (i.e., speed of the treadmill or stepping rate of the under-desk stepping device) would reduce energy expenditure in the workplace. In fact, many treadmill desks have a maximum speed of 2 mph, which is lower than the participants’ self-selected pace. Participants allowed to self-select the amount and intensity they utilized a treadmill workstation over a 6-12 month workplace intervention significantly decrease sitting time by about 77 minutes per day and increased EE by about 74 calories per day (Ben-ner, Hamann, Koepp, Manohar, & Levine, 2014). In addition, walking on a treadmill at 1 mph during a simulated 8 hr work day (medical transcription) increased EE about 100 kcal/hour during the day (actual completion time = ~7 hr), as compared to sitting (Thompson and Levine, 2011).

Pedaling

Pedaling while working has also shown promise in increasing EE over traditional seated desks. Elmer and Martin (2014) compared 10 minutes of sitting while typing to 10 minutes of pedaling while typing and found an increased EE for pedaling vs. sitting (255±14 vs. 100±11 kcal/h, respectively). Participants were given a chance to self-select a “resistance level that they could maintain for prolonged periods while performing computer tasks” during a familiarization phase before EE data was collected. It is unknown if the pedaling rate or resistance level would change over the course of a whole day in a real-world office setting.

How Have School (K-12) Interventions Changed the Classroom Environment?

It is reasonable to assume the current work day for most occupations is similar to the current school day for K-12 students, and even college students even though they are in class a shorter portion of the day, as the classroom environment has not changed for some time. The following shows there have been a small number of interventions, limited to grades 1-6, to address the sedentary design of the classroom environment. Benden, Blake, Wendel, and Huber (2011) converted all sitting desks to standing desks in the two treatment classrooms of first graders. This complete conversion to a standing classroom is similar to what has been done in workplace settings. The control group utilized standard desks, which would be similar in function to the typical desk in the workplace. In this study a small increase in energy expenditure was found in those using standing desks. A pilot study by Hinckson et al. (2013) changed third and fourth-grade classrooms, and used an additional fourth-grade classroom as a control group, in an effort to determine the acceptability of standing workstations. Five standing desks were placed in one classroom and four in another, and the sitting desks were replaced with exercise balls, bean bags, and floor mats for sitting. The experimental classroom setup fostered less sitting and more standing. It was reported that one of the teachers was motivated to use the standing workstations and one was not; the less motivated teacher had fewer study participants which may have affected motivation levels. Having fewer participants should have allowed greater access to the standing desks but it is unknown if having a larger number of non-participants in addition to a teacher less motivated to have the desks in the classroom would have affected their use. From a feasibility standpoint, it seems more likely that schools or workplaces would only be able to provide standing or walking options for a limited number of students or workers instead of all of them and that motivated users could be in close proximity to nonusers.

A few school interventions have also attempted to increase activity during school hours. Cardon, De Clercq, De Bourdeaudhuij, and Breithecker (2004) created “Moving school: the school as a place of work” in an effort to “increase the seating quality, i.e. the relationship between sitting and working as well as the sitting postures of schoolchildren” (p. 135) in 8 year old children. A major finding was that the control students (traditional classroom with sitting-desks) sat an average of 97% of the class time and a third of the students sat with greater than 45 degree truck flexion. The “Moving School” students spent more time in dynamic sitting, standing, and walking even though both groups of students spent an equal time reading and writing. An even more dramatically altered classroom design was examined by Lanningham-Foster et al. (2008) in a class of grade 4/5 students in three classroom designs: a large activity-permissive environment created for the study (The Neighborhood), a classroom with adjustable-height desks for standing or siting on a stability ball, and a traditional classroom with only sitting-desks. The PA of students in all three classrooms was compared to the movements of a group of similar aged children on summer vacation. Over the 12-week intervention period, “The Neighborhood” elicited significantly greater movements as compared to the other two classrooms, as well as movements that approximated the amount of PA of a group of same-age students during summer vacation. In addition to these interventions, a pilot study using a small group of sixth graders by Koepp et al. (2012) gave each participant a standing desk with stool in a 5-month intervention. The authors utilized pedometers to measure movements and reported a non-significant increase in steps/day during the intervention. The use of a stool, which essentially provides for a taller sitting-desk, may have accounted for the statistically non-significant results.

At present, no interventions have been conducted in a college classroom in a similar fashion to the previous mentioned interventions aimed at elementary students. A short paper by Rutten, Savelberg, Biddle, and Kremers (2013) introduced Stand Up For Fitness (STUFF) which "can be defined as 'interrupting long sitting periods by short breaks', for instance, interrupting sitting every 30 min by standing for at least five minutes" (p. 2) and indicated their "preliminary experience" in using prompts during lectures for college health-science students was positive. More research is needed to determine if classroom interventions can be effective in the K-12 and college classrooms.

Is Work Performance Impacted by Standing, Treadmill Walking, Cycling, or Stepping?

If the previously described devices are used to increase standing and movement while doing work or study tasks (e.g., typing, computer mouse movements, talking on the phone, reading, writing, etc.), will they change the performance of these tasks? Numerous studies have been conducted to determine the effects of these interventions on work performance. It appears that standing or walking on a treadmill while performing work tasks either do not negatively impact or may only slightly decrease performance, as compared to performance while sitting, but that these initial performance decrements may return after the subject gains familiarity with the new body position (stand or walk). In fact, performance may even increase as of function of being more alert. For example, a walking workstation increased satisfaction and arousal, and decreased boredom and stress as compared to seated and standing workstations (Sliter & Yuan, 2014). However, the cycling workstation had the lowest satisfaction and performance rating compared to the seated, standing, and walking workstations. It may be that enough movement to break the sedentary nature of sitting or standing is beneficial but that too much movement, or a movement that people are not as comfortable with (e.g., cycling), might decrease focus or lead to more performance errors.

Commissaris et al. (2014) looked at simulated office tasks (typing, reading, telephone, and mouse dexterity) in a variety of positions and devices (sit, stand, treadmill desk, semi-recumbent elliptical trainer, and bicycle ergometer). Perceived performance was negatively affected by the conditions requiring movement as compared to sitting (control). Objective performance on mouse dexterity also decreased for all the movement conditions while only typing speed was decreased for the treadmill condition. Reading performance did not differ between conditions and cognitive performance decreased only for the higher intensity bicycle ergometer condition. In addition to the previously mentioned studies, an investigation on speech quality while sitting, standing, and walking on a treadmill at 1.61 km/h found no significant difference in speech quality (number of syllables per phrase or ungrammatical pause(s) per reading) between the three conditions (Cox et al., 2011).

Sit-Stand

Hassegawa, Inoue, Tsutsue, and Kumashiro (2001) studied sitting, standing, and a variety of different length sit-stand combination positions (50% sit, 50% stand) during 60 and 90 minute sessions. Work performance decreased with the longer sessions and with the standing or sitting conditions; the combination positions that alternated between sitting and standing improved work performance. Similarly, performance in an English transcription task was highest in an alternating sit and stand condition as compared to sitting and sitting in a high-chair (Ebara et al., 2008). A field experiment by Hedge and Ray (2004) compared existing fixed-height workstations (FHWs) to electronic height adjustable workstations (EHAWs) and found the EHAWs had significantly higher productivity ratings. In contrast to the previous studies, Drury et al. (2008) did not find any difference in the performance of security operators during an X-ray baggage screening task between sitting, sitting on a high-chair, and standing conditions. Also, an intervention to get subjects to “Stand Up, Sit Less, Move More” did not result in any differences in self-rated work performance or moving more; however, subjects had significantly more standing and less sitting (Healy et al., 2013). There was also a high preference rate (82.4%) for the EHAW.

Treadmill

Various measures of work performance have been evaluated during treadmill use and have shown mixed results. No difference in cognitive function (using the Stroop Test, Flanker task, and SAT equivalent reading comprehension tests) was found between being in a seated position and walking on a treadmill at a self-selected pace (Alderman, Olson, & Mattina, 2014). Funk et al. (2012) evaluated typing performance in a seated condition and on a treadmill at three difference speeds (1.3, 2.25, and 3.2 km/hr; equivalent to 0.8, 1.4, and 2.0 mph, respectively). The seated condition had better performance than the slow and fast walking conditions but there was no difference in typing performance between the seated and 2.25 km/hr walking speed conditions. The 2.25 km/hr walking speed was most preferred by the subjects (11 of 24 subjects) and the 3.2 km/hr was preferred by 9 of 24 subjects. John, Bassett, Thompson, Fairbrother, and Baldwin (2009) compared sitting and walking on a treadmill at 1 mph on simulated office work tasks and found no difference in reading comprehension but lower scores for typing and mouse proficiency and a lower math solving ability while walking on the treadmill. Accuracy of medical transcription (number of transcription errors) during 8-hr of treadmill walking and 8-hr of sitting did not differ from one another but treadmill walking had a significantly slower completion time of the dictation task as compared to sitting (~7 hr vs. ~6 hr, respectively) (Thompson & Levine, 2011).

Work performance during long-term use of treadmill desks has also been evaluated. Interestingly, Ben-ner, Hamann, Koepp, Manohar, and Levine (2014) found that using a treadmill desk was initially associated with a slight decrease in employee self-rated and supervisor-rated overall work performance but that overall performance subsequently increased after hitting the low point around 21-24 weeks into the year-long intervention. At the end of the study the overall performance measures were 0.69 points and 1.11 points higher for employee self-rated and supervisor-rated performance, respectively. A one-year trial of using Treadmill desks in the workplace found similar results in that there was no difference in employee self-assessed or supervisor-assessed workplace performance; however, there was a trend for performance to decrease slightly from baseline in the first 3-5 months and then return to slightly over baseline by the end of the intervention (Koepp et al., 2013).

Cycle

There are fewer studies on pedaling devices but they may show promise because they do not drastically change the position of the user compared to traditional seated desks. A perception questionnaire completed by subjects using a pedal exercise machine found most reported “disagree” or “strongly disagree” responses associated with the following statements: My work-related productivity decreased while using the machine, the quality of my work deceased while using the machine, and the machine interfered with my daily work-related tasks (Carr, Walaska, & Marcus, 2012). A transcription typing task in seated while typing and pedaling while typing conditions resulted in no significant differences in typing performance between the two conditions (Elmer & Martin, 2014).

How Have Workplace Interventions Altered Workspaces and Were the Changes Effective?

Yates et al. (2011) identified a common business approach, “where human motion is explicitly viewed as ‘waste’, which has resulted in a workforce increasingly enslaved to their desks and computers” (p. 294). The following research is aimed at reversing this increase in sedentary time, which is likely caused by several mechanisms, by increasing standing and moving in the workplace. Since many occupations require long bouts of sitting the workplace environment is fertile ground for movement interventions. The interventions have some similarities (i.e., getting workers to stand or walk at their desk) but there has also been a variety of devices, methods of implementing, and intervention lengths in an effort to get subjects to replace sitting time with standing (Table 2), stepping (Table 3), or pedaling.

Sit-Stand

Alkhajah et al. (2012) allowed workers to utilize a sit-stand desk and adjust it as they saw fit but did not otherwise change their workspaces. The subjects were given written instructions on “the importance of regular postural changes throughout the day” (p. 299). The pilot intervention resulted in a reduction of sitting and a subsequent increase in standing of nearly two hours at the workplace after 1-week and 3-months of using the sit-stand desks. The participants of a similar 3-month workplace intervention using manual and electronic adjustable sit-stand desks significantly reduced the proportion of sitting time at work by an average of 23% and the overall time spent sitting by an average of 1.7 hr (Grunseit, Chau, van der Ploeg, & Bauman, 2013). The Take-A-Stand project utilized sit-stand desks over a 4-week intervention and 2-week post-intervention period for an intervention group (n=24) and a comparison group (n=10), which did not receive a sit-stand desk (Pronk, Katz, Lowry, & Payfer, 2012). Standing and sitting time, as evaluated via experience-sampling methodology (ESM), showed significantly less sitting (increased ESM scores by 224%) in the sit-stand group during the intervention period. Interestingly, the sit-stand group showed a significant increase in sitting during the post-intervention period, to a level significantly greater than baseline levels. Similar results were found in self-reported work sitting time (a reduction of sitting by 66 minutes during intervention and a return to baseline in the post-intervention period). Schofield et al. (2009) implemented a sit-stand desk for one week and found an increase in standing time (0.4 hr – 2.8 hr). This part of the study only had three subjects so it is hard to compare these results to other studies.

For many businesses it may not be feasible to purchase a standing-desk for each individual which may necessitate sharing desks. Gilson, Suppini, Ryde, Brown, and Brown (2012) explored this situation by setting four height-adjustable desks in the center of an office for one week to allow workers to use as they saw fit. Use of the standing desks for the 11 participants averaged 3:54±3:18 hr (range 0-9:35 hr) each day. The percentage of sedentary time ranged from a decrease of 5.9% to an increase of 6.4% (six participants decreased and five increased sedentary time), the change in light activity ranged from -6.8 to 7.9 %, and the change in moderate activity ranged from -1.8 to 2.3%. It is possible the small number of desks may have limited their use for some participants. However, having only a few desks to share may represent a more realistic situation due to the cost of equipping all workers with their own standing-desk.

Table 2

Standing-Desk Workplace Interventions

Source	Duration	Speed (mph)	Results
Gilson et al., 2012	1 wk.	Shared 4 (n=11)	↓/↑ sit (mixed results)
Dutta et al., 2014	4 wk.	Individual Desks	↓ sit = 4.8 min/hr @ work
Pronk et al., 2012	4 wk.	Individual Desks	↓ sit = 66 min/workday
Grunseit et al., 2013	3 mo.	Individual Desks	↓ sit = 1.7 hr/workday
Alkhajah et al., 2012	3 mo.	Individual Desks	↓ sit = 2.4 hr/workday
Stephens et al., 2014	4 wk.	Indiv. Desks (MC)*	↓ sit = 125.2 min/workday
Healy et al., 2013	4 wk.	Indiv. Desks (MC)*	↓ sit (338.5±35.3 v. 216.7±67.9 min)
Neuhaus et al., 2014	3 mo.	Indiv. Desks (MC)*	↓ sit 89 min/8 hr day
Wilks et al., 2006	± 1 yr.	Indiv. Desks (MC)*	20% of subjects used ≥ 1x/day

*MC = Multicomponent – several intervention strategies were implemented

There are several multicomponent interventions that offer participants more than just an altered desk. For example, a pilot study by Stephens et al. (2014) evaluated sit-stand workstations as part of a 4-week, multicomponent Stand Up Comcare workplace intervention. Use of the sit-stand desks resulted in a significant decrease in total sitting time (-125.2 min; range -29 to -262 min per 8 h workday), sitting bout duration (-5.6 min), and a reduction in sitting time during all hours of the day compared to the control group. The greatest declines in sitting generally occurred in the morning hours. As part of the Stand Up Comcare project, Healy et al. (2013) coupled sit-stand workstations with a workshop to inform participants of the health effects of sitting and a person within the organization to help participants with any issues and to send out tips via email to get participants to stand more. Standing time significantly increased from baseline to the end of the 4-week multicomponent intervention (99.9±26.2 vs. 221.1±68.1 min/8-hr workday) and sitting time significantly decreased (338.5±35.3 vs. 216.7±67.9 min/8-hr workday) with no changes in workday steps, stepping time, or MVPA MET minutes. Neuhaus, Healy, Dunstan, Owen, and Eakin (2014) also created a multicomponent intervention that coupled a sit-stand workstation with additional resources (face-to-face coaching, email, phone calls, and a tracking tool) to facilitate increased usage of the sit-stand desks. This 3-month multicomponent intervention was compared to a workstation-only group that did not receive any additional resources other than the sit-stand desk and a comparison group that did not have any modifications to their workspace or receive the additional resources. There was a significant increase in standing time between the multicomponent and comparison group (+93 minutes per 8 hr workday for multicomponent) and the multicomponent and workstation-only group (59 minutes per 8 hr workday for multicomponent), as well as a significant decrease in sitting time between the multicomponent and comparison group (-89 minutes/8 hr workday for multicomponent) and the multicomponent and workstation-only group (-56 minutes/8 hr workday for multicomponent). Another study utilizing a multicomponent intervention evaluated the use of a combination of manual (n=24) and electronic (n=141) adjust sit-stand workstations at four workplaces (Wilks, Mortimer, & Nylén, 2006). Sit-stand desks were available to all, or nearly all, employees within a department at these workplaces. Questionnaire data on desk utilization showed 20% of the participants used the desk “at least once per day” with 60% using it “once monthly or less” (this percentage increased to 70% for those over 51 years). No significant difference in utilization was found for electric vs. manual desks or having the desk < 1 year vs. > 1 year. One of the four workplaces utilized additional resources (a nurse providing lectures and motivation) which increased usage of the sit-stand desks, particularly in the use “at least once a day” category, although the results were not significant. The results from Healy et al., Neuhaus et al., and Wilks et al. support the use of additional resources to facilitate using the altered work desks.

Walking on Treadmills

Some treadmill workstations have been created by combining separate treadmills and desks, which does not allow for sit-stand transitions. Using non-adjustable walking workstations (treadmill walking at 1 mph) in a 6-week intervention (2-week baseline period followed by 2-week acclimation period followed by 2-week intervention period) resulted in a significant increase in steps taken from baseline to acclimation period to intervention period (2200 vs. 4000 vs. 4200, respectively) (Thompson, Foster, Eide, & Levine, 2008). The walking workstation also resulted in all subjects walking at least an additional 30 minutes and an estimated average increase in EE of 100 kcal/day (estimated range = 44-253). Another study used a non-adjustable walking workstation to determine if it had an effect on radiologists' interpretation of computed tomographic (CT) images (Fidler et al., 2008). Two radiologists reviewed CT images in short sessions (10 cases per session), while walking on a treadmill at 1 mph, over an 8-month time period. Both reviewers had significantly higher mean detection rates as compared to convention interpretation (99.0±5.3 % (range 67-100%) vs. 88.9±25.3 % (range 0-100%) for reviewer 1; 99.1±6.3 % (range = 50-100%) vs. 81.3±34.1% (range = 0-100%) for reviewer 2). The authors acknowledged the small number of cases reviewed per session and a quieter room compared to normal interpretation, as well as a second interpretation and a greater focus on interpretation (Hawthorne effect), as possible reasons for the improvement in detection rates that make it difficult to know the exact effect of the walking workstation.

