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Treadmill Workstations: An Obesity Intervention?

Dinesh John
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Dinesh John entitled "Treadmill Workstations: An Obesity Intervention?." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Exercise and Sport Sciences.

David R. Bassett, Major Professor

We have read this dissertation and recommend its acceptance:

Dixie L. Thompson, Eugene C. Fitzhugh, Naima Moustaid-Moussa, Bob Rider

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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TREADMILL WORKSTATIONS: AN OBESITY INTERVENTION?

A Dissertation

Presented for the

Doctor of Philosophy Degree

The University of Tennessee, Knoxville

Dinesh John

August 2009

DEDICATION

This dissertation is dedicated to my mother, Mariamma John, for making my life better with her love and affection and for always believing in me. She would have been extremely pleased to see this achievement.

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I would like to thank Dr. David R. Bassett, for being a great mentor and sharing his vast knowledge with me. His guidance in shaping my abilities professionally is a debt that can never be repaid. Apart from mentoring me, Dr Bassett, has also been more than a good and kind friend. I cherish his friendship and feel blessed to have met such a wonderful person.

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ABSTRACT

The purpose of this dissertation was to examine the feasibility and effectiveness of treadmill workstations as a weight loss intervention. Specific aims were (a) to determine if walking while working at a treadmill workstation affects selective attention and mental processing speed, and performance of simulated office work tasks involving fine motor movements (typing and mouse movements) and mathematical and verbal reasoning, and (b) To determine if using of a treadmill workstation favorably influences anthropometric, body composition, cardiovascular, metabolic, musculoskeletal, and mental stress variables in overweight and obese office workers.

For the first aim, 20 participants completed tests to assess selective attention and processing speed, typing speed, mouse clicking/drag-and-drop speed, and GRE math and reading comprehension under seated and walking conditions. The seated condition produced significantly better results for mouse clicking (26.6 ±3.0 *vs.* 28.2 ±2.5 s) and drag-and-drop (40.3 ±4.2 *vs.* 43.9 ±2.5 s), typing (40.2 ±9.1 *vs.* 36.9 ±10.2 adjusted words/min), and math tests (71.4 ±15.2 *vs.* 64.3 ±13.4%). There were no significant differences between the 2 conditions in selective attention and processing speed or in reading comprehension. The 6 to 11% decrease in measures of fine motor skills and math problem solving could be eliminated through acclimation to the treadmill workstation.

For the second aim, 12 overweight or obese office workers used a treadmill workstation for a period of 9 months. Weight, waist and hip circumferences, body composition, resting heart rate and blood pressure, lipid and metabolic profile, bone mineral density, physical activity, musculoskeletal discomfort, and mental stress variables were measured at baseline, 3 months,

and at the end of the study. Significant reductions were observed in waist (by 5.5 cm) and hip (by 4.8 cm) circumferences, LDL (by 16 mg/dL), total cholesterol (by 15 mg/dL), and in the median time spent sitting/lying ($p<0.05$). Participants significantly increased the median times spent standing and stepping and their total steps/day by the end of the study ($p<0.05$). Additional energy expenditure from using a treadmill workstation may be sufficient to stop weight gain or even result in weight loss among overweight and obese office workers.

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NOMENCLATURE

AWPM	adjusted words per minute
$beats \cdot min^{-1}$	beats per minute
cm	centimeter
cm^3	cubic centimeters
$counts \cdot min^{-1}$	counts per minute
g	grams
g	force of gravity
GHz	gigahertz
$g \cdot day^{-1}$	grams per day
$hours \cdot day^{-1}$	hours per day
$hrs \cdot day^{-1}$	hours per day
Hz	Hertz
kb	kilobytes
$kcal \cdot day^{-1}$	kilocalorie per day
$kcal \cdot hr^{-1}$	kcal per hour
$kcal \cdot kg^{-1} \cdot day^{-1}$	kilocalories per kilogram per day
kg	kilogram
$kg \cdot m^{-2}$	kilograms per meter
$kg \cdot year^{-1}$	kilograms per year
$km \cdot day^{-1}$	kilometers per day
$km \cdot hr^{-1}$	kilometers per hour
kV	kilo volt
$lbs \cdot year^{-1}$	pounds per year
$m.min^{-1}$	meters per minute
Mb	Megabytes
MET	resting metabolic equivalent
$MET \cdot hours \cdot day^{-1}$	MET hours per day
$MET \cdot hours \cdot wk^{-1}$	MET hours per week
$MET \cdot min \cdot day^{-1}$	MET minutes per day
$mg \cdot dL^{-1}$	milligrams per deciliter
$mg \cdot day^{-1}$	milligrams per day
$min \cdot day^{-1}$	minutes per day
$mmol \cdot L^{-1}$	millimoles per liter
mm	millimeter
mmHg	millimeters of mercury
mph	miles per hour
$steps \cdot day^{-1}$	steps per day
wpm	words per minute
s	seconds
yrs	years
$\mu IU \cdot ml^{-1}$	micro international unit per milliliter

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
BC	Before the Common Era
BMI	Body mass index
BRFSS	Behavior and Risk Factor Surveillance Survey
CDC	Centers for Disease Control and Prevention
CT	Computerized tomography
GRE	Graduate record examination
ICC	Intra class correlation
IPAQ	International Physical Activity Questionnaire
ISO	International Organization of Standardization
LPL	Lipoprotein lipase
NEAT	Non Exercise Activity Thermogenesis
PAMS	Physical Activity Monitoring System
PDA	Personal digital assistant
RAM	Random access memory
SEM	Standard error of the measurement
TV	Television
WHO	World Health Organization

PART I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Evidence that obesity is one of the oldest known health conditions can be found throughout human history. Historical evidence of obesity can be found in art and literary works describing ancient medicine. For example, one of the earliest artistic images of a human, i.e., the 'Venus of Willendorf,' which dates back to 24,000 BC, is portrayed as being obese. Obesity has also been depicted in medical literature and artistic images found in ancient Egyptian tombs (91). Other literary references to obesity can be found in Chinese history (3000 BC to the mid-1800's) where a ruling emperor (3000 BC) ordered his obese subjects to consume green tea to reduce obesity and several other prominent figures of Chinese society were portrayed as obese (63).

Although obesity has been around for thousands of years, its prevalence has increased in the past 30 to 35 years and has become a major public health concern. Popkin and Doak (1998) state that obesity is not exclusive to the developed nations, as some developing countries have comparable if not higher obesity prevalence rates (97). Obesity has deleterious effects on health, which are pervasive across age groups and gender. In America, the relationship between obesity and mortality gained prominence mainly in 1959, when the Metropolitan Life Insurance Company released a table containing 'desirable weights' for a particular height to predict longevity (25). Additionally, the relationship between obesity and related co-morbidities like diabetes, cardiovascular diseases, and cancer are also well documented (89). Therefore, in 1985, a National Institutes of Health consensus panel declared obesity as a disease and a potential killer (66). Apart from its effects on health, obesity also has adverse economic ramifications. Finkelstein et al. (2005) stated that the total cost of obesity in America could be as high as $140

billon per year (39). These costs include both direct (medical costs) and indirect costs (e.g., lost wages and productivity due to absenteeism) incurred due to obesity (39).

The word ‘Obese’ is the Latin derivative of ‘Obesus’, which is used to describe a person who eats everything he/she can lay his/her hands on (87). However, obesity in a more scientific sense is a pathological condition arising from a chronic imbalance in the rate of change of energy stores when the rate of energy intake exceeds the rate of energy expenditure, i.e., a positive energy balance. Thus, obesity is a two-pronged problem and the obesity epidemic facing the world today is due to a widening gap between energy intake and expenditure. The International Obesity Task Force states that obesity is caused by a sustained consumption of energy dense foods in a ‘toxic’ environment that limits physical activity and promotes sedentary lifestyles (1).

Currently, approximately one third of American adults are obese (Body Mass Index > 30 $kg \cdot m^{-2}$) (BMI) (92). The prevalence of obesity has seen a great increase in the last 35 years. Time trend data point towards both an increased caloric intake and decreased energy expenditure among American adults as mediating factors (23, 121). Brownson et al. suggest that technological advances and urbanization in the past 50 years have made the environment more conducive to physical inactivity and sedentary lifestyles. Although there has been no decline in leisure time physical time, some of the most important changes in how Americans accrue physical activity have occurred in the domain of occupational physical activity (23, 103). Using census data from 2002, Brownson et al. found that between the years 1950 and 2000, the percentage of adults employed in high-activity occupations saw a 33% decline while those employed in sedentary occupations saw a 76% increase (23). Brownson et al. also reported that in 2002, approximately 46% of the American labor force was employed in occupations that

forced them to be seated during most of their time spent at work (23). The increased prevalence of obesity accompanied a shift from highly active jobs to more sedentary jobs in American adults. Additionally, epidemiological studies have also found that occupations with higher levels physical activity reduce the risk for being overweight or obese (64). Because most Americans spend almost 50% of their waking hours at work, it is reasonable to think that the gap between energy intake and energy expenditure could be bridged by increasing occupational physical activity.