Table 3

Treadmill-Desk Workplace Interventions

Source	Duration	Speed (mph)	Desk height	Results
Thompson et al., 2008	2 wk. (n=8)	1	non-adjust	↑ 2000 steps/d
Fidler et al., 2008	8 mo. (n=2)	1	non-adjust	↑ perf. - Radiology
John et al., 2011	9 mo.	Self-select	adjustable	↓ sit; ↑ steps
Ben-Ner et al., 2014	1 yr	max 2	adjustable	↓ SED; ↑ PA
Koepp et al., 2013	1 yr	max 2	adjustable	↓ SED; ↑ light/active
Schuna et al., 2014	1 yr (S)*	max 2	adjustable	↓ SED; ↑ steps
Thompson et al., 2014	12 wk (MC)*	1	non-adjust	↑ activity units/d
Tudor-Locke et al., 2014	3-6 mo (S-MC)*	1.6-1.9	adjustable	2x45 min/d=disruptive

*S = Shared - desks were shared amongst participants
*MC = Multicomponent – several intervention strategies were simultaneously implemented

Other treadmill interventions have utilized adjustable height desks with treadmills allowing for quick adjustment between sitting and standing positions. Treadmill workstations were placed in the workspaces of overweight/obese office workers and no information was given to the participants on how they should use the workstations allowing for self-selected use patterns during the 9-month intervention (John et al., 2011). Use of the adjustable treadmill workstation resulted in a significant decrease in the time (min/day) in sitting or lying down, and increased standing time, stepping time, and the number of steps per day at the end of the intervention. Ben-ner et al. (2014) conducted a 12-month treadmill workstation intervention in office workers with day, evening, and night shifts. Participants were allowed to adjust the speed (max = 2 mph) and position (sit vs. stand) of the treadmill at their discretion. Those workers that used the treadmill during the day increased caloric expenditure more than those using it during the evening, as compared to not having a treadmill, while those working the night shift did not increase caloric expenditure compared to not having a treadmill. Having a treadmill was also associated with a decrease in sedentary time of about 77 minutes per day, with an associated increase in “light” activity of 41 minutes and “active” activity of 39 minutes. A similar 1-year electric-adjustable treadmill desk intervention allowed a mixture of lean, overweight, and obese subjects to self-select the position and the speed (max = 2 mph) of their treadmill (Koepp et al. 2013). There was a significantly decreased sedentary time and increased daily PA at 6 and 12-months, although for both variables the values at 6 months were more pronounced than at 12 months. The amount of walking at work followed a similar pattern from baseline, 6-months, and 12-months (70±25 vs. 128±62 vs. 109±62 min/day, respectively). Another treadmill-desk intervention investigated shared desks with overweight and obese office workers and found treadmill desks were associated with a decrease in sedentary time (-3.6 minutes/hour) and an increase in daily steps (1622 steps/day) (Schuna et al., 2014).

Some studies utilizing treadmill workstations have created multicomponent interventions by providing participants additional resources to facilitate greater movement. For example, a 24-week crossover-design intervention with overweight and obese physicians had subjects use a treadmill desk for 12 weeks with weekly counseling and accelerometer feedback and 12-weeks with accelerometer feedback only (Thompson, Koepp, & Levine, 2014). Compared to the control group, using the treadmill desk at 1 mph during work tasks (not when seeing patients) resulted in significantly greater change in EE per day (-40.3±108.5 vs. 156.9±259.1 kcals, respectively) and Activity Units Per Day (-0.341±0.564 vs. 0.899±1.26 AU*10^6, respectively). A multicomponent Workstation Pilot Study by Tudor-Locke et al. (2014) provided the intervention groups with shared treadmill desks (two 45-minute sessions/day) and support from an interventionist, at the same time the company was implementing other health campaigns in the workplace, over the 3-6 month intervention (Cohort 1 = 6 months and Cohort 2 = 3 months). Self-selected walking speed for participants ranged from 1.6 to 1.9 miles/hr (~ 2 METS). The use of the treadmills (adherence % and minutes/day) were higher for the first three months than the last three months of the intervention. The need to adhere to scheduled use times, having to move work materials to the treadmill-desk, and other work conflicts (i.e., meetings) were identified as disruptive and decreased use of the treadmill-desks. Interestingly, the patterns of treadmill use of supervisors affected the use of workers that reported to them; in this case the supervisors had the lowest usage. The results of the previous studies show that multicomponent interventions, in addition to being able to provide all individuals with their own device, appear to have a positive effect on the use of treadmill-desks, particularly over longer intervention durations.

Pedal

A pedal exercise machine used under or next to a desk resulted in pedaling an average of 23.4±20.4 minutes and 4.8±3.6 miles on the 12.2±6.6 (range 2-20) days participants used the pedal machine over the course of a four-week (a total of 20 work days) workplace intervention (Carr et al., 2012). No other instructions, suggestions, resources, or prompts related to increasing use of the device were given to the participants.

Movement Breaks

Some studies have attempted a similar goal to the previously mentioned studies, that is to sit less and stand/move more, but have done so without altering the desks or work environment of the participants. For example, Taylor et al. (2013) introduced Booster Breaks, which incorporated 12-15 minutes of aerobic, strengthening, stretching, and flexibility movements, led by a trained facilitator, into a 6-12 month workplace intervention. The Booster Break occurred once each workday. The qualitative data indicated the Booster Breaks reduced stress, as well as increased enjoyment, health awareness, and workplace interactions. The subjects also identified variety in the routine and support from management (e.g., encourage worker participation and increased management participation) as areas that could enhance the Booster Breaks. In contrast to Taylor et al., Cooley & Pedersen, (2013) implemented a passive prompting workplace intervention to get employees to self-select an activity, as well as the duration and intensity of the movements, from a list of office activities. The study utilized an “e-health software program” and was divided into an initial 13-week period with the software providing prompts (for the participant to move) that could not be ignored (“passive prompt”) and a subsequent 13-week period that required participants to voluntarily use the software to receive prompts to move (“active prompt”). Results indicated participants were much more likely to engage in movement with passive prompts than active prompts (2320 participant days vs. 573) and to have more days with movements in each hour of the workday (1216 participant days for passive vs. 108 for active prompts). The passive prompt condition also had the highest number of movements for an individual (23 vs. 16 for active prompts).

The results of these workplace interventions indicate that NEAT can be increased in the workplace via the use of standing-desks, treadmill desks, mini steppers, or elliptical/pedal stations under a desk. Physical activity was highest with the use of individual treadmill desks or cycling stations.

Does Standing or Walking at Work or School Improve Health Outcomes Over Sitting?

The increase in sedentary time that we have seen in recent years can lead to increased risk of chronic disease. A review of longitudinal studies from 1996-2011 by Thorp, Owen, Neuhaus, and Dunstan (2011) determined that sedentary behaviors (movements requiring 1.0-1.5 METs of energy expenditure) are linked to higher risk of obesity during childhood and/or adolescence, cardiovascular disease, mental disorders, and all-cause mortality and controlling for the time spent in PA did not modify these associations. Can the devices that have been used in workplace interventions to decrease sedentary time also lead to improved anthropometric and cardio-metabolic values and ultimately reduce risk of disease? Addressing the amount of NEAT that people engage in throughout the day, particularly in situations that people are likely to engage in large amounts of sedentary behaviors (e.g., work or school), may represent an opportunity to maintain, or even improve, anthropometric and cardio-metabolic values. The results of Levine, Eberhardt, and Jensen (1999), in which they overfed subjects by 1000 kcal/day and determined the ability to resist weight gain was facilitated by changes in NEAT, provide support for this concept.

Large-scale studies provide an opportunity to observe behaviors of large groups of people and associate their behaviors with various health outcomes. Ekelund et al. (2015) utilized a subset (334,161 subjects) of the EPIC cohort study to investigate the relationships between physical activity, adiposity, and all-cause mortality. It was determined that moving from "inactive" to "moderately inactive" had the most significant decreased hazard ratios, a theoretical reductions of deaths of 7.35%, and an increase in life expectancy of 0.70 years. The authors were encouraged "that our results suggest small increases in PA in those who are currently categorized as inactive appear to be associated with significant reductions in all-cause mortality at all levels of BMI and WC" (Ekelund et al., p. 7). Healy et al. (2008) utilized a subset (168 subjects) of the participants in the Australian Diabetes, Obesity, and Lifestyle (AusDiab) study to look at the effects of breaking up sedentary time on metabolic risk factors. The breaks were of light intensity and short duration (less than 5 minutes) and were associated with more favorable waist circumference, body mass index (BMI), triglycerides, and 2-h plasma glucose profiles. The authors acknowledged the difficulty in elucidating the likely complex mechanisms for the observed improvements in several metabolic risk factors. Providing further evidence to reduce sitting is the Danish Health2006 study (2544 subjects) compared sitting time assessed from the Physical Activity Scale 2 (PAS2) with a variety of cardio-metabolic risk factors (Saidj, Jørgensen, Jacobsen, Linneberg, & Aadahl, 2013). Overall sitting time was significantly associated with detrimental effects on waist circumference, BMI, body fat %, high density lipoprotein (HDL) and low density lipoprotein (LDL) cholesterol, triglycerides, and insulin. Interestingly, occupational sitting time was found to have detrimental effects on fewer cardio-metabolic risk factors as compared to leisure-time sitting. The authors suggested differences in the amount of snacking or breaks during work or leisure time as possible explanations for the observed differences.

Smaller-scale studies give the opportunity to determine if health outcomes can be improved by interventions aimed specifically at altering the sedentary environments common in workplaces or schools. Bailey and Locke (2014) looked at the effects of sitting, sitting with 2-min of standing per 20 minutes, and sitting with 2-min of walking per 20 minutes (each trial lasted five hours) on plasma glucose, blood pressure (BP), total cholesterol, HDL, and triglycerides. The postprandial glucose response was significantly lower for the sitting with walking condition than the other two conditions. The authors speculated that more time standing may be necessary to initiate changes. There was no difference in any of the conditions for any of the other cardio-metabolic risk markers. Buckley, Mellor, Morris, and Joseph (2014) also looked at the effects of sitting and standing on postprandial glucose levels. The standing condition resulted in a 43% lower excursion of blood glucose, a lower peak blood glucose response, and a peak that occurred slightly earlier as compared to the sitting condition. Similar interventions have been introduced into classrooms. A five-month pilot-study to implement standing desks in a sixth-grade classroom found an increase in body weight and height, which would be expected in children over nearly half a year, but BMI did not change significantly (Koepp et al., 2012). A small sample size and the ability of the students to use a stool at the standing-desk may have contributed to the lack of significant changes in pedometer steps or BMI.

In addition to incorporating more standing during the day, some studies have introduced walking, often using a treadmill-desk, as a way to create beneficial health outcomes. A multicomponent office intervention (“Stand Up, Sit Less, Move More”) attempted to reduce sitting time in office workers and also monitored anthropometric, cardio-metabolic factors, and self-reported measure of fatigue and work performance (Healy et al., 2013). An improvement in glucose was observed in the intervention group but there were no other significant differences between the baseline and follow-up or between the intervention and control groups for any of the anthropometric, cardio-metabolic factors, and self-reported measures. John et al. (2011) also implemented a worksite intervention to increase PA in office workers. Treadmill-workstations (TMWS) were utilized over a 9-month time period resulted in a significant reduction in waist and hip circumference, LDL and total cholesterol, and a significant negative correlation between steps per day and resting systolic BP. Trends for reduced body weight, BMI, and body fat % were also observed but these results were not statistically significant. The results of a similar workplace intervention utilizing treadmills over the course of one year showed a significant decrease in fat free mass at 6 months, a decrease in body weight, waist circumference, and systolic BP at 6 and 12 months, and an increase in Hemoglobin A1c at 6 months and HDL at 12 months (Koepp et al., 2013). It appears that the likelihood of seeing changes in anthropometric or cardio-metabolic variables increase with the longer interventions. Along with small samples sizes, this may be why the shorter interventions tended to not show significant changes in these variables. For example, a treadmill-desk intervention by Thompson, Koepp, and Levine (2013) over a 24-week intervention period (12 weeks of treadmill, accelerometer, and exercise counseling and 12 weeks with only accelerometer feedback) resulted in a significant change in weight when using the treadmill compared to control (-1.33±2.51 kg for treadmill vs. 0.52±0.99 kg for control) and body fat % (-0.44±1.31 for treadmill vs. 1.45±1.59 for control), but no differences in metabolic or well-being measures.

The effects of sedentary behaviors on various aspects of lipid metabolism has been investigated in both rats and humans. Unloading the hind limbs significantly decreased heparin-released lipoprotein lipase (HR-LPL) activity in the skeletal muscle of unloaded limbs of rats (Bey & Hamilton, 2003). The HR-LPL levels are restored by ambulatory activity and the authors concluded it may provide support for the public health messages derived from human epidemiological studies. In a subsequent study, Zderic and Hamilton (2006) unloaded the hind limbs of rats and found that lowering plasma lipids, via nicotinic acid, was able to prevent a decrease in HR-LPL in inactive rats. More recently, Miyashita et al. (2013) investigated postprandial lipaemia in sitting, standing, and treadmill walking conditions in humans. The walking condition (30 minutes of brisk walking at a self-selected pace on a treadmill) had significantly lower postprandial serum triglyceride and plasma glucose concentrations as compared to the sitting or standing conditions.

The increase in occupational and leisure-time sedentary behaviors can lead to deleterious effects on mental health as well. A cross-sectional sample of 3367 government employees in Australia evaluated the associations between sitting at work and mental health (Kilpatrick, Sanderson, Blizzard, Teale, & Venn, 2013). Self-reported measures of sitting time at work, survey data from the International Physical Activity Questionnaire (IPAQ), and scores of psychological distress from the Kessler psychological Distress scale (K10) were analyzed. Generally, sitting more and engaging in the less PA were correlated with more psychological distress; moderate distress for men and moderate to high distress for women. These results remained significant after controlling for leisure time PA and BMI. The Take-A-Stand-Project introduced standing desks for a 4-week intervention period in a work setting (Pronk et al., 2012). The standing-desks resulted in significant improvements for the following self-reported mood states: fatigue, vigor, tension, confusion, depression, and total mood disturbance. Values for mood states were also evaluated after reverting back to standard desks for a two-week period after the intervention and, interestingly, vigor and total mood disturbance reverted to original levels in this short time frame. A review on the association of sitting and cognitive health concluded “that sedentary behavior could be a lifestyle factor that uniquely affects brain health and risk for dementia” (Voss, Carr, Clark, & Weng, 2014, p. 18). The findings of these studies related to mental health and psychological distress may necessitate the implementation of effective workplace interventions aimed at all employees to decrease workers’ distress, improve mood states, and ultimately increase their workplace performance.

Musculoskeletal pain and fatigue during standing, walking, and pedaling interventions has also been investigated to determine if these new positions lead to more or less discomfort as compared to sitting. Ebara et al. (2008) had subjects perform work tasks for 3-40 minute sessions in each of the following conditions: sitting in a standard chair, sitting in a high-chair, and a combination sit-stand position consisting of alternating between sitting in a high-chair for 10 minutes and standing for five minutes. Generally, musculoskeletal discomfort level increased over time for each body part and higher discomfort levels resulted from the high-chair and sit-stand positions as compared to the standard sitting position. Chester, Rys, and Konz (2002) investigated leg swelling, comfort, and fatigue in sitting, standing, and a sit/stand position and found the standing positon had the worst upper leg, knee, lower leg, ankle, and foot comfort level. The authors concluded these results were "understandable, considering no movement was allowed for 90 minutes" (p. 295). Similarly, Hassegawa et al. (2001) investigated 60 and 90 minute sessions of sitting, standing, or a variety of different length sit-stand combination positions (total time split equally between sit and stand) resulted in higher fatigue in the longer sessions and in the standing position. In a longer study (6 months), Cifuentes, Qin, Fulmer, and Bello (2014) initially saw similar results (increased discomfort) to the previously mentioned studies but found that it took an average of two weeks for the discomfort symptoms in the foot and knees to recede.

In contrast to the studies showing increased pain or discomfort, musculoskeletal discomfort ratings have been shown to be better (i.e., lower) in the afternoons when using electronic-height adjustable workstations (EHAW) as compared to fixed-height standard desks; "across all body parts there was an average 27.5% decrease in symptoms prevalence with the EHAWs" (Hedge & Ray, 2004, p. 1093). Also, little to no musculoskeletal pain or fatigue was found in New Zealand elementary school third and fourth graders when using standing desks in the classroom for four weeks (Hinckson et al., 2013). A perception questionnaire filled out by subjects using a pedal exercise machine found all reported "disagree" or "strongly disagree" responses associated with the following statements: I had more back pain on days I used the machine, I had more joint pain on days I used the machine, and I had more muscle aches on days I used the machine (Carr, Walaska, & Marcus, 2012). Botter et al. (2013) found that all standing workstations (conventional standing and treadmill desk) had lower cervical spine flexion and trunk flexion, which may have the potential to decrease musculoskeletal pain in the long run, but they did not assess participants' comfort levels.

Do Participants Like Using Standing or Moving Desks During Work or School?

In addition to objectively measuring the benefits, it is also valuable to determine if people like to use these redesigned desks for standing, walking, stepping, or pedaling, and if they perceive them as being useful (Table 4). Beers, Roemmich, Epstein, & Horvath (2008) found that subjects gave a greater liking score to typing in a sitting position compared to standing, but there was no difference in liking between sitting on an office chair or a therapy ball. The study protocol required the subjects to keep their feet on the floor and did not allow them to move their feet for each 20-minute trial. The authors acknowledged that this, as well as the absence of time to accommodate to the "novel postures", as potentially limiting energy expenditure or liking scores. Perceptions related to using a portable pedal exercise machine showed all subjects responding "agree" or "strongly agree" (Likert-scale questionnaire; 1=strongly disagree, 5 = strongly agree) associated with the following statements: The pedal machine is easy to use, I would use the machine as an alternative activity in bad weather, I would use the machine while at home, I could read comfortably while using the machine (Carr et al., 2012). Similarly, the subjects all reported "disagree" or "strongly disagree" responses associated with the following statements: The quality of my work decreased while using the machine, and the machine interfered with my daily work-related tasks. Thompson & Levine (2011) also used a Likert-scale questionnaire to evaluate participants' opinions of the use of a treadmill during a medical transcription task during a full workday. Results showed disagreement with the statement "The workstation interfered with my quality of work" and "If the workstation was available, I would not use it regularity" indicating a positive response to the treadmill workstation. A similar questionnaire related to the perceptions of using a walking workstation during a 2-week acclimatization and subsequent 2-week work period resulted in a mean score of 4.4 for “If this were an option, I would use it”, 4.1 for “The new workstation could be used in the clinical environment”, and 3.9 for “The new workstation did not interfere with patient care” (Thompson et al., 2008, p. 227). The question “I was more tired at the end of the day had a mean score of 3.0 and generated the most variety in participant responses. Cifuentes et al., (2014) also reported that an electric adjustable desk exceeded the worker’s expectations, but the treadmill workstation did not. At present, there is no data from the k-12 school interventions to indicate if the students liked the changes to the classroom environment and no interventions in a University classroom setting exist.

Table 4

Are Standing/Walking/Pedaling Desks Liked/Tolerated?

Source	Liked?	Mode	Duration	Movement instruction
Beers et al., 2008	No	standing	1x - 20 min	could not move feet
Beers et al., 2008	Yes	sitting on a ball	1x - 20 min	could not move feet
Frost & Terbizan, 2015	Yes	stand	3 weeks	choice – sit or stand
Dutta et al., 2014	Yes	stand	4 weeks	Goal = 50% standing
Carr et al., 2012	Yes	pedal (portable)	4 weeks	pedal as they saw fit
Thompson & Levine, 2011	Yes	treadmill	full workday	walk @1 mph 7-8 hr
Thompson et al., 2008	Yes	treadmill	2 weeks work	choice – sit or stand
Cifuentes et al., 2014	Yes*	treadmill	6 months	use at will
Cifuentes et al., 2014	No*	treadmill	6 months	use at will

*YES = Enjoyed the electric adjustable desk
*NO = Treadmill created difficulties in talking with people, foot/knee discomfort for first few weeks, hard to draw or do spreadsheets

What Are the Components of a Successful Intervention?