Even though worksite wellness programs have been shown to be modestly effective in improving health, employee participation in these programs has been low and most participants are those who are already healthy (70, 78, 102, 108). This may be due to the fact that participants may have to allocate time specifically to exercise and this may not be appealing to most employees. Therefore, there is the need for a worksite intervention, which increases energy expenditure leading to weight loss in overweight and obese individuals, and at the same time does not force the employee to leave his/her desk allowing continuous work. Such an intervention may be more effective than previous wellness programs in narrowing the gap between energy intake and expenditure.

In 2007, Levine and Miller proposed the idea of a treadmill workstation that would allow employees to alternate between sitting and walking while working in front of a computer. The treadmill workstation consists of a conventional motorized treadmill that slides under a height adjustable sit-to-stand table. A regular office chair allows the user to sit, if they choose. Treadmill workstations allow users to alternate between sitting and walking while working during a regular workday. Levine and Miller compared the energy expenditure of sitting and

working to that of walking and working at a treadmill workstation (77). It was found that walking at around 1 mph while working expended two and a half times the energy expended during seated work (77). The authors concluded that replacing 2 to 3 hours per day of seated work with slow walking while working could result in a weight loss of 20 to 30 $kg \cdot year^{-1}$ (77). Although these findings were very promising, there is a need to determine if the concept of alternating between sitting and walking while working at a treadmill workstation would indeed result in weight loss.

Statement of the Problem

Before implementing the treadmill workstation as a weight loss intervention at the work place, it is necessary to determine if using it would detrimentally affect work performance. Because walking while working requires multitasking and a division of attentional resources, it may be possible that work productivity while walking and working would be substantially lower than that during seated work. If this is true, it would not be feasible to implement the treadmill workstation as a worksite weight loss intervention. Additionally, no longitudinal study to date has determined whether installing treadmill workstations in the work place causes overweight or obese office workers to regularly replace seated work with slow walking and working and lose weight. Therefore, it is necessary to investigate if using the treadmill workstation results in (a) lowered work performance and work productivity and (b) results in weight loss in overweight or obese office workers.

Statement of Purpose

The purpose of this dissertation was to examine the feasibility and effectiveness of treadmill workstations as a weight loss intervention. Feasibility was determined in the first study where the purpose was to determine if walking while working at a treadmill workstation affects selective attention and mental processing speed, as well as simulated office work tasks involving 1) fine motor movements (typing and mouse movements) and 2) mathematical and verbal reasoning. Effectiveness was determined in the second study where the purpose was to determine if using of a treadmill workstation favorably influences anthropometric, body composition, cardiovascular, metabolic, musculoskeletal, and mental stress variables in overweight and obese office workers.

Significance of These Studies

It is critical to establish that using a treadmill workstation to replace seated work with walking and working will not result in decreased work performance. A study comparing the performance of simulated office tasks between the seated and walking conditions will help determine if the treadmill workstation can be implemented as a weight loss intervention without compromising on the quality of work done. Additionally favorable results in the longitudinal study examining physiological health effects and anthropometric changes in overweight and obese office workers will help to determine whether treadmill workstations are an effective weight loss intervention. The results of both these studies will help employers make more informed decisions about investing in treadmill workstations as a health and weight loss strategy for their overweight and obese employees.

Review of Literature

Obesity: An Epidemic

It has been suggested that the obesity epidemic facing the world today is a result of the interaction between the current environment, genome, and inactive human lifestyle (16, 97). According to the World Health Organization (WHO) classification, an adult is said to be overweight if his/her BMI is between 25 and 30 $kg \cdot m^{-2}$ and obese if BMI is $\geq$ 30 $kg \cdot m^{-2}$. WHO has estimated that more than 1 billion adults worldwide are overweight, which includes at least 300 million that are obese. Being overweight or obese has also been declared as one of the top ten health risks in the world and is within the top five health risks in developed countries (98). Obesity rates in developed countries show a rising trend (97). In countries like the United States and Germany, more than 60% of adults are either overweight or obese (2). Similar trends have also been observed in developing countries (97). For example, although the overall obesity rate is less than 5% in China, the obesity rates in some Chinese cities are almost 20% (3). Some of the highest rates of obesity have been recorded in the Pacific Islands; for example, in Nauru, 79% of adults are obese (3).

The International Obesity Task Force attributes the recent rise in obesity rates to the increased availability of inexpensive energy-dense foods in conjunction with a modern environment that has reduced opportunities to be physically active (1). In addition to an increase in the types of highly palatable energy rich foods, portion sizes have also become large (54). In conjunction with the easy availability of energy dense foods, technological advances have changed the nature of our jobs, transport, and entertainment. Today, there are many more people employed in sedentary jobs than labor intensive jobs. Additionally, increased use of motorized

transport and sedentary forms of leisure time entertainment like television and videogames promote inactivity. In other words, the obesity epidemic is due to a mismatch between the rate of energy intake and the rate of energy expenditure. Current data indicate that over the past forty years, there has been an increase in the average American's caloric consumption and a concurrent decrease in energy expenditure (23, 121). A cumulative effect of this imbalance between energy intake and energy expenditure causes the average American adult to gain 1.8 to 2.0 pounds per year (54).

Physical Activity

The importance of being physically active to deal with obesity was recognized as early as 480 BC by Hippocrates (15). The Greek philosopher suggested that obese people must perform hard work, eat only once a day, avoid bathing, and walk naked as much as possible (15).

The components of total daily energy expenditure are resting energy expenditure (50 to 70%), the thermic effect of feeding (10 to 15%), and physical activity energy expenditure (20 to 40%) (100). The most variable component of energy expenditure is physical activity energy expenditure (100). Physical activity can be classified into two categories: exercise and non-exercise activity thermogenesis (NEAT) (72). Exercise related activity thermogenesis involves participation in planned and purposeful physical activities (e.g., sports and recreational pursuits) with the objective of improving health, fitness, and/or performance (74). NEAT includes energy expenditure due to an individual's occupation, mode of transport, and all other activities of daily life excluding exercise activity thermogenesis. A discussion on NEAT will follow shortly.

Physical Activity in Historical Context

Human cultural development can be divided into three distinct phases (a) hunter-gatherers, (b) traditional agrarian societies, and (c) modern industrialized civilizations. Our knowledge of the hunter-gatherer tribes and agrarian societies is deeply rooted in anthropological, archaeological, and historical data. Information on these cultures suggests that physical activity was an essential and obligatory characteristic of their existence (26).

Data on the existing hunter-gatherer tribes of the !Kung San of Botswana and the Ache of Paraguay gives us an understanding of the lives of our hunter-gatherer ancestors. Daily physical activity in the !Kung San and Ache tribes averaged 12 to 14 hours per day, which included 4 to 7 hours of heavy exertion (69). Additionally, hunter-gatherers also perform other vigorous activities like tool making, butchering, carrying fire wood and water, and dancing for recreation (16).

Similarly, studying the lifestyle of the Old Order Amish allows us to comprehend the role of physical activity in agrarian societies (10, 85). Amish men and women reportedly engage in approximately 52 and 43 hours per week of moderate to vigorous physical activity in addition to several hours of walking (10). Based on the lifestyles of the existing hunter-gatherers and the Amish, we can say that high levels of human physical activity were maintained even when humans were transitioning from being hunter-gatherers to an agriculturalist (31).

A disruption in the relationship between food acquisition and physical activity began about 250 to 300 years ago during the industrial revolution (31). Modernization and industrialization resulted in rapid economic growth, which in turn led to a shift in the type of jobs available, i.e., jobs started becoming less labor intensive and more sedentary. Time trend studies

reveal that physical activity at the work place has declined drastically in most industrialized countries (17, 23, 45, 110, 111, 115). Although the decline in occupational physical activity is offset to a certain extent by an increase in leisure time physical activity, most scientists today believe that the average total physical activity of current humans is far below that of our ancestors (10, 17, 23, 111).

Booth et al. (2002) have proposed that our current inactive lifestyle is mismatched with our genome that is designed for high levels of physical activity (16, 32). It is speculated that interactions between an inactive lifestyle, the environment, and genome have disrupted complex homeostatic systems of the body and are the cause of several diseases and health issues faced by humans today (32). For example, modernized Arizona Pima Indians who consume a typical American diet and engage in only one-fifth the occupational physical activity as the more traditional Mexican Pima Indians, have a 6-fold greater prevalence of type-2 diabetes (117). Evidence of the high levels of physical activity maintained by our ancestors has led Booth and colleagues to suggest that our genome was shaped by evolutionary forces over thousands of years. They state that "our current genome is maladapted, resulting in abnormal gene expression, which in turn frequently manifests itself as clinically overt diseases (16)." They further suggest that while comparing the existing humans to our physically active ancestors, the control group for comparison should be the physically active phenotype (our ancestors) rather than the existing inactive one (16).