The variety of workplace and school interventions to date allow us to create some guidelines to follow in creating an intervention that would maximize success in getting users to stand and move more during portions of the day that are currently filled with sedentary behaviors. Inside workers currently most often have very few (mode=0, median =3) sit-stand movements per hour during the day (Dall & Kerr, 2010) and this needs to increase. Promoting a larger amount of daily sit-stand movements is supported by the finding that more breaks in sedentary time were associated with more favorable waist circumference, BMI, triglycerides, and 2-hr plasma glucose (Healy et al., 2008).

To promote breaks in prolonged sitting time, “an intervention should ideally be simple, should not require much cognitive energy, and should be easy to perform” (Rutten, Savelberg, Biddle, & Kremers, 2013, p. 2). It would make sense then that any devices utilized in the interventions would also be easy to use from a cognitive and physical sense. Levine (2007) agrees about the ease of use (low behavioral cost), and added that individuals should not feel forced into a particular activity or device, the device should be individualized, there is a delay in getting an outcome or reward from the new behavior, and that a more valued NEAT-promoting behavior will increase the likelihood of a person participating in that behavior. A study of the perceptions of occupational sitting echoed Levine’s findings in that responses from occupational health and safety practitioners showed an awareness of “the dichotomy between providing choices for employees to stand and move more (e.g., sit-stand desks), as opposed to obligating change through adapting job and office design (e.g., centralizing printing and scanners)” (Gilson, Straker, & Parry, 2012, p. 208). The practitioners interviewed in this study also suggested being cautious of creating new health issues that arise from our attempts to eliminate other health issues.

Increasing participants' motivation and education can be important tools to increasing the effectiveness of sit-stand devices (Wilks et al., 2006). Motivation and physical activity have been improved using a repeat-visit website designed to get sedentary employees to move more (Irvine et al, 2011) and it is reasonable to assume this could be successful in increasing the use of the sit-stand, treadmill, stepping, or pedaling devices described above. Increasing motivation and education also extends beyond just instructing users on the proper set up or adjustment of the devices to having users understand the health benefits of continued use of the devices. Perceived health benefits have been identified as a potential motivator for subjects to use standing desks, even though they were not explicitly described to them before the intervention (Grunseit et al., 2013). This qualitative data shows it is also reasonable to assume that promoting the health benefits prior to implementation may increase the use of these devices.

The type of device utilized can also have an effect on the amount of use it gets and, ultimately, its effectiveness. For example, participant responses in small group interviews indicated the manual-adjust sit-stand desks may have been used less than the electric-adjust desks (Grunseit et al., 2013). Wilks et al. (2006) also utilized electric-adjust and manual-adjust desks and found that the users of the electric desks were adjusted slightly more frequently, although it was not significantly different than the manual desks. The slightly decreased usage of manual-adjust desks in the previous studies may result from the time, effort, and distraction from work tasks associated with adjusting the desk, giving some support to the previously mentioned suggestion that the devices are easy to use. Technology may further enhance use by allowing users to engage in higher intensity activity while still working. Treadmill desks may provide this ability to burn more calories during work and may, therefore, be perceived as more valuable. At the end of a worksite intervention using Treadmill workstations (TMWS), 11 of 12 participants chose to keep it (John et al., 2011). This may suggest that moving workstations may create more interest than standing or sitting desks and may lead to greater use of the device.

Any activity that is sedentary that could be altered with a standing or active desk provides an opportunity to reduce sedentary time. Bringing these ideas to the masses instead of identifying smaller target groups may get society as a whole to buy into the concept of moving more throughout the day. In a review on behavior economics and promoting physical activity, Zimmerman (2009) indicates it would be more efficient to intervene on a whole society basis and that we must change the context for everyone to be successful in changing individual behaviors. The suggestion of Owen, Healy, Matthews, and Dunstan (2010) to provide non-sitting alternatives at community events addresses the idea of reaching larger groups and keeping the idea in the minds of people. This was also supported by the suggestion of Dunstan, Howard, Healy, and Owen (2012) for more scientific research aimed at "intervention studies in 'real-world' settings targeting the feasibility, acceptability, and efficacy in reducing and breaking up occupational, transit, and domestic sedentary time" (p. 373). In contrast, Levine (2007) contends there is no evidence to suggest an individualized approach or a population approach (environmental reengineering) is better than the other so perhaps both should be focused on to address the obesity issue.

Conclusions

The identification of the amount of time spent in sedentary behaviors, independent of the amount of PA, as a risk factor for negative health outcomes has been established. The triggers for sedentary behavior have also been investigated during both work and leisure time. Recent research has explored novel methods for addressing sedentary behaviors mainly in occupational settings, but also in a school setting with younger children. These interventions have altered the traditional sitting-desk to allow standing at a manual or electric adjustable sit-stand desk, walking on a treadmill while at the desk, or pedaling or stepping on devices under a sitting-desk. These devices aim to increase the number of skeletal muscle contractions, which hopefully has cumulative beneficial health effects over time, and thereby reduce the deleterious health effects of sitting too much. It appears that all methods show promise for reducing sitting time but their feasibility in work or school settings and the exact extent to which they are utilized in various real-world settings, as well as their ability to increase energy expenditure, improve anthropometric and cardio-metabolic risk factors, improve mental health, reduce musculoskeletal discomfort and injuries, and maintain or improve various types of work performance needs continued exploration. Future research should incorporate larger sample sizes, increase the number of interventions in school settings (K-12 and college), and implement changes in the work environment on both a small and large scale.

METHODS

Purpose of the Study

The purpose of this investigation is to determine the effects of an adjustable-height sit-stand desk on classroom sitting time, on attention, stress, anxiety, and musculoskeletal discomfort level, on academic performance, and on movement outside of the classroom of college students over the course of a full semester.

Introduction

A shift in recent years is placing more focus on the behaviors and environments that cause people to sit for long periods of time on a daily basis and the potential deleterious health consequences of accumulating large amounts of sitting time. Sedentary time is now thought to be associated with negative health consequences independent of the level of PA (Biswas et al., 2015) or body mass index (BMI) (Thorp, Owen, Neuhaus, & Dunstan, 2011). Much of the research addressing sedentary behaviors has focused on the work environment, with a few studies addressing the school environments of elementary-aged-students, leaving a gap in the research which addresses students in the college setting. In many respects, the college population has the same difficulty in engaging in the proper amount and intensity of physical activity as does the general population (Keating, Guan, Pinero, & Bridges, 2005). It has been reported that a large percentage of the college population does not engage in the proper amount of MVPA and they accumulate nearly 30 hours of sedentary time from studying, and computer and television use (Buckworth & Nigg, 2004). In addition, the college classroom environment is similar to the office and school environments targeted by the previously mentioned interventions in that they have utilized standard chairs and sitting-biased desks for students for many years. However, the college setting is different in that students are not often limited to sitting for a full workday, like in an office environment, but rather they are intermittently sitting in class, at work, to study, to relax, etc., with sporadic opportunities for movement as they switch between some or all of these activities each day. It is currently unknown if the wave of newly designed desks would have a positive impact on classroom sitting time, or attention, stress, anxiety, and musculoskeletal discomfort levels, or academic performance of students in the college environment.

Procedures and Research Design

The data was collected during Spring semester (January - May, 2016). The class met three days per week (Monday & Wednesday for 110 minutes and Friday for 50 minutes). The first two weeks of the course were not utilized for data collection. Visual Analogue Scale (VAS) measures of Attention (AT), Stress (ST), Musculoskeletal Discomfort (MD), and Anxiety (AN) were collected from weeks 3-15, with weeks 3-4 being utilized as baseline. Fourteen sit-stand desks were placed in the back of a college classroom prior to week 5. Data on daily in-class sitting and standing patterns was collected during weeks 5-15, accelerometer data were collected during weeks 7 and 14, perception of use data were collected during weeks 7 and 15. Direct observation of attention (OAT) Attentive (“on-task”) behavior was obtained by watching video from weeks 9, 12, and 13.

The Sit-Stand desks (LearnFit model manufactured by Ergotron Inc., St. Paul, Minnesota) provided a work surface measuring 24” x 22” (61 x 56 cm) and height adjustment from a minimum height of 33.3” (85 cm) to a maximum height of 49.3” (125 cm). There were 14 Sit-Stand desks placed at the back of the classroom that replaced standard sitting desks so the total number of desks was the same as the room was previously set up. Each sit-stand desk setup had a high chair (24” or 29”) with a back on it for the participants to use when seated and was assigned to a participant (no sit-stand desks were shared with any other students in the class). In addition, an 18”x24” anti-fatigue foam mat was available for the subjects to stand on. If a participant dropped out of the class, their sit-stand was removed from the classroom.

Participants were given instruction on how to adjust the height of the sit-stand desk at the beginning of week 5. They were told that it is believed sitting too much has a negative impact on overall health and standing can be good for your health in a variety of ways. The participants were instructed to use the sit-stand desks in the standing position as much as they want and to shift from one position to the other as they see fit and that any movement would not be disruptive.

A video camera was used each class session to record the participants using the sit-stand desks. The camera only captured those subjects participating in the study. Standing time was defined as any time the participant’s legs were not in contact with the sitting surface of the chair.

An Actigraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) was used to record sitting, standing, and movement duration and intensity during two separate 7-day periods in the semester. Participants were instructed to wear the accelerometers for all waking hours during each 7-day collection period, except for showering/bathing or swimming activities (Appendix A). The GT3X+ model has been shown to be valid and reliable in classifying movement into sedentary, light, moderate, hard, and very hard intensities (Berendssen et al., 2014; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011; Sasaki, John, & Freedson, 2011. Wear/Nonwear time was determined according to criteria set by Choi, Liu, Matthews, and Buchowski (2011), and the number of minutes spent in each intensity category (e.g., sedentary, light, etc.) was determined according to criteria set by Freedson, Melanson, and Sirard (1998).

A 16-item, five-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) questionnaire to assess the users' attitudes toward the use of a sit-stand desk in a college classroom and their feeling on potential use outside of the classroom was administered week 7 and 15 (adapted from Carr, Waleska, & Marcus, 2012) (Appendix B).

Subjective attention, stress, anxiety, and musculoskeletal discomfort level were measured using a visual analog scale (VAS), which is a 100 mm long line with statements on both ends indicating the absence (e.g., "no stress") or full amount (e.g., "high stress") of that variable (Appendix C). A general definition for each subjective measure was created from definitions retrieved from The Free Dictionary website (http://www.thefreedictionary.com/) and was also included on each VAS. The definition of Attention was "the act of close or careful observing or listening; ability to concentrate". The definition of Stress was "psychological strain, usually in response to adverse events". The definition of Musculoskeletal Discomfort was "relating to the skeleton and musculature taken together; an absence of comfort or ease; hardship or mild pain". The definition of Anxiety was "a state of uneasiness and apprehension, as about future uncertainties". The participant was instructed to put a vertical mark on the line that best represents their feelings *right now.* A space for optional comments was placed next to each VAS. The VAS has been shown to be reliable and valid for a variety of subjective measures (Cela & Perry, 1986; Davey, Barratt, Butow, and Deeks, 2007; Hornblow & Kidson, 1976; Lesage & Berjot, 2011).

Direct observation of attentive (OAT) behavior was measured on three Wednesdays (week 9, 12, and 13) for both control and intervention groups. Video recordings of the class sessions were used to complete the direct observation of participants. Observation sessions lasted 30 minutes with a maximum of three subjects observed per session and each subject being observed every third minute (total observation time per subject was 10 minutes per day). Similar to Mahar et al., 2006), an audio recording that instructed the observers when to observe and record was utilized. In addition, each subject was observed in one minute bouts in the following pattern: 10 seconds to observe followed by 5 seconds to record if the subject was attentive and if they were sitting or standing. After four observations, the second subject was observed in the same pattern for one minute, followed by the third subject, then returning to the first subject, and continued in this pattern until each subject accumulated 40 observations (10 minutes total). The observation time continued beyond thirty minutes only if a subject was blocked from view (e.g., instructor stood in front of the camera) and extra time was needed to reach 40 observations.

Two observers completed two practice sessions and observed all participants on the three observation days. The first practice session utilized eight subjects and the interobserver reliability was 84.7% (287 agreements/360 total observations). The observers discussed and reviewed video for observations that were in disagreement. The definition of attentive (on-task) behavior was updated and a second round of practice utilizing seven subjects resulted in an interobserver reliability of 88% (221 agreements/251 total observations). The observers again discussed and reviewed video for observations that were in disagreement. A subject was marked as being attentive if they were observed doing one of the following behaviors: appears they are looking at and/or listening to the instructor, video screen, textbook/handouts, or classmate who is discussing class material; actively writing or typing class notes; asking the instructor or classmate a question related to the class. A subject was marked as being non-attentive (off-task) if they were observed doing one of the following behaviors: appears they are *not* looking at and/or listening to the instructor, video screen, textbook/handouts, or classmate who is discussing class material, which may include sleeping, head on desk, spacing out, doodling in notebook, playing with hair, chewing nails, or engaging in non-class related discussion with classmates.

All statistical analyses were conducted using SAS (version 9.4; SAS Institute Inc., Cary, NC). Descriptive statistics and correlations were conducted on the following data: participant age, year in college, height, weight, credit load, exam scores, and class grade; daily, weekly, and total classroom standing time and standing bouts; accelerometer determined minutes of moderate-to-vigorous physical activity (MVPA); weekly VAS scores for attention, stress, anxiety, and musculoskeletal discomfort; and overall score for direct observation of attention.

Mixed Model repeated measures analysis of variance was used to analyze the percentage of daily attendance time spent standing (PSTAND) and the percentage of weekly attendance time spent standing (WPSTAND); daily time spent in sedentary (ASED), light (ALIGHT), and moderate to vigorous (AMVPA) during the two accelerometer collection periods; weekly VAS scores for attention (AT), stress (ST), anxiety (AN), and musculoskeletal discomfort (MD); Exam scores (EXAM); and weekly scores for direct observation of attention (OAT). A heterogeneous compound symmetry variance-covariance structure was determined to be the best fit for the data. The data from the perception of use questionnaire were used to calculate medians and quartile scores. A level of significance (α) of .05 was used for all analyses.

PAPER 1. DAILY AND WEEKLY STANDING PATTERNS WHEN USING A SIT-STAND DESK IN A COLLEGE CLASS

A shift in recent years is placing more focus on the behaviors and environments that cause people to sit for long periods of time on a daily basis and the potential deleterious health consequences of accumulating large amounts of sitting time. However, previously there was more of a focus on increasing people's levels of moderate physical activity (MPA) and vigorous physical activity (VPA) as one of the major mechanisms to reduce morbidity and mortality. Less attention is given to daily body position or movement outside of this "exercise" time. The rest of the day provides ample opportunity to potentially accumulate sedentary time, despite possibly meeting or even exceeding the current Physical Activity (PA) guidelines, due to office, classroom, or neighborhood designs that limit movement. Sedentary time is now thought to be associated with negative health consequences independent of the level of PA (Biswas et al., 2015) or body mass index (BMI) (Thorp, Owen, Neuhaus, & Dunstan, 2011).

The trend of moderate physical activity occupations being replaced with occupations requiring only sedentary or light intensities over the last 50 years (Church et al., 2011) may provide a rationale to the recent efforts to design numerous devices to address the increasingly sedentary nature of work and school environments. The standard desks and chairs used in work and school settings, unchanged for many years, have been altered to change the body position for workers and students while still allowing them to complete normal work or school tasks (i.e., typing, writing, talking on the phone, using a computer, etc.). Less expensive examples of these alterations include removing all chairs and desks to have standing meetings (Levine, 2007) or using physio balls or stools instead of chairs (Beers et al., 2008; Speck & Schmitz, 2011). Costlier examples of devices created to reduce sedentary time include rigid (Wilks, Mortimer, &

Nylén, 2006) or adjustable (Alkhajah et al., 2012) standing-height desks and rigid (Thompson et al., 2014) or adjustable (Ben-Ner et al., 2014) treadmill desks that incorporate walking on a treadmill at low speeds (e.g., 0.5-2.0 mph) instead of desks requiring a static, seated position, as well as pedal desks that allow a self-selected pedaling motion (Carr et al., 2012).

Much of the research addressing sedentary behaviors has focused on the work environment, with a few studies addressing the school environments of elementary-aged-students, leaving a gap in the research which addresses students in the college setting. In many respects, the college population has the same difficulty in engaging in the proper amount and intensity of physical activity as does the general population (Keating, Guan, Pinero, & Bridges, 2005). It has been reported that a large percentage of the college population does not engage in the proper amount of moderate-to-vigorous physical activity (MVPA) and they accumulate nearly 30 hours of sedentary time from studying, and computer and television use (Buckworth & Nigg, 2004). In addition, the college classroom environment is similar to the office and school environments targeted by the previously mentioned interventions in that they have utilized standard chairs and sitting-biased desks for students for many years. However, the college setting is different in that students are not often limited to sitting for a full workday, like in an office environment, but rather they are intermittently sitting in class, at work, to study, to relax, etc., with sporadic opportunities for movement as they switch between some or all of these activities each day. It is currently unknown if the wave of newly designed desks would have a positive impact on classroom sitting time or will be liked by college-aged students. Therefore, the purpose of the study was to determine the pattern of sit-stand desk usage over the course of a semester, the relationship to movement outside of class, and if the participants liked using the sit-stand desks.

Methods

Participants

Participants were recruited from two sections of a Human Anatomy & Kinesiology course at a public university in central Minnesota. The class sections were randomly selected as either standing or control group prior to participant recruitment. A total of 23 students (14 standing; 9 control) participated in the study.

Sit-Stand Desks

The Sit-Stand desks (LearnFit model manufactured by Ergotron Inc., St. Paul, Minnesota) provided a work surface measuring 24” x 22” (61 x 56 cm) and height adjustment from a minimum height of 33.3” (85 cm) to a maximum height of 49.3” (125 cm). There were 14 Sit-Stand desks placed at the back of the classroom that replaced standard sitting desks so the total number of desks was the same as the room was previously set up. Each sit-stand desk setup had a high chair (24” or 29”) with a back on it for the participants to use when seated and an 18”x24” anti-fatigue foam mat was available for the subjects to stand on. A sit-stand desk was assigned to each participant (no sit-stand desks were shared with any other students in the class). If a participant dropped out of the class, their sit-stand desk was removed from the classroom.

Study Design

Data was collected during Spring semester (January - May, 2016). The class met three days per week (Monday & Wednesday for 110 minutes and Friday for 50 minutes). One section began at 10:00 am (control group) and the other at 1:00 pm (standing group). The first two weeks of the course were not utilized for data collection. Weeks 3-4 were utilized for baseline measurements. Fourteen sit-stand desks were placed in the back of a college classroom prior to week 5. Data on daily in-class sitting and standing patterns was collected during weeks 5-15, accelerometer data were collected during weeks 7 and 14, and perception of use data were collected during weeks 7 and 15.

Participants were given instruction on how to adjust the height of the sit-stand desk at the beginning of week 5. They were told that it is believed sitting too much has a negative impact on overall health and standing can be good for your health in a variety of ways. The participants were instructed to use the sit-stand desks in the standing position as much as they want and to shift from one position to the other as they see fit and that any movement will not be disruptive.