Time Trends in Physical Activity

Physical activity can also be categorized into four domains, i.e., transportation, domestic, leisure time, and occupational physical activity (2). Researchers have examined time trends in

physical activity for each specific domain. A recent study examined 30-year time trends from 1972 to 2002 in leisure time, occupational, and transportation physical activity among Finnish adults (17). The study found that between 1972 and 2002, leisure time physical activity increased from 66 to 77% and from 49 to 76% in men and women, respectively (17). However, there was a decline in physically demanding work (e.g., forestry and farm work) in both Finnish men and women. The percentage of men involved in physically demanding work dropped from 60 to 38% and from 47 to 25% in women (17). These declines could primarily be attributed to a marked decline in agricultural jobs and a corresponding increase in seated office work. In addition, among women, there also was a dramatic decline in the total number of housewives, which suggests that domestic physical activity has been replaced by sedentary office jobs (17). In addition to the decline in occupational physical activity, both men and women showed declines in transportation physical activity from 30 to 10% and 34 to 22%, respectively (17).

Brownson et al. described current patterns and long term trends in leisure time, occupation, and transportation physical activity (23). Using data from the Behavior Risk Factor Surveillance Survey (BRFSS), the researchers compared existing physical activity in American adults to the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) recommendation of accumulating at least 30 minutes of moderate-vigorous physical activity on most, preferably all days of the week. They found that in the year 2000, only 26.2% of Americans engaged in the recommended physical activity levels during leisure time, with men being slightly more active than women. Between 1990 and 2000, the percentage of population meeting physical activity recommendations experienced an increase of only 7.5% (23). In addition, they report data from the census bureau, which showed that 42.6%

of employed individuals were in low-activity occupations as compared to only 22.6% who had high-activity jobs (23). Between 1950 and 2000, the percentage of individuals working in high-activity occupations declined from 30 to 22.6% whereas, the proportion of people employed in low activity jobs saw a large increase from 23.3 to 42.6% (23). Although economic growth and other advancements contributed to the increase in low-activity occupations, a contributor to the imbalance between high and low activity jobs is the decrease in agricultural employment (considered to be high-activity), which decreased from 12.2% in 1950 to less than 2% in 2000 (23). All of these changes indicate that there has been a significant decline in occupational physical activity in America.

Similarly, declines in transportation physical activity have also been observed. Based on the 2000 US Census Data, Brownson et al. reported that only 9.4% of American households did not use a car (23). The average American adult drove a mean distance of 29 miles in 55 minutes every day. Eighty six percent of trips taken by Americans are in an automobile and only 8.6% of trips are made walking (23). The percentage of adults using a car to get to work increased from 67% in 1960 to 88% in 2000 (23). The authors suggest that the built environment may be partly responsible for excessive automobile use and reduced walking or bicycling (23). Brownson et al. concluded that although levels of leisure time physical activity has increased, occupational, transportation, and domestic physical activity have witnessed considerable declines. Increased use of sedentary entertainment like television (TV) viewing has further aggravated the problem of decreasing physical activity. As a cumulative effect of all these factors, total physical activity is declining in America (23).

Similar trends were also observed between 1980 and 2002 in Minnesota where energy expenditure from leisure time and lifestyle physical activity increased but there was a major increase in the time spent sitting at work (111). The percentage of people who spent more than half their time sitting at work increased from 57.4% to 71.2% (111). Not surprisingly, the researchers also reported that adults who spent less than half their time sitting at work had a BMI that was 0.25 $kg \cdot m^{-2}$ less than those who spent most of their time sitting (111). It was also observed that during the study period, the proportion of people who walked at least half a mile to work decreased from 10% to around 5.5% (111).

In summary, although the time spent in leisure time physical activity has increased, time spent by the average American in occupational, and transportation physical activity has dramatically decreased with a concurrent increase in time spent in sedentary forms of entertainment. As a result the overall time spent being inactive has increased.

Effect of a Changing Environment

Modernization and technology have significantly changed the human lifestyle. Traditional hunter-gather and agricultural lifestyles have been largely replaced by the urban lifestyle. Additionally, the pervasive effects of technology have also influenced the existing rural lifestyle. For example, almost 100% of US households have electricity and use appliances like electric stoves and refrigerators and more than 95% of households have access to sedentary forms of entertainment like the television and the radio (86). Labor saving devices like laundry washers and dryers, microwave ovens, and dishwashers have found their way in to approximately 65 to 90% of American homes (86). A study by Lanningham-Foster et al. demonstrated that labor saving appliances like laundry washers and dryers and dish washers

decreased energy expenditure up to 56% when compared to manual performance of these tasks (67). These researchers also showed that individuals using the elevator expended 200% less energy as compared to that while performing the task of climbing stairs (67). Although modern medicine has increased lifespan, the prevalence of diseases like obesity, diabetes, and cardiovascular disorders have also increased. Therefore, it can be suggested that the recent increase in obesity prevalence is associated with the modernization of the human race. This section discusses a few studies that examined how acculturation influences the living environment, habitual physical activity, and weight status.

Between the 1960s and the 1990s, Shephard and Rode conducted a comprehensive longitudinal study of the lifestyles of several Eskimo settlements around the North Pole region (107). Traditionally, these nomadic communities engaged in high levels of physical activity to survive the harsh climactic conditions of the North Pole. These activities included, hunting, fishing, reindeer herding, and forestry, which resulted in an average daily energy expenditure between 3500 to 4000 $kcal \cdot day^{-1}$ (107). However, exposure to modern cultures from neighboring Greenland, Canada, and Alaska during the course of the study caused several changes in the lifestyles of these Eskimos (107). Importantly, there was a decline in habitual physical activity from the increased use of mechanized transport, reduced hunting and fishing due to the availability of 'Market Foods,' and the replacement of active entertainment (drum dancing, blanket tossing, and wrestling) with more sedentary pursuits like TV viewing (107). This decline in habitual physical activity was accompanied by increased rates of obesity, hyperglycemia, and hypercholesterolemia. Additionally, Shephard and Rode also reported that during this period of

acculturation and lifestyle change, the aerobic fitness and muscular strength of these populations declined to levels that were equivalent to those in urban populations (107).

Another study that demonstrates the undesirable effects of modernization is that by Kirchengast, which examined anthropometric differences among three different African communities living in the same habitat in northern Namibia (65). Although from the same habitat, these three communities differed greatly in their subsistence patterns. One community consisted of hunter-gatherers from the !Kung San tribe and demonstrated high levels of habitual physical activity due to their foraging subsistence pattern (N=93). The second group consisted of rural Kavango horticulturalists and cattle herding pastoralists (N =63) who had relatively lower levels of physical activity as compared to the !Kung San. The third group comprised of acculturated urbanized wage earning Kavango tribesmen that lived in a town, were relatively sedentary, and had access to western goods and lifestyle (N =85) (65). Settlements in the Kavango regions comprise of people who originally were hunter-gatherers but slowly over time transitioned from being traditional hunter-gatherers to pastoralists and leading urbanized lifestyles (55). Kirchengast (1998) found that the urbanized Kavango and the Kavango horticulturalists and pastoralists weighed 20 to 27% and 15 to 16% more than the !Kung San foragers, respectively (65). Although the participants in this study were not obese, the trends observed in this study demonstrated that switching from a traditional physically active lifestyle to a less active sedentary or modern lifestyle unfavorably influences weight status (65).

The ill-effects of eliminating the traditional foraging lifestyle and replacing it with a sedentary lifestyle and exposure to an abundance of food have also been observed in animal models. Altmann et al. made body composition and physical activity comparisons between two

troops of free-living adult baboons (*N* =63), i.e., (a) wild-fed foraging baboons and (b) baboons that self-selected to live near and feed from a garbage dump belonging to a nearby tourist lodge, which ensured a constant and inexhaustible supply of food (7). The researchers found that the garbage-fed females and males, while maintaining a similar caloric intake as the wild-fed animals were 49 and 19% heavier than their wild-fed counterparts, respectively (7). Interestingly, the researchers also found lower levels of physical activity in the garbage-fed animals as compared to the wild-fed animals (7). The garbage-fed animals traversed only 2 to 4 $km \cdot day^{-1}$ as compared to the wild-fed animals that traversed at least 8 to 10 $km \cdot day^{-1}$ (7). A greater difference in weight was observed in females because like male baboons, females are not forced to leave the troop during maturation and therefore do not experience any change in feeding conditions (7). Altmann et al. also found significantly large differences in percent body fat between garbage-fed (23.2%) and wild-fed (1.9%) females (7). This comparison in males could not be made in males because the researchers determined percent body fat in only 4 male baboons.

It has been seen that even within a modern environment, the access and availability of avenues that may increase physical activity and affect weight status. Considerable attention has been devoted to determining if lifestyle and physical environmental factors like the availability of sidewalks, bike paths, and the proximity to recreational parks have an effect on habitual physical activity and obesity prevalence. Walking for utilitarian purposes (e.g., shopping) and pedestrian behavior may be highly dependent on the built environment. Additionally, public transit and patterns of commercial land use could influence individual physical activity behavior. For example, close proximity to required goods and services encourages walking and reduces reliance on cars (105). Giles-Corti et al. showed that the perception of the availability of no

sidewalks, no walking or bike paths, no stores within walking distance, and a lack of recreational facilities in an Australian city increased the risk of being obese by 69, 60, 84, and 68%, respectively (42). Saelens et al. observed that residents in neighborhoods with restaurants, grocery, stores, and other retail outlets along the main corridor of the neighborhood (i.e., high-walkability neighborhoods) engaged in approximately 70 minutes of additional daily physical activity and had a 71% lower prevalence of overweight and obesity as compared to neighborhoods where the commercial area was peripherally located (i.e., low-walkability neighborhoods) (105). Similarly, an ecologic study by Ewing et al. that examined the relationship between urban sprawl, health, and health related behaviors showed that as compared to living in less sprawling and more compact counties, living in sprawling urban communities significantly decreased (p=0.004) the likelihood of leisure time physical activity and utilitarian walking, which were significantly associated with weight gain and obesity (p=0.04) (37).