Standing and Movement Time

A video camera was used each class session to record the participants using the sit-stand desks. The camera only captured those subjects participating in the study. Standing time was defined as any time the participant’s legs were not in contact with the sitting surface of the chair.

An Actigraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) was used to record sitting, standing, and movement duration and intensity during two separate 7-day periods in the semester. Participants were instructed to wear the accelerometers for all waking hours during each 7-day collection period, except for showering/bathing or swimming activities. The GT3X+ model has been shown to be valid and reliable in classifying movement into sedentary, light, moderate, hard, and very hard intensities (Berendssen et al., 2014; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011; Sasaki, John, & Freedson, 2011). Wear/Nonwear time was determined according to criteria set by Choi, Liu, Matthews, and Buchowski (2011), and the number of minutes spent in each intensity category (e.g., sedentary, light, etc.) was determined according to criteria set by Freedson, Melanson, and Sirard (1998).

Perception Questionnaire

A 16-item, five-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) questionnaire to assess the users' attitudes toward the use of a sit-stand desk in a college classroom and their feeling on potential use outside of the classroom was administered week 7 and 15 (adapted from Carr, Waleska, & Marcus, 2012).

Statistical Analyses

All statistical analyses were conducted using SAS (version 9.4; SAS Institute Inc., Cary, NC). Descriptive statistics and correlations was conducted on the data relating to participant age, year in college, height, weight, credit load, exam scores, class grade, and daily, weekly, and total classroom standing time, and daily, weekly, and total classroom standing bouts, and accelerometer determined minutes of moderate-to-vigorous physical activity (MVPA). Mixed Model analysis of variance was used to determine the differences in the percentage of daily attendance time spent standing (PSTAND) and the percentage of weekly attendance time spent standing (WPSTAND), as well as time spent in sedentary (SED), light (LIGHT), and MVPA during the two accelerometer collection periods. A heterogeneous compound symmetry variance-covariance structure was determined to be the best fit for the data. The data from the perception of use questionnaire were used to calculate medians and quartile scores. A level of significance (α) of .05 was used for all analyses.

Results

A total of 23 participants (14 standing, 9 control) started the study. Five students withdrew from the course resulting in 18 participants (12 standing, 6 control) completing the study; descriptive statistics for these subjects are located in Table 5. Data on daily in-class sitting and standing patterns were analyzed for the 12 standing participants, and all movement data measured via accelerometer were analyzed for all 18 participants. Accelerometer data for 4 standing participants was excluded due to not meeting minimum wear time requirements during the two collection periods, leaving valid accelerometer data for 14 participants (8 standing, 6 control). There was no difference in age, height, weight, or credits between the two groups.

Table 5

Participant Characteristics

Group	n	Age	Height	Weight	Credits	Year
Control	6	23.8 (6.6)	65.5 (14.3)	153.0 (27.6)	13.7 (2.4)	3.3 (0.8)
Standing	12	21.2 (3.5)	66.7 (5.1)	157.8 (37.5)	14.0 (3.3)	2.3 (1.1)

Note: Data are Mean (SD).

The differences in standing for the standing group are represented graphically based on percent of daily attendance time for daily standing (Figure 1) and weekly standing (Figure 2). There were significant ($p = 0.0043$) daily differences in the percent of daily attendance time spent standing. Post-hoc analysis of all comparisons via Tukey-Kramer procedure indicated the following significant ($p < .05$) relationships: day 2 and 27 were higher than day 18 and 28, and day 15 and 27 were higher than day 9. There were also significant ($p = 0.0016$) weekly differences in the percent of weekly attendance time spent standing. Post-hoc analysis of all comparisons via Tukey-Kramer procedure indicated the following significant ($p < .05$) relationships: week 5, 9, 11, 13 and 15 were higher than week 8, and week 12 was lower than week 5 and 9.

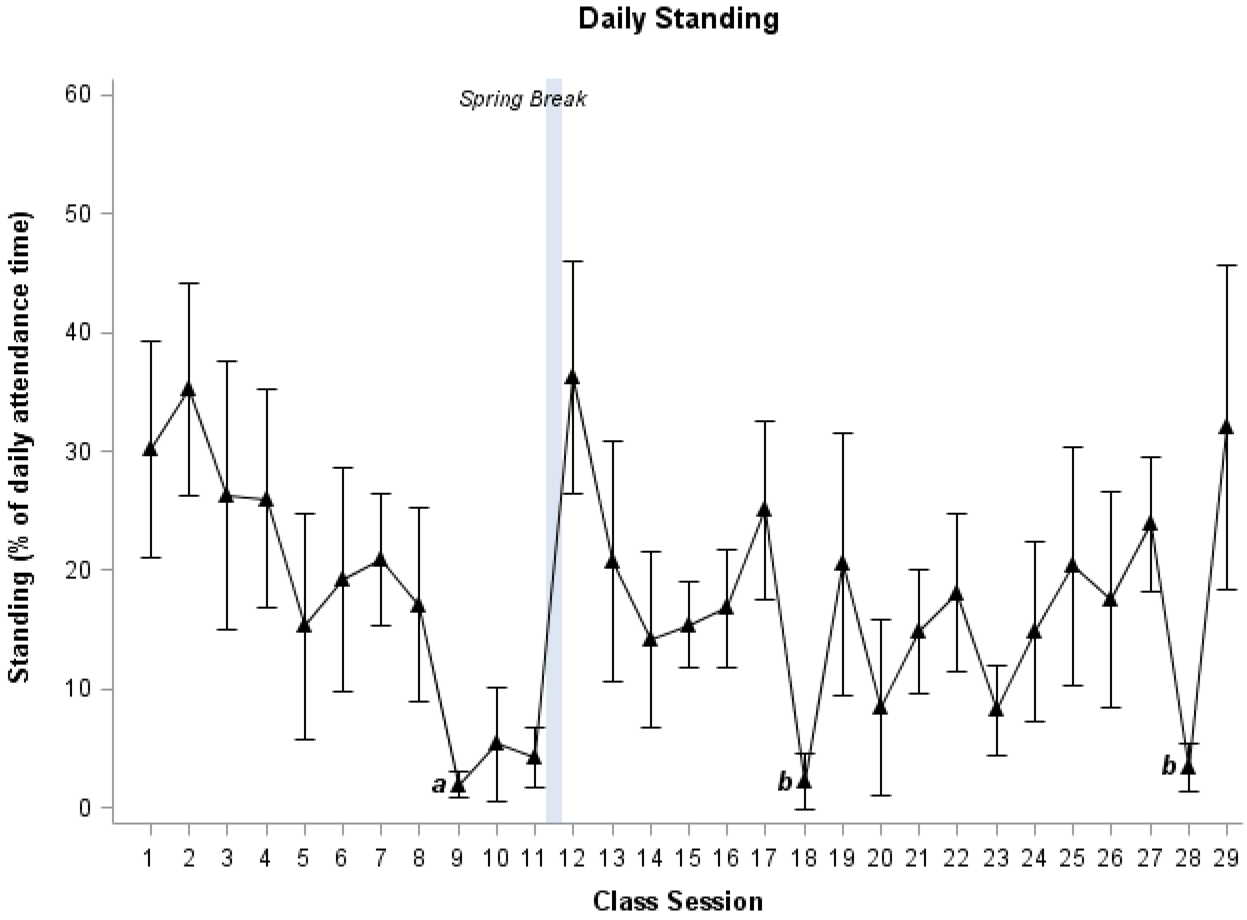

Figure 1. Daily Standing (percent of daily attendance time). Data are adjusted means ± SE.
a = lower than day 15 and 27 ($p < 0.05$)
b = lower than day 2 and 27 ($p < 0.05$).

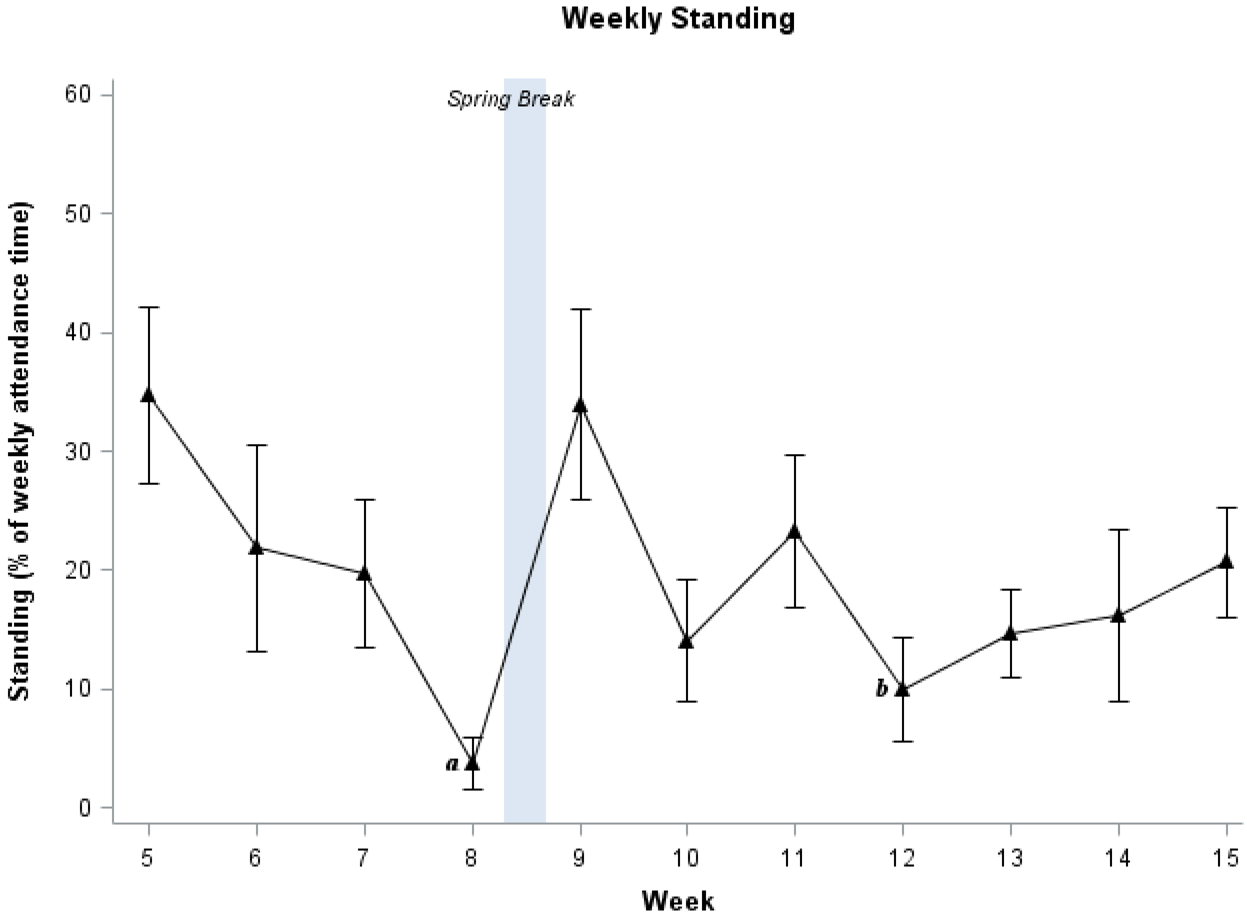

Figure 2. Weekly Standing (percent of weekly attendance time). Data are adjusted means ± SE.
a = lower than week 5, 9, 11, 13, and 15 ($p < 0.05$)
b = lower than week 5 and 9 ($p < 0.05$).

The following significant correlations were found: the amount of sleep in week 14 (SLEEP14) with the amount of moderate-to-vigorous physical activity in week 14 (MVPA14) ($r = 0.62$, $p = 0.019$), the amount of physical activity in week 7 (MVPA7) with MVPA14 ($r = 0.58$, $p = 0.031$), the amount of sleep in week 7 (SLEEP7) with SLEEP14 ($r = 0.77$, $p < 0.001$), and participant age (AGE) with the average daily standing percentage (APSTAND) ($r=0.86$, $p < 0.001$).

The percentage of the total number of standing bouts is categorized by the length of the standing bout in Table 6, with the total number of standing bouts over the 29 class sessions (weeks 5-15) included in the last column. The total number of bouts was significantly correlated with APSTAND (r = 0.60, p = 0.039). The daily number of standing bouts ranged from 0-16 bouts/day, with an average of 0.7-4.7 bouts/day and a median of 2 bouts/day.

Table 6

Percentage of the Total Number of Standing Bouts Categorized by Bout Length.

ID#	≤ 0.3 min	≤ 1 min	≤ 2 min	≤ 5 min	≤ 10 min	≤ 20 min	Total # bouts
7	12.3	29.2	38.5	53.8	70.8	81.5	65.0
8	31.1	46.7	56.6	81.1	92.6	96.7	122.0
9	36.7	69.4	75.5	83.7	91.8	98.0	49.0
10	40.4	54.4	61.4	73.7	82.5	91.2	57.0
11	50.9	67.3	72.7	89.1	90.9	98.2	55.0
12	40.3	63.6	70.1	83.1	84.4	93.5	77.0
13	50.0	66.7	72.2	94.4	94.4	100.0	18.0
14	19.8	42.0	50.6	60.5	70.4	79.0	81.0
15	26.5	50.0	58.8	82.4	86.8	95.6	68.0
16	28.2	43.6	74.4	84.6	92.3	94.9	39.0
17	31.4	68.6	71.4	91.4	91.4	97.1	35.0
18	35.1	59.5	70.3	91.9	91.9	100.0	37.0
AVG %	33.6	55.1	64.4	80.8	86.7	93.8	

Data related to the total number of weekly minutes spent in moderate-to-vigorous intensity physical activity (MVPA), as well as the average daily number of MVPA minutes (AMVPA) based on valid days of accelerometer wear, are contained in Table 7, and the AMVPA data is represented graphically in Figure 3. There was no significant interaction (*F*[1, 12] = 1.31, p = 0.274), treatment (*F*[1, 12] = 1.51, p = 0.243), or week (*F*[1, 12] = 0.12, p = 0.737) effect for AMVPA. In addition, there was not a significant correlation between standing in week 7 (WPSTAND7) and MVPA minutes in week 7 (MVPA7) (r = -0.31, p = 0.454), or between standing in week 14 (WPSTAND14) and MVPA minutes in week 14 (MVPA14) (r = 0.04, p = 0.925).

Table 7

Daily and Weekly Minutes of Moderate-to-Vigorous Physical Activity (MVPA)

ID#	AMVPA7	AMVPA14	MVPA7	MVPA14
1	35.6	20.4	249	102
2	30.6	30.4	214	213
3	44.9	61.5	314	369
4	23.5	38.7	141	271
5	16.4	20.1	115	141
6	30.3	43.1	212	302
8	29.9	19.5	209	117
10	23	33.4	69	167
11	61.3	46.3	184	139
12	25.8	29	103	87
13	93.7	108.3	562	325
14	22	33.5	132	201
15	104.7	81	314	243
18	46.5	32.3	186	129

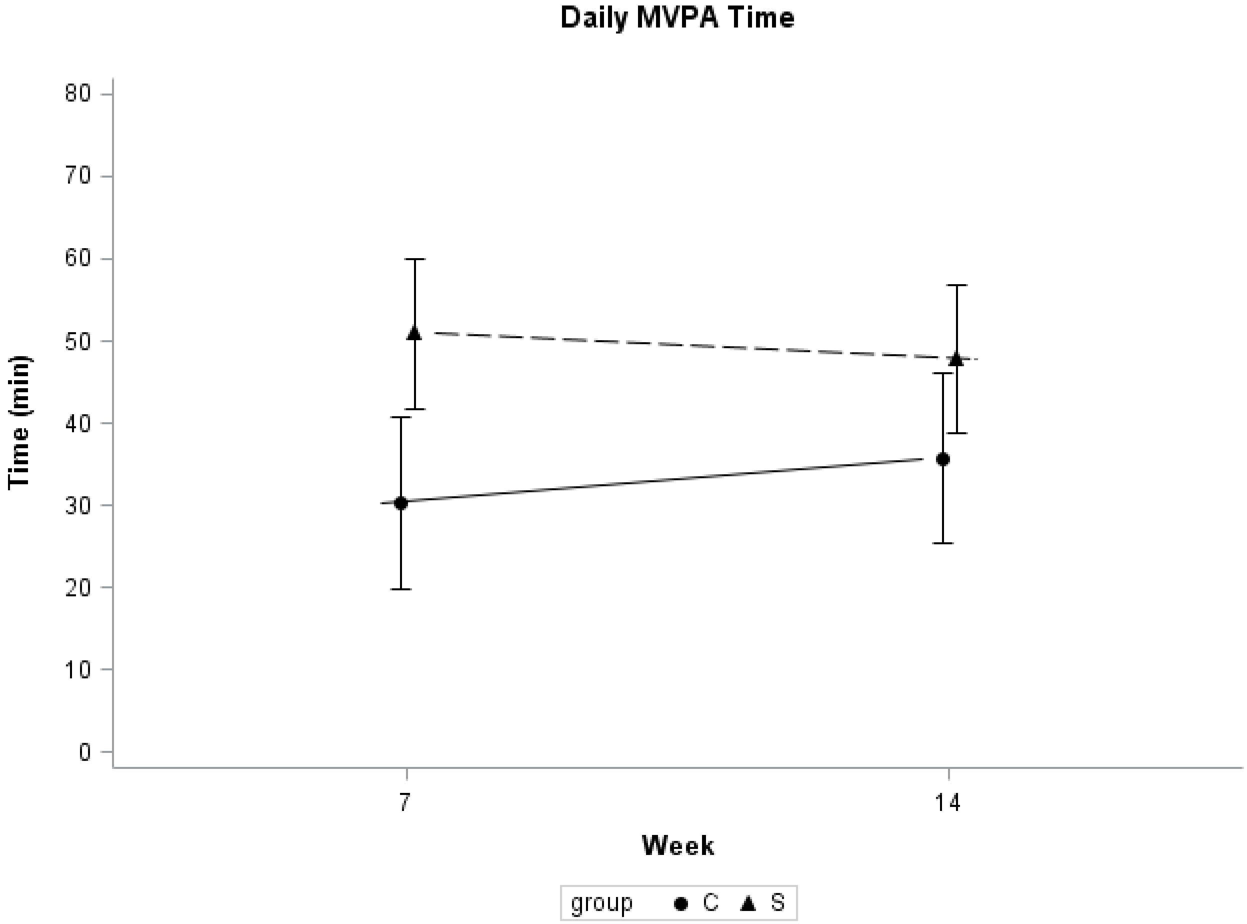

Figure 3. Daily MVPA time (AMVPA). Data are adjusted means ± SE.

Data from the 16-question Likert-scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) Sit-Stand Desk Perception Questionnaire are contained in Table 8 and are represented as quartiles.