In summary, the environment plays a pivotal role in determining the amount of physical activity that can be accrued by humans today. There is ample evidence to suggest that modernization and changing environmental factors have minimized opportunities to be physically active and play a role in aggravating the obesity epidemic. However, in today's urban environment, proper planning of the built environment, i.e., building sidewalks, accessibility to goods and services by foot, and availability of recreational parks can promote habitual physical activity and may help in controlling obesity.

NEAT

Levine and co-workers coined the term NEAT in 1999 (71). They defined it as the energy expended by all physical activities (walking, fidgeting, and other bodily movements) other than planned structured exercise (71). According to Levine, NEAT is highly variable. He suggests that NEAT could represent 10 to 15 percent of total daily energy expenditure in very sedentary individuals but, could be greater than 50 percent in highly active individuals (73). NEAT is impacted to a great extent by the environment (73). The amount of NEAT accumulated depends on occupation, preference of activities during leisure time, mode of travel, and the use of automated appliances to perform household chores (73). Levine also suggests that NEAT is under biological control (73). An example of biological control is the associated changes in NEAT as a result of extreme energy balance manipulation. Levine reports findings from several overfeeding studies where NEAT increased as energy intake increased. Normally, in an attempt to restore energy balance due to a small but consistent increase in energy intake, the body increases resting energy expenditure and the energy cost of activity (73). However, Levine argues that in the case of large increases in energy intake (e.g., overfeeding studies), an increase in resting energy expenditure is insufficient to restore energy balance and energy balance is restored via a biologically influenced increase in NEAT, which offsets the increased energy intake (73). Individuals in overfeeding studies who experienced the greatest increases in NEAT, gained the least weight (73). It has also been seen in several animal studies that NEAT decreases during sustained negative energy balance, which is the opposite of what occurs during positive energy balance (73).

To examine if being obese influenced body posture, Bloom et al. invented an objective monitor to measure total standing time (14). These researchers modified a watch to contain a gravity activated switch that would allow the watch to work only when the participants were standing (14). This watch was strapped laterally above the knee of 7 obese and 6 lean participants for up to 35 days (14). Time spent lying was manually recorded by the participants (14). Bloom et al. found that obese participants stood for 173 minutes less than lean participants per day and also sat for approximately 121 $min \cdot day^{-1}$ longer than the lean individuals (14). Levine and colleagues examined the same question posed by Bloom et al. using a novel objective monitor (75). These researchers developed and validated the Physical Activity Monitoring System (PAMS) and used it to objectively measure posture and body movements (75, 76). The PAMS consists of 4 dual axis inclinometers and two triaxial accelerometers that measure activity and two data loggers into which data from the 6 objective monitors are stored every half second (76). All activity monitors were attached to specially designed underwear and data loggers were placed in a pouch worn around the waist. The total weight of the PAMS was 1 kg (76). Activity data from the data loggers were downloaded onto a personal computer and analyzed using specific software scripts every 24 hours. Total energy expenditure was measured using the doubly labeled water technique. NEAT and its components were derived using analyses that combines total daily energy expenditure and output from the posture allocation measurement system (75). Analyses revealed that obese participants (N =10) were seated longer (by 164 $min \cdot day^{-1}$) and spent less time upright (by 152 $min \cdot day^{-1}$) than lean participants (N =10) (75). Similarly, Johannsen et al. observed that obese women stood for approximately 150 $min \cdot day^{-1}$ less and sat for around 120 $min \cdot day^{-1}$ more than lean women (60).

A more recent study by Levine et al. examined whether free-living daily walking (the principal component of NEAT) distance was lower in obese individuals (12) as compared to lean controls (*N* =10) and if experimental weight gain reduced daily free living walking (76). Baseline measurement showed that lean controls walked approximately 3.5 miles more than their obese counterparts (76). After over-feeding by 1000 kcal.day^{-1} for 8 weeks, participants gained approximately 3.6 kg in weight. Following weight gain, walking measurements revealed that free living walking distance decreased with overfeeding due to significantly shortened bouts and decreased velocity of walking (76). These results are not consistent with Levine's assumption that NEAT increases in a state of positive energy balance (73). However, he provides a rationale for his assumption and suggests that the duration (2 months) of overfeeding and weight gain was short and there may have been a gradual increase in walking volume if subjects were followed for a longer period of time after the study was completed (76).