Table 8

Sit-Stand Desk Perception Questionnaire Results

Question (*Italics* = negatively worded)	Q1	Median (Q2)	Q3
1) The sit-stand desk is easy to use.	4.75	5	5
2) I felt comfortable using the sit-stand desk in the presence of others in the class	4.75	5	5
3) My work-related productivity decreased while using the sit-stand -desk	*1*	*1*	*2*
4) The quality of my note-taking decreased while using the sit-stand -desk	*1*	*1*	*2*
5) The sit-stand desk interfered with my class-related activities	*1*	*1*	*2*
6) I could conduct normal class-related tasks while using the sit-stand desk	4	5	5
7) I could easily see the PowerPoint slides (or chalkboard/dry-erase board notes) while using the sit-stand desk.	4	5	5
8) I could read comfortably while using the sit-stand desk	4.75	5	5
9) I could communicate with the professor, if necessary, while using the sit-stand desk	5	5	5
10) I could write comfortably while using the sit-stand desk	5	5	5
11) I was more tired after class on days I used the sit-stand desk	*1*	*1.5*	*2*
12) I had more physical discomfort on days I used the sit-stand desk	*1*	*1.5*	*2*
13) I was distracted by students adjusting the sit-stand desk during class	*1*	*1*	*2*
14) I used the sit-stand desk more than I thought I would at the beginning of the semester	2.75	3.5	5
15) I would use a sit-stand desk in my other classes if it was available	4	4.5	5
16) I would use a sit-stand desk while studying outside of class (at home or in a study area on campus) if one was available.	3	4	5

Note: Week 15 Data are represented as quartiles. Italicized questions are negatively worded (questions 3-5 and 11-13). Values represent the following categories: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Discussion

The purpose of the study was to examine the pattern of sit-stand desk usage in a college class over the course of a semester, the relationship of sit-stand desk usage to movement outside of class, and if the participants liked using the sit-stand desks. The main findings revealed variable daily and weekly standing between subjects with some participants that stood for a higher percentage of their daily/weekly attendance time, had more standing bouts per class, and stood for a longer length of time per standing bout, (i.e., they were “high-responders”; Koepp et al., 2013) and others who have very low values for percentage of daily and weekly standing, number of stand bouts, and standing bout length (i.e., they were “non-responders”). This variability was shown in the large spacing between days that standing amounts significantly differed; days 2 and 27 both were higher than days 18 and 28, and days 15 and 27 higher than day 9. Expressing the data in weekly form shows the amount of daily standing by the intervention group was significantly lower in the week before Spring Break (week 8) than the beginning of the intervention (week 5) and every other week after Spring Break (weeks 9, 11, 13, and 15). The ability of the sit-stand desks to increase standing in some subjects shows that it may be useful in reducing sitting and be an effective mechanism to combat the independent deleterious effects sedentary behavior can have on health (Ekblom-bak, Hellénius, & Ekblom, 2010; Hamilton, Hamilton, & Zderic, 2007).

A strength of the study is the objective measurement of actual standing for each class period during the 11-week standing period. In this study, the first week showed as high an amount of standing as different weeks later in the semester. Had this intervention stopped after four weeks and only utilized pre-post measurements, the data would have suggested lower standing amounts than what actually occurred during the semester. Several workplace sit-stand desk interventions indicating increased standing and decreased sitting primarily collected measurements at baseline and the end of the intervention (Alkhajah et al., 2012; Grunseit, Chau, van der Ploeg, & Bauman, 2013; Healy et al., 2013); Neuhaus, Healy, Dunstan, Owen, & Eakin, 2014; Pronk, Katz, Lowry, & Payfer, 2012; Stephens et al., 2014). In contrast, two treadmill desk interventions utilized post-session surveys to collect usage data from each session and show different week to week (Schuna Jr. et al., 2014) or month to month (Tudor-Locke et al., 2014) changes in workstation use over time, and an intervention investigating an under-desk pedal machine (Carr, Waleska, & Marcus, 2012) utilized software to collect real-time data and displayed daily usage over four weeks. The different pattern of standing (or walking or cycling) seen in workplace and educational interventions may suggest that the environment creates, or the participants have, alternative motivations or incentives for using the desks in the “active” position. For example, it is possible the participants’ lower amount of standing before Spring Break in this study was the result of having more exams (e.g., midterm exams) in the week before Spring Break, since it was the middle point of the semester, which may have affected the amount of standing at that time. Regardless of the setting, it may be helpful to objectively quantify the amount of daily standing, walking, or pedaling, as opposed to only comparing pre-post data, as the patterns of use may provide insight to improving interventions to optimize desk use and any associated benefits.

There was not a pattern of less standing on Fridays (class session 3, 5, 8, 11, 13, 20, 23, 26, 29) compared to the previous Wednesday of that week. The standing data was calculated as a percentage of the daily attendance time to account for the shorter scheduled class time on Friday (50 min.), compared to Monday and Wednesday (110 min.) as well as differences in attendance. The actual class duration between Monday/Wednesday and Friday (75.0 vs. 45.1 min., respectively) may have been similar enough to prevent participants from needing to stand more on the longer days to relieve stress, anxiety, boredom, discomfort from sitting, or for other reasons. The fluctuations from one class period to another show a need for an intervention methodology that can promote consistent higher daily standing, if maximizing standing is the goal, as opposed to the repeated fluctuations seen in this study.

Sit-to-stand (STS) transitions were investigated during each hour of a workday by Dall and Kerr (2010) and they found that workers most often had zero STS movements with a median of three. Although the overall time of a college class is much shorter, the standing bouts pattern seen in this study is similar in that some students exhibited no standing (18.1% of attended class days had zero standing) with a median of two standing bouts. An intervention attempting to increase the number of STS movements in a college setting may be advantageous as students often have no need to stand in class; however, this may oppose an intervention that tries to maximize standing time as it might act to decrease the total standing time of the "high-responders", who displayed high amounts of standing. Based on the low number of standing bouts and the high amount of short-duration bouts for many participants in this study, an intervention focused on increased STS movement may be useful for targeting the "non-responders" and thereby increase their standing time. This is supported by the work of Rutten, Savelberg, Biddle, and Kremers (2013) to create the acronym STUFF (Stand Up For Fitness) in hopes it would be remembered and get people to stand when they heard it. They gave an example of standing for five minutes after 30 minutes of sitting as a way to implement STUFF and received positive feedback after preliminarily applying it to lectures with health science students.

The MVPA data in Table 3 shows that 9 participants (5 intervention) in week 7, met the 150 minutes of MVPA per week guidelines suggested by Haskell et. al. (2007). In week 14, 8 participants (4 intervention) met the guidelines. There were 5 intervention and 2 control participants that met the PA guidelines in one measurement period but not the other, with some participants meeting the goal in the first and some in the second collection period. The daily number of MVPA minutes (AMVPA) was calculated by dividing the total number of MVPA minutes by the number of valid accelerometer wear days. These values show a trend of participants having similar amounts of daily MVPA in both collection periods (i.e., both were low or both were high) as opposed to having one high and one low value.

Work performance did not seem to be affected by the sit-stand desks as indicated by the answers to question 11 and 12 on the Sit-Stand Desk Perception Questionnaire. Participants primarily marked "disagree" or "strongly disagree" for the following statements: *I was more tired after class on days I used the sit-stand desk* and *I had more physical discomfort on days I used the sit-stand desk.* These results are supported by several studies that have looked at work performance while using standing desks. Standing resulted in no change in self-rated work performance (Healy et al., 2013), reading and cognitive performance (Commissaris et al., 2014), and speech quality (Cox et al., 2011). In addition, improvements while using combination sit-stand position were seen in work performance (Hassegawa, Inoue, Tsutsue, & Kumashiro, 2001), transcription (Ebara et al., 2008), or productivity (Hedge & Ray, 2004).

Lastly, the video cameras recorded one intervention participant before class saying "I wish I had these desks in all my classes". Interestingly, this participant had a low percentage of daily attendance time spent in the standing position (M=7.11%, range = 0 - 28.35%). It is unknown why the positive feelings towards the sit-stand desks, as evidenced by the positive questionnaire scores and verbal comments provided by the intervention participants, did not result in higher overall standing amounts. It is possible that the freedom of movement allowed by the sit-stand desk when sitting in taller than normal chairs was enough to provide a benefit to the user such that they did not feel compelled to stand. Anecdotally, there appeared to be more fidgeting in students sitting at the sit-stand desks as they could move their legs and adjust the desk up and down without having to stand. However, the exact amount of fidgeting was not measured in this study and may be difficult to measure accurately.

Limitations

There are several potential limitations in this study. First, there was a low number of subjects in this study. In addition, the students who chose to participate in the study may be more interested in standing during class and therefore may not accurately represent the standing patterns of all students. However, given the high variability in standing by the participants in this study, we feel it accurately represents the standing patterns of students when given the instructions to use the sit-stand desk as they see fit.

In addition, the use of video to capture standing time may affect the participants' use of the sit-stand desks (specifically, they may use them more because they know they are being recorded). To address this issue, we placed the video cameras in the classroom during the baseline period but did not record. We feel this helped acclimate the students to having cameras in the classroom so that the impact of the cameras on standing and sitting patterns was minimized.

This class may not represent the typical college class format. The class used in this study was chosen because it provided additional class time, and potentially additional sitting time, than a standard length class (maximum of 270 vs. 150 min/week in a standard class format). However, as mentioned above, average class length on Monday and Wednesday was 75.0 min, which is not that much more than a typical class of 50 min. In addition, the students displayed a large variety of attendance time. The students were allowed to come and go as they saw fit by the professor (i.e., attendance was not mandatory) and research staff were not allowed to mandate full attendance. To address the issue of varied attendance time, the daily standing time is represented as a percentage of the total time the participant attended that class session. A positive aspect is that it represents a more likely “real-world” exposure pattern to any classroom changes in a university setting.

Another potential limitation is the use of accelerometer data with 3 or more days of valid wear time (≥ 10 hours/day) over a 7-day measurement period, which differs from the typical requirement of needing at least four days of valid wear (Troiano et al., 2008). Tudor-Locke, Johnson, and Katzmarzyk (2009) suggested a benefit to including accelerometer data from participants with at least one day of valid wear time because it is reasonable that people do not wear the accelerometer on days they are not active and, therefore, low wear time may still be a valid indicator of the amount and intensity of weekly movement. In addition to lower the number of valid wear days, using accelerometers to measure movement during only two weeks of the study may not give an accurate measure of the participants’ movement during other points in the semester or how much they would move at other points during the school year (e.g., September – December). We feel that the time points selected, late-February and late-April, represent similar weather, school, and work patterns experienced by the participants throughout the school year and, therefore, is representative of how much activity they engage in while attending college in Minnesota.

Conclusion

The sit-stand desks in this study were well liked and did not appear to affect amount of movement outside of class (did not increase SED or decrease MVPA). However, the overall daily fluctuations, as well as between-subject fluctuations, of sit-stand desk use in this study highlight the need to find intervention protocols that are immune to these fluctuations in use that we see when participants have the choice to stand or sit as they see fit, which previous research has indicated should be given to intervention participants (Gilson, Straker, & Parry, 2012; Levine, 2007). However, perhaps taking that freedom of when and how much they use the device away may be best for maximizing its use (e.g., achieving 90-100% of class time spent standing) and evaluating if this would have any effect on the perceptions of the sit-stand desks, any relationships to the amount of movement outside of class, or any other possible beneficial health impacts.

Acknowledgements

This study was supported by a Faculty Research Grant from St. Cloud State University.

PAPER 2. PATTERN OF ATTENTION, STRESS, ANXIETY, AND MUSCULOSKETAL DISCOMFORT LEVELS WHEN USING A SIT-STAND DESK IN A COLLEGE CLASS

The potential for movement, or not moving, exists for each person as they go about their daily activities. This encompasses work or school time and free/recreational time. Past recommendations often focused on increasing the amount and intensity of purposeful physical activity (i.e., exercise) (Haskell et al., 2007). However, there is a growing emphasis being placed on sedentary behaviors and the independent effects of these behaviors on health and wellness (Ekblom-bak, Hellénius, & Ekblom, 2010; Hamilton, Hamilton, & Zderic, 2007).

There have been numerous devices created or modified for the purpose of gaining health benefits during what has always been, or has evolved into, a sedentary activity (Levine, 2007). For instance, standard desks are now height-adjustable so a person can stand while working. An important question to answer is whether all of these modifications, and the expense that goes into them, provides any benefit during work, school, or free time. Since most studies have found only minimal increases in energy expenditure in standing compared to sitting (Benden, Blake, Wendel, & Huber, 2011; Buckley, Mellor, Morris, & Joseph, 2014; Creasy, Rogers, Byard, Kowalsky, & Jakicic, 2016; Reiff, Marlatt, & Dengel, 2012), looking at other potential areas of improvement are necessary.

The increase in occupational and leisure-time sedentary behaviors can also lead to deleterious effects on cognitive health and performance as well. A cross-sectional sample of 3367 government employees in Australia evaluated the associations between sitting at work and mental health found that sitting more and engaging in less physical activity (PA) were correlated with more psychological distress (moderate distress for men and moderate to high distress for women), even after controlling for leisure time PA and body mass index (BMI) (Kilpatrick, Sanderson, Blizzard, Teale, & Venn, 2013). To address prolonged sitting, the Take-A-Stand-Project introduced standing desks for a 4-week intervention period in a work setting (Pronk et al., 2012). The standing-desks resulted in significant improvements for the following self-reported mood states: fatigue, vigor, tension, confusion, depression, and total mood disturbance. Values for mood states were also evaluated after reverting back to standard desks for a two-week period after the intervention and, interestingly, vigor and total mood disturbance reverted to original levels in this short time frame. a longer school intervention using sit-stand desk in Grades 2-4 during a school year found a greater academic engagement score in the fall, but not in the spring, compared to classes with sitting desks, with females also showing a higher academic engagement score compared to males (Dornhecker, Blake, Benden, Zhao, & Wendel, 2015). In contrast, an investigation into the effects of acute standing on cognitive function found that Complex Attention was the only factor that was significantly decreased in the standing position (Schraefel, Jay, & Andersen, 2012). The findings of these studies related to cognitive health and performance may necessitate the implementation of effective interventions to decrease distress, improve mood states and attention/engagement, and ultimately increase work performance.

Musculoskeletal pain and fatigue during standing-desk interventions have also been investigated to determine if these new positions lead to more or less discomfort as compared to sitting, a result that could counteract any potential positive effects of standing. A few studies found that standing increased fatigue or musculoskeletal discomfort (Chester, Rys, and Konz, 2002; Ebara et al., 2008; Hassegawa et al., 2001). In a longer study (6 months), Cifuentes, Qin, Fulmer, and Bello (2014) initially saw similar results (increased discomfort) to the previously mentioned studies but found that it took an average of two weeks for the discomfort symptoms in the foot and knees to recede. In contrast to the studies showing increased pain or discomfort, musculoskeletal discomfort ratings have been shown to be better (i.e., lower) using electronic-height adjustable workstations (EHAW) (Hedge & Ray, 2004, p. 1093) and in New Zealand elementary school third and fourth graders when using standing desks in the classroom for four weeks (Hinckson et al., 2013). In addition, Botter et al. (2013) found that all standing workstations (conventional standing and treadmill desk) had lower cervical spine flexion and trunk flexion, which may have the potential to decrease musculoskeletal pain in the long run, but they did not assess participants' comfort levels.

It is unknown if standing will have an effect on cognitive health or performance, or musculoskeletal discomfort, in limited doses in a college class. Therefore, the purpose of this study is to determine the effect of using adjustable-height (sit-stand) desks in a college class on attention, stress, anxiety, musculoskeletal discomfort, and academic performance.

Methods

Participants

Participants were recruited from two sections of a Human Anatomy & Kinesiology course at a public university in central Minnesota. The class sections were randomly selected as either intervention or control group prior to participant recruitment. A total of 23 students (14 standing; 9 control) participated in the study.

Sit-Stand Desks

The Sit-Stand desks (LearnFit model manufactured by Ergotron Inc., St. Paul, Minnesota) provided a work surface measuring 24" x 22" (61 x 56 cm) and height adjustment from a minimum height of 33.3" (85 cm) to a maximum height of 49.3" (125 cm). There were 15 Sit-Stand desks placed at the back of the classroom that replaced standard sitting desks so the total number of desks was the same as the room was previously set up. Each sit-stand desk setup had a high chair (24” or 29”) with a back on it for the participants to use when seated and an 18”x24” anti-fatigue foam mat was available for the subjects to stand on. A sit-stand desk was assigned to each participant (no sit-stand desks were shared with any other students in the class). If a participant dropped out of the class, their sit-stand desk was removed from the classroom.

Study Design

Data was collected during Spring semester (January - May, 2016). The class met three days per week (Monday & Wednesday for 110 minutes and Friday for 50 minutes). One section began at 10:00 am (control group) and the other at 1:00 pm (standing group). The first two weeks of the course were not utilized for data collection. Visual Analogue Scale measures of Attention, Stress, Musculoskeletal Discomfort, and Anxiety were collected from weeks 3-15, with weeks 3-4 being utilized as baseline. Fourteen sit-stand desks were placed in the back of the classroom prior to week 5. Direct observation of attention (OAT) Attentive (“on-task”) behavior was obtained by watching video from weeks 9, 12, and 13.

Participants were given instruction on how to adjust the height of the sit-stand desk at the beginning of week 5. They were told that it is believed sitting too much has a negative impact on overall health and standing can be good for your health in a variety of ways. The participants were instructed to use the sit-stand desks in the standing position as much as they want and to shift from one position to the other as they see fit and that any movement will not be disruptive.

Direct Observation of Attention (OAT)

Observed attentive (on-task) behavior was measured on three Wednesdays (week 9, 12, and 13) for both control and standing groups. Video recordings of the class sessions were used to complete the direct observation of participants. Observation sessions lasted 30 minutes with a maximum of three subjects observed per session and each subject being observed every third minute (total observation time per subject was 10 minutes per day). Similar to Mahar et al., (2006), an audio recording that instructed the observers when to observe and record was utilized. Each subject was observed in one minute bouts in the following pattern: 10 seconds to observe followed by 5 seconds to record if the subject was attentive and if they were sitting or standing. After four observations, the second subject was observed in the same pattern for one minute, followed by the third subject, then returning to the first subject, and continued in this pattern until each subject accumulated 40 observations (10 minutes total). The observation time continued beyond thirty minutes only if a subject was blocked from view (e.g., instructor stood in from of the camera) and extra time was needed to reach 40 observations.

Two observers completed two practice sessions and observed all participants on the three observation days. The first practice session utilized eight subjects and the interobserver reliability was 84.7% (287 agreements/360 total observations). The observers discussed and reviewed video for observations that were in disagreement. The definition of attentive (on-task) behavior was updated and a second round of practice utilizing seven subjects resulted in an interobserver reliability of 88% (221 agreements/251 total observations). The observers again discussed and reviewed video for observations that were in disagreement. A subject was marked as being attentive if they were observed doing one of the following behaviors: appears they are looking at and/or listening to the instructor, video screen, textbook/handouts, or classmate who is discussing class material; actively writing or typing class notes; asking the instructor or classmate a question related to the class. A subject was marked as being non-attentive (off-task) if they were observed doing one of the following behaviors: appears they are *not* looking at and/or listening to the instructor, video screen, textbook/handouts, or classmate who is discussing class material, which may include sleeping, head on desk, spacing out, doodling in notebook, playing with hair, chewing nails, or engaging in non-class related discussion with classmates.

Visual Analogue Scale

Subjective attention, stress, anxiety, and musculoskeletal discomfort level were measured using a visual analog scale (VAS), which is a 100 mm long line with statements on both ends indicating the absence (e.g., “no stress”) or full amount (e.g., “high stress”) of that variable. A general definition for each subjective measure was created from definitions retrieved from The Free Dictionary website (http://www.thefreedictionary.com/) and was also included on each VAS. The definition of Attention was “the act of close or careful observing or listening; ability to concentrate”. The definition of Stress was “psychological strain, usually in response to adverse events”. The definition of Musculoskeletal Discomfort was “relating to the skeleton and musculature taken together; an absence of comfort or ease; hardship or mild pain”. The definition of Anxiety was “a state of uneasiness and apprehension, as about future uncertainties”. The participant was instructed to put a vertical mark on the line that best represents their feelings *right now.* A space for optional comments was placed next to each VAS. The VAS has been shown to be reliable and valid for a variety of subjective measures (Cela & Perry, 1986; Davey, Barratt, Butow, and Deeks, 2007; Hornblow & Kidson, 1976; Lesage & Berjot, 2011).

Statistical Analyses

All statistical analyses were conducted using SAS (version 9.4; SAS Institute Inc., Cary, NC, 2015). Descriptive statistics and correlations were conducted on the following data: participant age, year in college, height, weight, credit load, exam scores, and class grade; weekly VAS scores for attention, stress, anxiety, and musculoskeletal discomfort; and overall score for direct observation of attention. The data from the VAS for attention, stress, anxiety, and musculoskeletal discomfort, as well as scores for direct observation of attention, were analyzed for weekly differences using a Mixed model repeated measures Analysis of Variance (ANOVA). A heterogeneous compound symmetry variance-covariance structure was determined to be the best fit for the data. A level of significance (α) of .05 was used for all analyses.

Results

A total of 23 participants (14 standing, 9 control) started the study. Five students withdrew from the course and 18 participants (12 standing) completed the study; descriptive statistics for these participants are located in Table 9. Data on the four VAS measures were analyzed for all 18 participants. Three standing group participants were excluded from direct observation of attention due to low attendance time on measurement days, leaving valid direct observation data for 15 participants (9 standing).

Graphical representations of weekly differences in Attention (AT), Stress (ST), Musculoskeletal Discomfort (MD), and Anxiety (AN) can be found in Figures 3-6, respectively.

Table 9

Participant Characteristics

Group	n	Age	Height	Weight	Credits	Year
Control	6	23.8 (6.6)	65.5 (4.3)	153.0 (27.6)	13.7 (2.4)	3.3 (0.8)
Standing	12	21.2 (3.5)	66.7 (5.1)	157.8 (37.5)	14.0 (3.3)	2.3 (1.1)

Note: Data are Mean (SD).

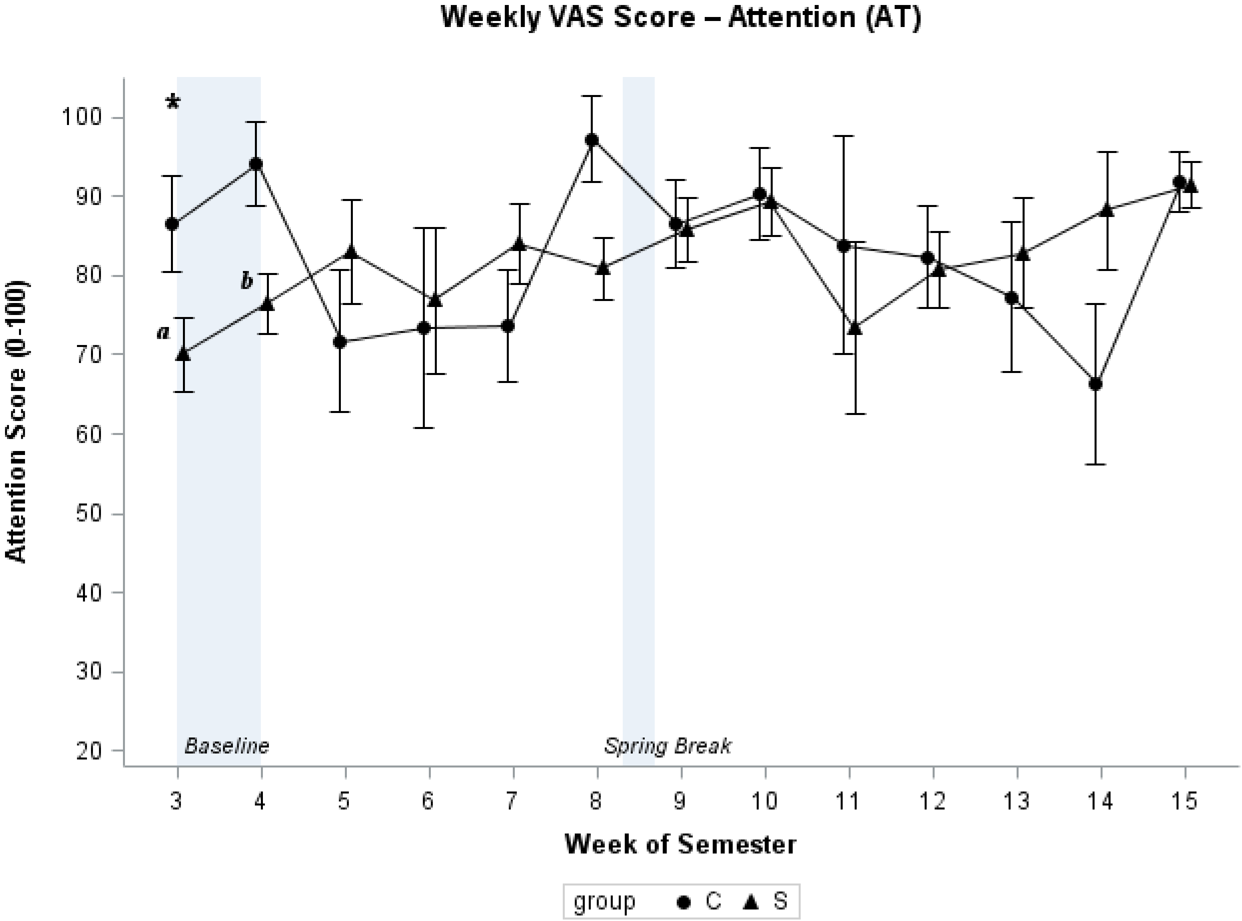

Figure 3. Weekly VAS Scores - Attention (AT). Data are adjusted means ± SE.
a = I-3 lower than C-8, I-10 and I-15 ($p < 0.05$).
b = I-4 lower than I-15 ($p < 0.05$).
* = week 3 lower than week 15 ($p < 0.05$).

For AT scores, there was a significant interaction (*F*[12, 166] = 2.79, p = 0.002) and week (*F*[12, 166] = 2.25, p = 0.012) effect, but no treatment (*F*[1, 16] = 0.02, p = 0.884) effect. Post-hoc analysis indicated week 3 was lower than week 15 ($p < 0.05$). For ST scores, there was a significant interaction (*F*[12, 166] = 2.15, *p* = 0.017) and week (*F*[12, 166] = 4.63, *p* < 0.0001) effect, but no treatment (*F*[1, 16] = 0.98, *p* = 0.338) effect. Post-hoc analysis indicated week 6 is higher than week 4, 9, 12, and 13 ($p < 0.05$) and week 11 is lower than week 3, 4, 5, 6, 7, 8, 10, 14, and 15 ($p < 0.05$). In addition, C-6 is different than C-4, C-11, C-12, C13, I-9, I-11, I-12, and I-13 ($p < 0.05$), C-11 is different than C-15 and I-5, and I-5 is different than I-11.

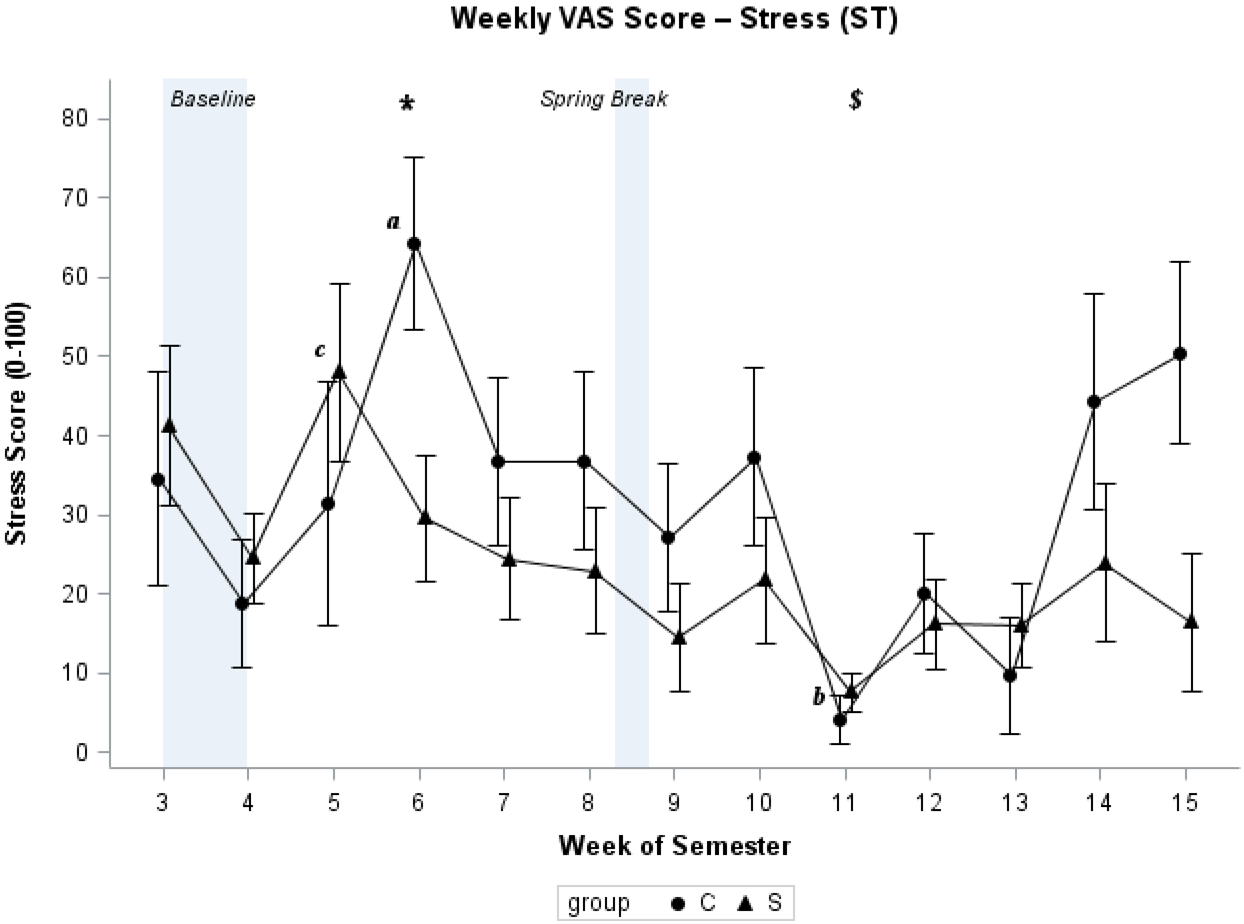

Figure 4. Weekly VAS Scores - Stress (ST). Data are adjusted means ± SE.
a = C-6 sig. different than C-4, C-11, C-12, C13, I-9, I-11, I-12, and I-13 ($p < 0.05$).
b = C-11 sig. different than C-15 and I-5;
c = I-5 sig. different than I-11 ($p < 0.05$).
* = week 6 higher than week 4, 9, 12, and 13 ($p < 0.05$).
*$* = week 11 lower than week 3, 4, 5, 6, 7, 8, 10, 14, and 15 ($p < 0.05$).

For MD scores, there was not a significant interaction (*F*[12, 166] = 0.89, p = .557), but there was a significant treatment (*F*[1, 16] = 14.24, p = 0.002) and week (*F*[12, 166] = 2.51, p = 0.005) effect. Tukey-Kramer post-hoc analysis indicated week 3 was higher than week 7, 10, and 11 ($p < 0.05$).

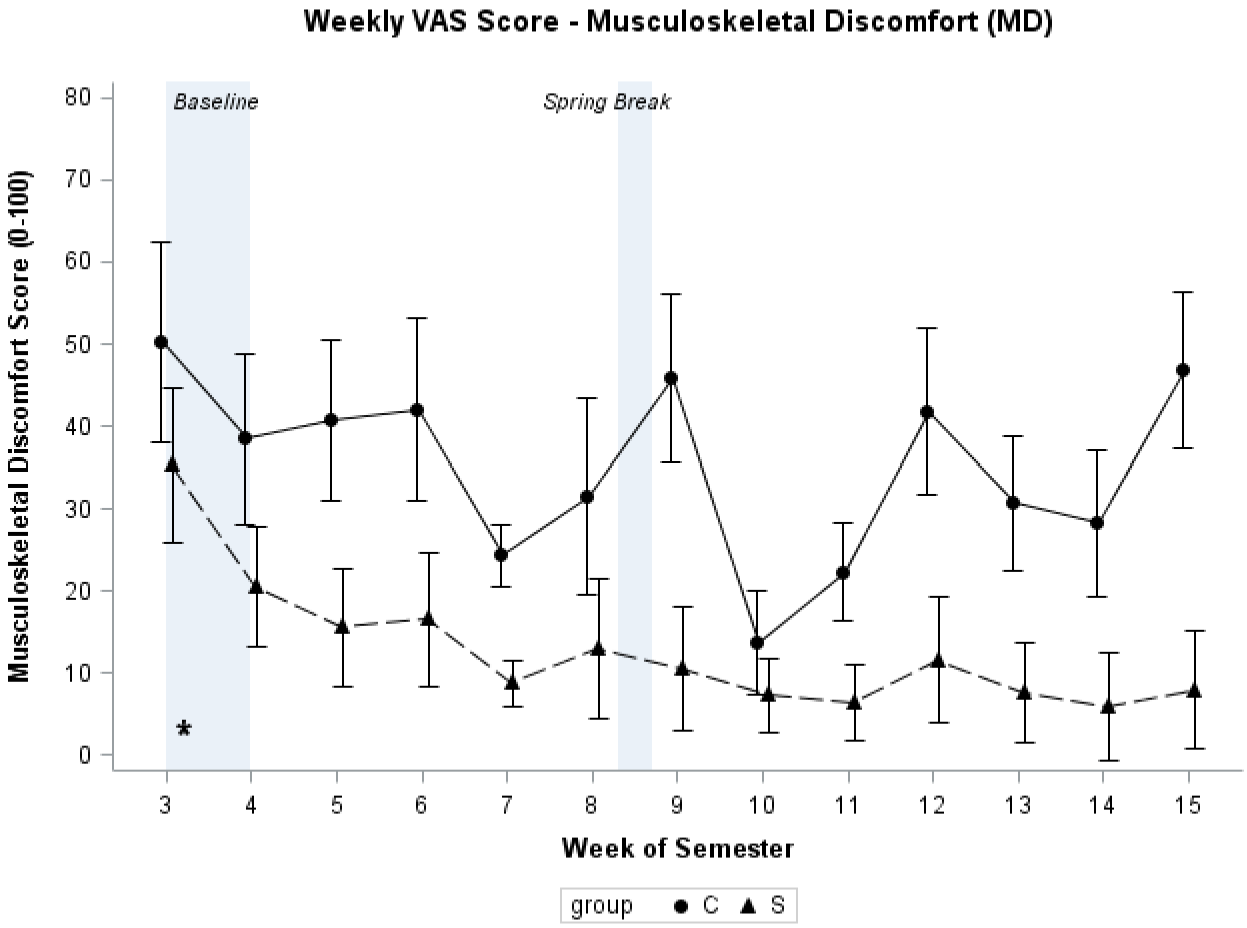

Figure 5. Weekly VAS Scores - Musculoskeletal Discomfort (MD).
Data are adjusted means ± SE.
* = week 3 higher than week 7, 10, and 11 ($p < 0.05$).

For AN scores, there was not a significant interaction (*F*[12, 166] = 1.50, p = 0.130) or treatment (*F*[1, 16] = 0.38, p = 0.544) effect, but there was a time (*F*[12, 166] = 2.26, p = 0.011) effect. Post-hoc analysis indicated week 6 was higher than week 11 ($p < 0.05$).

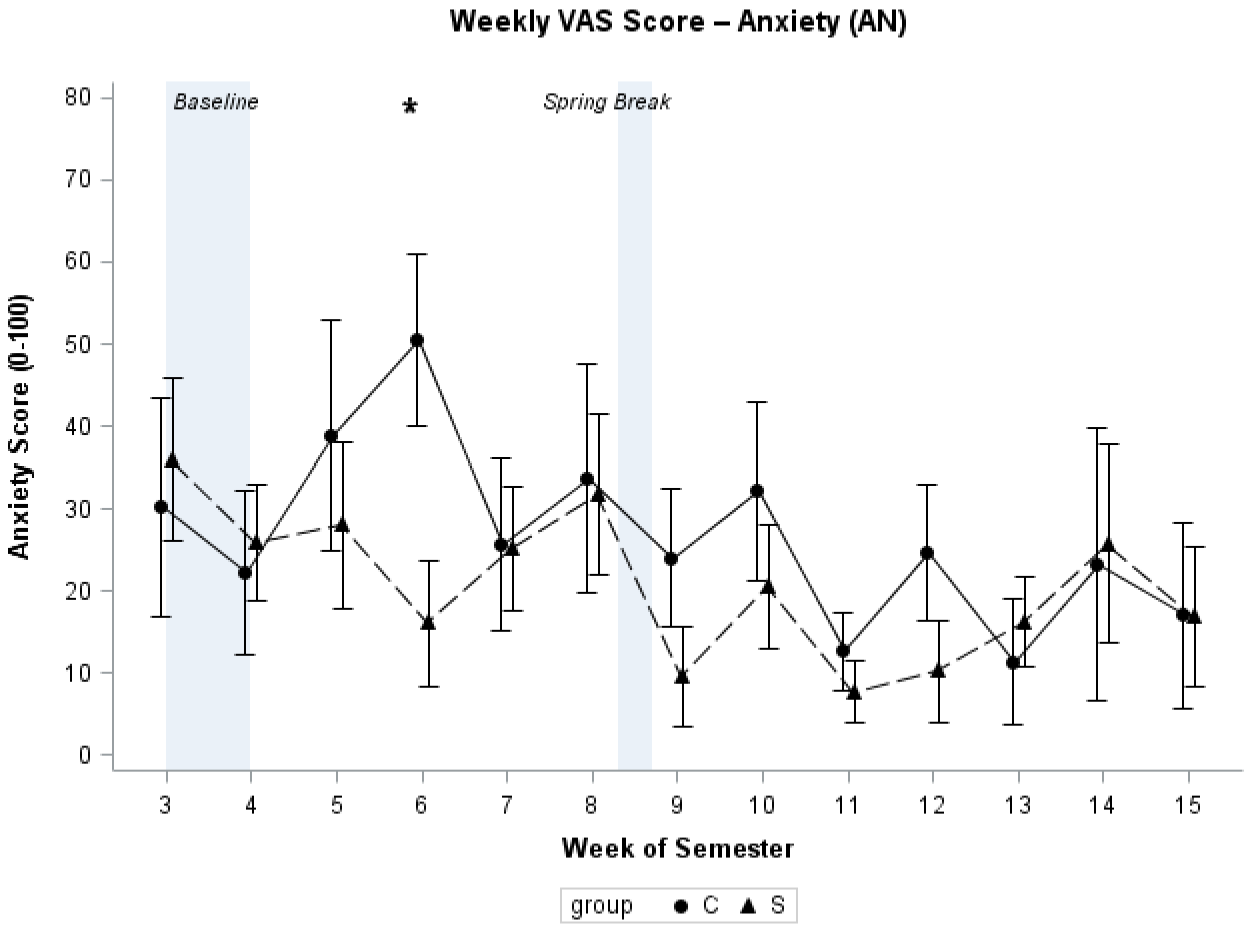

Figure 6. Weekly VAS Scores – Anxiety (AN). Data are adjusted means ± SE.
* = week 6 is higher than week 11 ($p < 0.05$).

Exam scores and direct observation of attention scores were also compared. EXAM scores did not have a significant interaction (*F*[6, 96] = 0.85, p = 0.537) or treatment (*F*[1, 16] = 1.52, p = 0.235) effect, but did have a week (*F*[6, 96] = 5.42, $p < 0.0001$) effect. Exam in week 12 was higher than week 4, 6, and 14, and week 15 higher than week 4 ($p < 0.05$) There was no significant difference in OAT scores (week 9, 12, and 13).

Attentive behavior as measured via direct observation (OAT) did not significantly correlate with Attention (AT) scores from the VAS in weeks 9, 12, or 13. AGE was significantly correlated with OATO (r=0.54, p = 0.038), PSTAND22 with OAT13 (r=0.69, p = 0.039), ST with MD in weeks 6, 8, 14 and 15 (r range = .60-.72, p < .05), and ST with AN for all weeks except 5 and 11 (r range = .61-.95, p < .05).

Qualitative Data

The comments section of the VAS data sheet was utilized by 5 control participants and 6 intervention participants, with two participants in each group providing many of the comments. Some of the comments were general while others specifically addressed some or all of VAS measures of Attention, Stress, Musculoskeletal Discomfort, and Anxiety. Positive general comments from intervention participants included the following statements: “The desk adjusts perfectly to the way I want to sit or stand. When a class is almost 2 hours long it's really nice to stand as well.”, “easy to interact with these tables in the environment”, “I felt like I could move and adjust without bothering classmates”, and “being able to adjust table has lowered my discomfort level helping me concentrate better thus having less stress.” Comments that were specific to a particular VAS measure, and that were low for Attention (below 35) or high for Stress, Musculoskeletal Discomfort, or Anxiety (above 75), are included in Table 10.

Table 10

Statements from the Comments Section of Weekly VAS Data Sheet

Week	ID	C/S	Score	Comment
ATTENTION				
5	1	C	32	very distracted thinking about car accident last night
7	8	S	5	I received bad news and so lost the will to pay attention
7	1	C	31	I couldn’t sit still I needed to stand
14	1	C	17	very unfocused and tired
STRESS				
3	1	C	98	sick, no free time, rugby captain, school 15 credits, working full time, a significant other, no time
5	1	C	100	car accident, money, no car now, how am I going to get to work
6	4	C	88	Starting a new job - studying for exams on Friday and Monday - work party on Sunday night
10	5	C	88	grade
10	1	C	77	very busy
15	1	C	99	planning a rugby tournament the weekend before finals
MUSCULOSKELETAL DISCOMFORT				
3	18	S	83	sore, uncomfortable from sitting
3	4	C	84	lower back pain
4	4	C	94	lower back pain still constant
5	1	C	84	my body hurts from the accident
6	4	C	96	back is in knots, hand cramps from cleaning kitchen at work
8	4	C	100	threw out back - hurts to move at all
9	4	C	89	pinched back/nerve inflammation
12	6	C	81	sore from working out yesterday. Back pain.
12	1	C	82	my shoulder hurts from rugby
ANXIETY				
3	1	C	95	I missed a question on my test that I knew the answer to and it was 3 points
5	1	C	96	no car till mine is fixed. And worrying how I'm going to fix it
6	1	C	87	worried I won't finish all my school work this weekend with work & polar plunge
8	10	S	91	Jeopardy (class review game)
10	5	C	78	worry about grade
10	1	C	80	afraid I'm not going to do as well as I want in my classes
15	16	S	77	I'm just anxious from the exam
15	1	C	77	I really want a 4.0

Discussion

The purpose of this study was to examine the effect of using adjustable-height (sit-stand) desks in a college class on the pattern of attention (AT), stress (ST), musculoskeletal discomfort (MD), and anxiety (AN) levels. The main findings revealed lower MD scores for the standing group, higher week 6 than week 11 scores for AN and ST, and more variability in AT and ST scores. Attendance was lowest for week 11 (n=10) compared to other weeks (n=15-18), which may account for the differences found in that week compared to other weeks. In addition, ST and AN scores were highly correlated for most weeks suggesting these measures captured similar information. There were no significant differences in exam scores or direct observation of attention scores between groups. Overall, these findings indicate that the amount of standing in this study did not negatively impact cognitive performance and was associated with less musculoskeletal discomfort.

Ebara et al. (2008) collected Visual Analogue Musculoskeletal Scale (VAMS) scores on 14 body regions and found higher scores for right and left lower leg, right forearm, and right wrist/hand in the sit-stand condition, whereas in this study MD scores represented discomfort in any region of the body. The lower discomfort ratings reported by Chester, Rys, and Konz (2002) may have been prevented in this study by allowing participants to move their feet and adjust the height of the desk. providing a pad for participants to stand on and by. The results of this study support the lower amounts of subjective feelings of fatigue reported when using a combination of sitting and standing (Hassegawa et al., 2002) during a 60 or 90-minute task and lower musculoskeletal discomfort ratings associated with using electronic height-adjustable workstations in a work setting (Hedge & Ray, 2004). However, it is unknown if using the sit-stand desks in this study resulted in lower MD scores for the intervention group, or if the higher

MD scores in the control group were caused by restricted movement of the standard sitting desks or for other reasons (e.g., chronic pain, acute soreness from physical activity, etc.).

Attention and academic engagement has been investigated in several other studies. Schraefel, Jay, and Andersen (2012) found that sitting resulted in higher Complex Attention scores as compared to standing, but was not different for several other measures related to the CNS Vital Signs (CNSVS) tests. The measure of attention in this study could be viewed as a general measure of attention, which may only partially relate to the CNSVS measure of Complex Attention, and was measured at more time points. Dornhecker et al. (2015) investigated academic engagement in elementary-aged students using stand-biased desks and found significantly higher engagement score in the treatment group in fall but no difference in spring. The observation protocol included 48 15-second intervals (12-min total), once in fall and once in spring, whereas this study utilized 40 15-second intervals (10-min total) during three separate sessions separated by 1-3 weeks. A similar study by Koepp et al. (2012) investigated sixth graders using standing desks and also found no difference in concentration levels after 5-months of use. The results of this study support the findings of Dorhecker et al. and Koepp et al. that standing does not negatively impact the ability of students at different levels to engage in attentive behavior in an academic setting.

The comments related to Attention, Stress, Musculoskeletal Discomfort, and Anxiety were optional but help provide some understanding of the participants' scores. The control group provided the large majority of comments. Attention scores appeared to be affected by low sleep levels in control participants. The intervention group did not have any comments related to sleep despite similar sleep levels between the two groups. Comments related to high scores for Musculoskeletal Discomfort show a combination of sitting, acute injury, or sport participation as the cause. One student’s comment mentioned a car accident but the student did not miss class, appear injured, or otherwise indicate any injuries existed. For Stress, homework/studying and a busy work, school, and personal schedule was stated as reasons for high stress scores. Similarly, high scores for Anxiety were associated with completing homework, and wanting to score high on a test and for their overall grade. Obtaining comments from more participants in future studies may shed more light on variation in VAS scores.

Limitations

There are several potential limitations in this study. First, the number of participants in both groups was small. In addition, the classes were offered at different times of the day (starting at 10:00 am for control group and 1:00 pm for the standing group), which may have affected the responses on the VAS measures. Also, the students who chose to participate in the study have been more interested in standing during class and therefore may not accurately represent the standing patterns of all students. However, given the high variability in standing by the participants in this study, we feel it accurately represents the standing patterns of students when given the instructions to use the sit-stand desk as they see fit.

The visual-analogue-scale (VAS) used to capture subjective attention, stress, musculoskeletal discomfort, and anxiety level are easy and quick to administer but do not capture specific reasons for the responses (i.e., it does not indicate why a participant responded with a low or high score). To address this, we added a comments section for participants to give reasons for their answers. However, not all participants utilized the comments section and only a few provided regular comments, with most comments coming from the control group. Therefore, fluctuations in these variables between the control and intervention groups may be attributed to different reasons.

Another limitation is that the participants in the control group mostly sat in the first (n=4) and second (n=2) row of the class and the standing group sat in the back or side of the class, which may have affected attention (AT or OAT) scores. This classroom arrangement was necessary so that standing students did not block the view of sitting students. However, the classroom was only four rows deep with the sit-stand desks in the fourth row, which minimized the distance from the front row. In addition, three of the 12 intervention participants were on one side of the classroom which corresponded with the second and third row of standard desks. We feel this placement of the sit-stand desks was close enough to the other students, professor, and screen to not affect the results. In addition, participants in both groups were noticed engaging in non-attentive or off-task behavior (e.g., using cell phones, talking to classmates about non-class material, spacing out, etc.).

Another limitation may be the use of exam scores as our measure of academic performance. Similar to VAS questionnaires, fluctuations in exam scores may be attributed to variables not measured in this study (e.g., previous experience with the course material, amount of studying, ability to memorize information, etc.). The exam questions were the same between groups and were given on the same days so we feel this provided a consistent measure of performance during the semester.

Conclusion

A strength of this study is the collection of weekly data on Attention, Stress, Musculoskeletal Discomfort, and Anxiety levels over the course of a semester. The sit-stand desks did not appear to cause a decrease in attention or an increase in stress, anxiety, or musculoskeletal discomfort and the participants in this study provided positive qualitative comments on the sit-stand desk usage. Further investigations should evaluate alternate intervention protocols to determine the optimal sit-stand desk usage that results in positive effects on attention, stress/anxiety, musculoskeletal discomfort, and academic performance.

Acknowledgements

This study was supported by a Faculty Research Grant from St. Cloud State University.

SUMMARY

A shift in recent years is placing more focus on the behaviors and environments that cause people to sit for long periods of time on a daily basis as sedentary time is now thought to be associated with negative health consequences independent of the level of PA (Biswas et al., 2015) or body mass index (BMI) (Thorp, Owen, Neuhaus, & Dunstan, 2011). The trend of moderate physical activity occupations being replaced with occupations requiring only sedentary or light intensities over the last 50 years (Church et al., 2011) may provide a rationale to the recent efforts to design numerous devices to address the increasingly sedentary nature of work and school environments. The standard desks and chairs used in work and school settings, unchanged for many years, have been altered to change the body position for workers and students while still allowing them to complete normal work or school tasks (i.e., typing, writing, talking on the phone, using a computer, etc.).

This disquisition examined the effects of sit-stand desks in a college classroom over the course of a semester and was split into two studies. Paper 1 determined the pattern of sit-stand desk usage over the course of a semester, the relationship to movement outside of class, and if the participants liked using the sit-stand desks. Paper 2 determined the pattern of attention (AT), stress (ST), musculoskeletal discomfort (MD), and anxiety (AN) while using adjustable-height (sit-stand) desks in a college class. Participants were recruited from two sections of the same course at a public university in central Minnesota; participants in one section served as the control group (n=6) and participants in the other section as the standing group (n=12).

The major findings of this disquisition were that individual daily standing time for the standing group ranged from 0-100% of daily attendance time and the daily group average ranged from 2.1-38.4%. Weekly standing was lower ($p<.05$) in week 8 than week 5, 9, 11, 13, and 15.

There was no significant difference in standing percentage between Wednesdays and Fridays. A third of all standing bouts were less than 0.3 min and two-thirds were less than 2 min in length. Perception Questionnaire answers were positive for using the desk and their effect on ability to work in class. The amount of daily moderate-to-vigorous physical activity (MVPA) did not differ between groups (total n=18; control=6) or between time points (week 7 vs. 14). All participants completed visual analogue scales (VAS) to measure AT, ST, MD, and AN from weeks 3-15, and exams at week 4, 6, 8, 10, 12, 14, and 15. The main findings revealed lower MD scores for the intervention group, higher week 6 than week 11 scores for AN and ST, and more variability in AT and ST scores. In addition, ST and AN scores were highly correlated for most weeks suggesting these measures captured similar information. Exam scores were not different between groups. There was also no difference in direct observation of attention (OAT) between groups (total n=15; control=6) at weeks 9, 12, or 13.

In conclusion, the strength of this study is the collection of weekly data related to the patterns of standing, AT, ST, MD, and AN over the course of a semester. The sit-stand desks did not appear to cause a decrease in attention or an increase in stress, anxiety, or musculoskeletal discomfort, nor did it appear to be associated with the amount of movement (MVPA) outside of class. In addition, the sit-stand desks in this study were well liked and the participants provided positive qualitative comments on the sit-stand desk usage. However, the overall daily fluctuations, as well as between-subject fluctuations, of sit-stand desk use in this study highlight the need to find intervention protocols that are immune to these fluctuations in use that we see when participants have the choice to stand or sit as they see fit, which previous research has indicated should be given to intervention participants (Gilson, Straker, & Parry, 2012; Levine, 2007). However, perhaps taking that freedom of when and how much they use the device away may be best for maximizing its use (e.g., achieving 90-100% of class time spent standing) in a university setting and evaluating if this would have any effect on the perceptions of the sit-stand desks, any relationships to the amount of movement outside of class, or any other possible beneficial physical or cognitive health impacts.

REFERENCES

Alderman, B. L., Olson, R. L., & Mattina, D. M. (2013). Cognitive function during low intensity walking: A test of the treadmill workstation. *Journal of Physical Activity & Health, 11*, 752-758.

Alkhajah, T. A., Reeves, M. M., Eakin, E. G., Winkler, E. A., Owen, N., & Healy, G. N. (2012). Sit–Stand workstations: a pilot intervention to reduce office sitting time. *American Journal of Preventive Medicine, 43*, 298-303.

Bailey, D. P., & Locke, C. D. (2014). Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. *Journal of Science and Medicine in Sport, 18*, 294-298.

Beers, E. A., Roemmich, J. N., Epstein, L. H., & Horvath, P. J. (2008). Increasing passive energy expenditure during clerical work. *European Journal of Applied Physiology, 103*, 353-360.

Benden, M. E., Blake, J. J., Wendel, M. L., & Huber Jr, J. C. (2011). The impact of stand-biased desks in classrooms on calorie expenditure in children. *American Journal of Public Health, 101*, 1433-1436.

Ben-Ner, A., Hamann, D. J., Koepp, G., Manohar, C. U., & Levine, J. (2014). Treadmill workstations: The effects of walking while working on physical activity and work performance. *PloS one, 9*, e88620. doi:10.1371/journal.pone.0088620

Berendsen, B. A., Hendriks, M. R., Meijer, K., Plasqui, G., Schaper, N. C., & Savelberg, H. H. (2014). Which activity monitor to use? Validity, reproducibility and user friendliness of three activity monitors. *Biomed Central Public Health*, *14*, 749.

Bey, L., & Hamilton, M. T. (2003). Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity. *The Journal of Physiology, 551*, 673-682.

Botter, J., Burford, E. M., Commissaris, D., Könemann, R., Hiemstra-van Mastrigt, S., & Ellegast, R. P. (2013). The biomechanical and physiological effect of two dynamic workstations. In Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management. Human Body Modeling and Ergonomics (pp. 196-204). Springer Berlin Heidelberg.

Buckley, J. P., Mellor, D. D., Morris, M., & Joseph, F. (2014). Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occupational and Environmental Medicine*, *71*, 109-111.

Burford, E. M., Botter, J., Commissaris, D., Könemann, R., Hiemstra-van Mastrigt, S., & Ellegast, R. P. (2013). The effect of dynamic workstations on the performance of various computer and office-based tasks. In Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management. Human Body Modeling and Ergonomics (pp. 205-212). Springer Berlin Heidelberg.

Cardon, G., De Clercq, D., De Bourdeaudhuij, I., & Breithecker, D. (2004). Sitting habits in elementary schoolchildren: a traditional versus a “Moving school”. *Patient Education and Counseling, 54*, 133-142.

Carr, L. J., Walaska, K. A., & Marcus, B. H. (2012). Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace. *British Journal of Sports Medicine, 46,* 430-435.

Cella, D. F., & Perry, S. W. (1986. Reliability and concurrent validity of three visual-analogue mood scales. *Psychological Reports, 59*, 827-833.

Chester, M. R., Rys, M. J., & Konz, S. A. (2002). Leg swelling, comfort and fatigue when sitting, standing, and sit/standing. *International Journal of Industrial Ergonomics, 29*, 289-296.

Chia, M. (2014). Sitting Made in Time to be Less Sedentary at Work (SMILES@ Work). *Journal of Obesity and Weight Loss Therapy*, S4. doi:10.4172/2165-7904.S4-004

Chia, M., & Suppiah, H. (2013). Inactivity Physiology-Standing up for Making Sitting Less Sedentary at Work. *Journal of Obesity and Weight Loss Therapy, 3*. doi:10.4172/2165-7904.1000171

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and Science in Sports and Exercise, 43*, 357-364.

Church, T. S., Thomas, D. M., Tudor-Locke, C., Katzmarzyk, P. T., Earnest, C. P., Rodarte, R. Q., ... & Bouchard, C. (2011). Trends over 5 decades in US occupation-related physical activity and their associations with obesity. *PloS one, 6*, e19657. doi:10.1371/journal.pone.0019657

Cifuentes, M., Qin, J., Fulmer, S., & Bello, A. (2014). Barriers and Facilitators of Supplying a Treadmill Workstation to Office Workers: usability, safety, comfort, and productivity. A qualitative study. *Occupational and Environmental Medicine, 71*(Suppl 1), A32. doi:10.1136/oemed-2014-102362.99

Commissaris, D. A., Könemann, R., Hiemstra-van Mastrigt, S., Burford, E. M., Botter, J., Douwes, M., & Ellegast, R. P. (2014). Effects of a standing and three dynamic workstations on computer task performance and cognitive function tests. *Applied Ergonomics, 45*, 1570-1578.

Cooley, C. & Pedersen, S. (2013). A pilot study of increasing nonpurposeful movement breaks at work as a means of reducing prolonged sitting. *Journal of Environmental and Public Health*. doi:10.1155/2013/128376

Cox, R. H., Guth, J., Siekemeyer, L., Kellems, B., Brehm, S. B., & Ohlinger, C. M. (2011). Metabolic cost and speech quality while using an active workstation. *Journal of Physical Activity and Health, 8*, 332-9.

Creasy, S. A., Rogers, R. J., Byard, T.D., Kowalsky, R. J., & Jakicic, J.M. (2016). Energy expenditure during acute periods of sitting, standing, and walking. *Journal of Physical Activity and Health, 13*, 573-578. doi:10.1123/jpah.2015-0419

Dall, P. M., & Kerr, A. (2010). Frequency of the sit to stand task: An observational study of free-living adults. *Applied Ergonomics, 41*, 58-61.

Davey, H. M., Barratt, A. L., Butow, P. N., & Deeks, J. J. (2007). A one-item question with a likert or visual analogue scale adequately measure current anxiety. *Journal of Clinical Epidemiology, 60*, 356-360.

Dornhecker, M., Blake, J. J., Benden, M., Zhao, H., & Wendel, M. (2015). The effects of stand-biased desks on academic engagement: An exploratory study. *International Journal of Health Promotion and Education, 53,* 271-280. doi:10.1080/14635240.2015.1029641

Drury, C. G., Hsiao, Y. L., Joseph, C., Joshi, S., Lapp, J., & Pennathur, P. R. (2008). Posture and performance: sitting vs. standing for security screening. *Ergonomics, 51*, 290-307.

Dunstan, D. W., Howard, B., Healy, G. N., & Owen, N. (2012). Too much sitting–a health hazard. *Diabetes Research and Clinical Practice, 97*, 368-376.

Dutta, N., Koepp, G. A., Stoviz, S. D., Levine, J. A., & Pereira, M. A. (2014). Using sit-stand workstations to decrease sedentary time in office workers: a randomized crossover trial. *International Journal of Environmental Research and Public Health*, *11*, 6653-6665.

Ebara, T., Kubo, T., Inoue, T., Murasaki, G. I., Takeyama, H., Sato, T., ... & Itani, T. (2008). Effects of adjustable sit-stand VDT workstations on workers' musculoskeletal discomfort, alertness and performance. *Industrial Health, 46,* 497-505.

Ekblom-Bak, E., Hellénius, M. L., & Ekblom, B. (2010). Are we facing a new paradigm of inactivity physiology? *British Journal of Sports Medicine, 44,* 834-835.

Ekelund, U., Ward, H. A., Norat, T., Luan, J. A., May, A. M., Weiderpass, E., ... & Riboli, E. (2015). Physical activity and all-cause mortality across levels of overall and abdominal adiposity in European men and women: The European Prospective Investigation into Cancer and Nutrition Study (EPIC). The *American Journal of Clinical Nutrition.* doi:10.3945/ajcn.114.100065

Elmer, S. J., & Martin, J. C. (2014). A cycling workstation to facilitate physical activity in office settings. *Applied Ergonomics, 45,* 1240-1246.

Feld, R. (2009). Re:"Walking Workstations: Ambulatory Medicine Redefined". *Journal of the American College of Radiology, 6,* 213.

Fidler, J. L., MacCarty, R. L., Swensen, S. J., Huprich, J. E., Thompson, W. G., Hoskin, T. L., & Levine, J. A. (2008). Feasibility of using a walking workstation during CT image interpretation. *Journal of the American College of Radiology, 5*, 1130-1136.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and science in sports and exercise, 30*(5), 777-781.

Funk, R. E., Taylor, M. L., Creekmur, C. C., Ohlinger, C. M., Cox, R. H., & Berg, W. P. (2012). Effect of walking speed on typing performance using an active workstation. *Perceptual and Motor Skills, 115*, 309-318.

Gilson, N. D., Burton, N. W., Van Uffelen, J. G., & Brown, W. J. (2011). Occupational sitting time: employees? perceptions of health risks and intervention strategies. *Health Promotion Journal of Australia, 22*, 38-43.

Gilson, N., Straker, L., & Parry, S. (2012). Occupational sitting: practitioner perceptions of health risks, intervention strategies and influences. *Health Promotion Journal of Australia, 23*, 208-212.

Gilson, N. D., Suppini, A., Ryde, G. C., Brown, H. E., & Brown, W. J. (2012). Does the use of standing 'hot' desks change sedentary work time in an open plan office? *Preventive Medicine, 54*, 65-67.

Grunseit, A. C., Chau, J. Y. Y., van der Ploeg, H. P., & Bauman, A. (2013). "Thinking on your feet": A qualitative evaluation of sit-stand desks in an Australian workplace. *BioMed Central Public Health, 13*, 1-10.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2004). Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. *Exercise and Sport Sciences Reviews, 32*, 161-166.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes, 56*, 2655-2667.

Hasegawa, T., Inoue, K., Tsutsue, O., & Kumashiro, M. (2001). Effects of a sit–stand schedule on a light repetitive task. *International Journal of Industrial Ergonomics, 28*, 219-224.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Breaks in Sedentary Time Beneficial associations with metabolic risk. *Diabetes Care, 31*, 661-666.

Healy, G. N., Eakin, E. G., La Montagne, A. D., Owen, N., Winkler, E. A., Wiesner, G., ... & Dunstan, D. W. (2013). Reducing sitting time in office workers: short-term efficacy of a multicomponent intervention. *Preventive Medicine, 57,* 43-48.

Hedge, A., & Ray, E. J. (2004, September). Effects of an electronic height-adjustable worksurface on computer worker musculoskeletal discomfort and productivity. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 48, No. 8, pp. 1091-1095). SAGE Publications.

Hinckson, E. A., Aminian, S., Ikeda, E., Stewart, T., Oliver, M., Duncan, S., & Schofield, G. (2013). Acceptability of standing workstations in elementary schools: A pilot study. *Preventive Medicine, 56*, 82-85.

Hornblow, A. R., & Kidson, M. A. (1976). The visual analogue scale for anxiety: A validation study. *Australian and New Zealand Journal of Psychiatry, 10,* 339-341.

Irvine, A. B., Philips, L., Seeley, J., Wyant, S., Duncan, S., & Moore, R. W. (2011). Get moving: a web site that increases physical activity of sedentary employees. *American Journal of Health Promotion, 25*, 199-206.

John, D., Bassett, D., Thompson, D., Fairbrother, J., & Baldwin, D. (2009). Effect of using a treadmill workstation on performance of simulated office work tasks. *Journal of Physical Activity and Health, 6,* 617-624.

John, D., Thompson, D. L., Raynor, H., Bielak, K., Rider, B., & Bassett, D. R. (2011). Treadmill workstations: a worksite physical activity intervention in overweight and obese office workers. *Journal of Physical Activity & Health, 8,* 1034.

Kilpatrick, M., Sanderson, K., Blizzard, L., Teale, B., & Venn, A. (2013). Cross-sectional associations between sitting at work and psychological distress: reducing sitting time may benefit mental health. *Mental Health and Physical Activity, 6,* 103-109.

Koepp, G. A., Manohar, C. U., McCrady-Spitzer, S. K., Ben-Ner, A., Hamann, D. J., Runge, C. F., & Levine, J. A. (2013). Treadmill desks: A 1-year prospective trial. *Obesity, 21,* 705-711.

Koepp, G. A., Snedden, B. J., Flynn, L., Puccinelli, D., Huntsman, B., & Levine, J. A. (2012). Feasibility analysis of standing desks for sixth graders. *ICAN: Infant, Child, & Adolescent Nutrition, 4,* 89-92.

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of wearable monitors for assessing sedentary behavior. *Medicine and Science in Sports and Exercise, 43,* 1561-1567.

Lanningham-Foster, L., Foster, R. C., McCrady, S. K., Manohar, C. U., Jensen, T. B., Mitre, N. G., ... & Levine, J. A. (2008). Changing the school environment to increase physical activity in children. *Obesity, 16*, 1849-1853.

Lesage, F. X., & Berjot, S. (2011). Validity of occupational stress assessment using a visual analogue scale. *Occupational Medicine, 61*, 434-436.

Levine, J. A. (2007). Nonexercise activity thermogenesis–liberating the life-force. *Journal of Internal Medicine, 262*, 273-287.

Levine, J. A., Eberhardt, N. L., & Jensen, M. D. (1999). Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science, 283*, 212-214.

Levine, J. A., Lanningham-Foster, L. M., McCrady, S. K., Krizan, A. C., Olson, L. R., Kane, P. H., ... & Clark, M. M. (2005). Interindividual variation in posture allocation: possible role in human obesity. *Science, 307*, 584-586.

Levine, J. A., & Miller, J. M. (2007). The energy expenditure of using a “walk-and-work” desk for office workers with obesity. *British Journal of Sports Medicine, 41*, 558-561.

MacEwen, B. T., MacDonald, D. J., & Burr, J. F. (2015). A systematic review of standing and treadmill desks in the workplace. *Preventive Medicine, 70*, 50-58.

Mahar, M. T., Murphy, S. K., Rowe, D. A., Golden, J., Shields, A. T., & Raedeke, T. D. (2006). Effects of a classroom-based program on physical activity and on-task behavior. *Medicine and Science in Sports and Exercise, 38*, 2086-2094.

McAlpine, D. A., Manohar, C. U., McCrady, S. K., Hensrud, D., & Levine, J. A. (2007). An office-place stepping device to promote workplace physical activity. *British Journal of Sports Medicine, 41*, 903-907.

Miyashita, M., Park, J. H., Takahashi, M., Suzuki, K., Stensel, D., & Nakamura, Y. (2013). Postprandial lipaemia: effects of sitting, standing and walking in healthy normolipidaemic humans. *International Journal of Sports Medicine, 34*, 21-27.

Nettlefold, L., McKay, H. A., Warburton, D. E. R., McGuire, K. A., Bredin, S. S. D., & Naylor, P. J. (2011). The challenge of low physical activity during the school day: at recess, lunch and in physical education. *British Journal of Sports Medicine, 45*, 813-819.

Neuhaus, M., Healy, G. N., Dunstan, D. W., Owen, N., & Eakin, E. G. (2014). Workplace Sitting and Height-Adjustable Workstations: A Randomized Controlled Trial. *American Journal of Preventive Medicine, 46*, 30-40.

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population-health science of sedentary behavior. *Exercise and Sport Sciences Reviews, 38*, 105.

Pina, L. R., Ramirez, E., & Griswold, W. G. (2012, May). Fitbit+: A behavior-based intervention system to reduce sedentary behavior. In Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2012 6th International Conference on (pp. 175-178). IEEE.

Pronk, N. P., Katz, A. S., Lowry, M., & Payfer, J. R. (2012). Reducing Occupational Sitting Time and Improving Worker Health: The Take-a-Stand Project, 2011. *Preventing Chronic Disease, 9*. doi:10.5888/pcd9.110323

Radas, A., Mackey, M., Leaver, A., Bouvier, A. L., Chau, J. Y., Shirley, D., & Bauman, A. (2013). Evaluation of ergonomic and education interventions to reduce occupational sitting in office-based university workers: study protocol for a randomized controlled trial. *Trials, 14*, 330.

Reiff, C., Marlatt, K., & Dengel, D. R. (2012). Difference in caloric expenditure in sitting versus standing desks. *Journal of Physical Activity & Health, 9*.

Rovniak, L. S., Denlinger, L., Duveneck, E., Sciamanna, C. N., Kong, L., Freivalds, A., & Ray, C. A. (2013). Feasibility of using a compact elliptical device to increase energy expenditure during sedentary activities. *Journal of Science and Medicine in Sport, 17*, 376-380.

Rutten, G. M., Savelberg, H. H., Biddle, S. J., & Kremers, S. P. (2013). Interrupting long periods of sitting: good STUFF. *International Journal of Behavioral Nutrition and Physical Activity, 10*, 1.

Saidj, M., Jørgensen, T., Jacobsen, R. K., Linneberg, A., & Aadahl, M. (2013). Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study. *PloS one, 8*, e70213. doi:10.1371/journal.pone.0070213

Sasaki, J. E., John, D., & Freedson, P. S. (2010). Calibration of the Actigraph GT3X activity monitor. In *3rd International Congress on Physical Activity and Public Health (ICPAPH). Toronto, Canada*.

Schofield, G., Kilding, A., Freese, R., Alison, A., & White, K. (2009). Standing up at work: The feasibility of using height adjustable desks to reduce sedentary behaviour and increase energy expenditure. *Journal of Science and Medicine in Sport, 12,* S17.

Schraefel, M. C., Jay, K., Andersen, L. L. (2012). Assessing the effect of self-positioning on cognitive executive function. *Journal of Ergonomics, 2*. doi: 10.4172/2165-7556.1000110

Schuna Jr, J. M., Swift, D. L., Hendrick, C. A., Duet, M. T., Johnson, W. D., Martin, C. K., ... & Tudor-Locke, C. (2014). Evaluation of a Workplace Treadmill Desk Intervention: A Randomized Controlled Trial. *Journal of Occupational and Environmental Medicine, 56,* 1266-1276.

Sliter, M., & Yuan, Z. (2015). Workout at Work: Laboratory Test of Psychological and Performance Outcomes of Active Workstations. *Journal of Occupational Health Psychology, 20*, 259-271. doi:10.1037/a0038175

Speck, R. M., & Schmitz, K. H. (2011). Energy expenditure comparison: a pilot study of standing instead of sitting at work for obesity prevention. *Preventive Medicine, 52*, 283-284.

Stephens, S.K., Winkler, E.A.H., Dunstan, D.W., Eakin, E.G., Healy, G.N., Trost, S.G., & Chastin, S.F.M. (2014). Intervening to reduce workplace sitting time: how and when do changes to sitting time occur. *British Journal of Sports Medicine, 48,* 1037-1042.

Straker, L., Abbott, R. A., Heiden, M., Mathiassen, S. E., & Toomingas, A. (2013). Sit–stand desks in call centres: Associations of use and ergonomics awareness with sedentary behavior. *Applied Ergonomics*, *44*, 517-522.

Taylor, W. C., King, K. E., Shegog, R., Paxton, R. J., Evans-Hudnall, G. L., Rempel, D. M., ... & Yancey, A. K. (2013). Booster Breaks in the workplace: participants' perspectives on health-promoting work breaks. *Health Education Research*. doi:10.1093/her/cyt001

Thompson, W. G., Foster, R. C., Eide, D. S., & Levine, J. A. (2008). Feasibility of a walking workstation to increase daily walking. *British Journal of Sports Medicine, 42*, 225-228.

Thompson, W. G., Koepp, G. A., & Levine, J. A. (2013). Increasing physician activity with treadmill desks. *Work: A Journal of Prevention, Assessment and Rehabilitation, 48*, 47-51.

Thompson, W. G., & Levine, J. A. (2011). Productivity of transcriptionists using a treadmill desk. Work: A *Journal of Prevention, Assessment and Rehabilitation, 40*, 473-477.

Thorp, A. A., Owen, N., Neuhaus, M., & Dunstan, D. W. (2011). Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. *American Journal of Preventive Medicine, 41*, 207-215.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*, 181-188.

Tudor-Locke, C., Hendrick, C. A., Duet, M. T., Swift, D. L., Schuna, Jr, J. M., Martin, C. K., ... & Church, T. S. (2014). Implementation and adherence issues in a workplace treadmill desk intervention. *Applied Physiology*, *Nutrition, and Metabolism, 39,* 1104-1111.

Tudor-Locke, C., Johnson, W. D., Katzmarzyk, P. T. (2009). Accelerometer-Determined steps per day in US adults. *Medicine and Science in Sports and Exercise, 41*, 1384-1391.

van der Ploeg, H. P., Chey, T., Korda, R. J., Banks, E., & Bauman, A. (2012). Sitting time and all-cause mortality risk in 222 497 Australian adults. *Archives of Internal Medicine, 172,* 494-500.

Van Uffelen, J. G., Wong, J., Chau, J. Y., van der Ploeg, H. P., Riphagen, I., Gilson, N. D., ... & Brown, W. J. (2010). Occupational sitting and health risks: a systematic review. *American Journal of Preventive Medicine, 39,* 379-388.

Voss, M. W., Carr, L. J., Clark, R., & Weng, T. (2014). Revenge of the “sit” II: Does lifestyle impact neuronal and cognitive health through distinct mechanisms associated with sedentary behavior and physical activity? *Mental Health and Physical Activity, 7*, 9-24.

Wilks, S., Mortimer, M., & Nylén, P. (2006). The introduction of sit–stand worktables; aspects of attitudes, compliance and satisfaction. *Applied Ergonomics, 37*, 359-365.

Yates, T., Wilmot, E. G., Khunti, K., Biddle, S., Gorely, T., & Davies, M. J. (2011). Stand up for your health: Is it time to rethink the physical activity paradigm?. *Diabetes Research and Clinical Practice, 93,* 292-294.

Zderic, T. W., & Hamilton, M. T. (2006). Physical inactivity amplifies the sensitivity of skeletal muscle to the lipid-induced downregulation of lipoprotein lipase activity. *Journal of Applied Physiology, 100*, 249-257.

Zimmerman, F. J. (2009). Using behavioral economics to promote physical activity. *Preventive Medicine, 49*, 289-291.

APPENDIX A. SLEEP LOG AND ACCELEROMETER INSTRUCTIONS

Subject #:______________________ Date start:________________

Actigraph #:____________________ Date end:_________________

Day	**Date (month/day)**	**Time you went to bed**	**Time you got up the *next* morning**
1			
2			
3			
4			
5			
6			
7			

Instructions for **Actigraph** use:

1. **Wear Actigraph at all times**, EXCEPT:
    - a. When sleeping (log times for when you take it off to go to bed and when you put it back on after you wake-up)
    - b. Showering/bathing
    - c. Swimming or other pool activities
2. **Wear Actigraph on your *right hip*** as shown (see Fig. 1).
3. You will not need to charge the Actigraph.

Figure 1 - Device worn on Right side

APPENDIX B. PERCEPTION QUESTIONNAIRE

Subject #: _____ Age: _____ Height: _____ Weight: _____ Yr in school: _____

How many credits are you taking this semester? __________

Sit-Stand Desk Perception Questionnaire	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
17) The sit-stand desk is easy to use.					
18) I felt comfortable using the sit-stand desk in the presence of others in the class					
19) My work-related productivity decreased while using the sit-stand -desk					
20) The quality of my note-taking decreased while using the sit-stand -desk					
21) The sit-stand desk interfered with my class-related activities					
22) I could conduct normal class-related tasks while using the sit-stand desk					
23) I could easily see the PowerPoint slides (or chalkboard/dry-erase board notes) while using the sit-stand desk.					
24) I could read comfortably while using the sit-stand desk					
25) I could communicate with the professor, if necessary, while using the sit-stand desk					
26) I could write comfortably while using the sit-stand desk					
27) I was more tired after class on days I used the sit-stand desk					
28) I had more physical discomfort on days I used the sit-stand desk					
29) I was distracted by students adjusting the sit-stand desk during class					
30) I used the sit-stand desk more than I thought I would at the beginning of the semester					
31) I would use a sit-stand desk in my other classes if it was available					
32) I would use a sit-stand desk while studying outside of class (at home or in a study area on campus) if one was available.					

APPENDIX C. VAS QUESTIONNAIRE

Sit-Stand Desk Study Subject #:_________ Date: _________________

Instructions: Draw a vertical line on each horizontal line to represent your feelings *right now*.

ATTENTION = the act of close or careful observing or listening; ability to concentrate

No attention High attention

0 ____ 100

STRESS = psychological strain, usually in response to adverse events

No stress High stress

0 ____ 100

MUSCULOSKELETAL DISCOMFORT = relating to the skeleton and musculature taken together; absence of comfort or ease; hardship or mild pain

No discomfort/pain High discomfort/pain

0 ____ 100

ANXIETY = state of uneasiness and apprehension, as about future uncertainties

No anxiety high anxiety

0 ____ 100

Optional Comments

Why did you respond this way?