Occupational NEAT

Time allocation surveys have shown that there has been an increase in leisure time physical activity and a marked decrease in occupational and transportation physical activity over the past 40 years (17, 23, 111). One of the ways to control the increasing obesity rates is to create a negative energy balance by increasing energy expenditure in the one or all physical activity domains. The American Time Use Survey revealed that on an average workday, an employed American between 25 and 54 years of age spent 8 hours at work (103). A recent study by McCrady and Levine examined the contribution of office work on sedentariness (84). It was hypothesized that time spent sitting daily would be greater on work days as compared to non-work (leisure) days (84). These researchers, recruited 21 participants (38 $\pm$ 8 years) who were

employed in sedentary (predominantly sitting) or semi-sedentary jobs (intermittent standing between seated work) and measured free living activity for ten days using a previously validated physical activity monitoring system (75, 84). It was found that participants sat for a significantly higher amount of time on work days (597 $min \cdot day^{-1}$) as compared to non-work days ($p<0.0001$) (84). Additionally, it was also seen that participants engaged in significantly more walking (417 $min \cdot day^{-1}$) and standing (341 $min \cdot day^{-1}$) on non-working days as compared to working days ($p=0.002$) (84). Because of the fast paced nature of our day to day lives, it seems logical that increasing occupational physical activity would be the ideal way to increase energy expenditure. Both anthropological data and several occupational physical activity studies have shown that, cross-sectionally, obesity increases with decreasing occupational physical activity.

Bassett et al. were interested in the effect of high occupational physical activity on the prevalence of obesity and obtaining a snapshot of the role physical activity played in the pre industrial revolution (10). These researchers examined physical activity in an Old Order Amish community (10). The Old Order Amish are known for a work ethic that emphasizes high physical activity and the community's resistance to modern social and technological practices (10, 85). Old Order Amish are primarily farmers living in rural conditions without electricity and do not use gasoline-powered transportation or any other modern technological innovations for entertainment or farming purposes (10, 85). Amish men mostly perform farm-related work and additionally, also engage in construction and carpentry work (10). Amish women take care of household chores, gardening, sale of produce, and take care of children and livestock (10). The researchers in this study asked 98 Amish men and women to wear pedometers for seven days. Data on total number of steps taken per day were obtained and analyzed at the end of seven days

(10). It was seen that Amish men and women averaged 18,400 and 14,100 steps$\cdot$day^{-1}, respectively (10). Self-reported time spent walking and in moderate to vigorous activities by men and women totaled more than 64 and 48 hours per week, respectively. Most of the time spent in moderate to vigorous activity was related to farming or other non-recreational tasks. This was much higher than the total time at work for an average employed American during a typical work week (10). None of the men and only 9% of women were obese. These low rates of obesity were observed in spite of the fact that the Amish have a higher estimated caloric consumption as compared to the average American (10). The authors concluded that the prevalence of low obesity rates in the Amish may have been attributable to their high levels of daily occupational physical activity (10).

Brown et al. examined relationships between sitting time, physical activity, and BMI between Australian mothers of young children and working adults (21). It was seen that employed workers sat about 6 hrs$\cdot$day^{-1} longer than mothers of young children (21). In addition individuals who sat more than 4.7 hrs$\cdot$day^{-1} had a 40 to 60% chance of being overweight or obese (21). Another study showed similar trends where sitting for more than 6 hrs$\cdot$day^{-1} at work was associated with a 92% greater chance of being overweight or obese as compared to individuals who sat for less than 45 minutes a day (88).

A classic study by Heady, Morris, and Raffle examined constitutional differences between bus drivers and bus conductors in London by comparing differences in company issued uniform sizes (49). The researchers felt that drivers may be heavier and gain more weight as compared to conductors because drivers had to continuously sit in comparison to conductors who were always standing or walking within or between single and double-decker bus decks (49).

This study found that in all age groups, drivers had a wider girth than conductors (49). Conductors also displayed lower skinfolds as compared to drivers (49). Another interesting finding from this study was that drivers who started as conductors had intermediate girths between that of conductors and drivers (49). This suggests a transition in girth status, i.e., moving from having a normal girth to having the girth of an overweight/obese person (49). It can be argued that the difference in girth could be attributed to a difference in dietary habits of conductors and drivers. However, evidence from a study done by Bramwell showed no significant differences between the total daily energy intake and their sources (20).

Mayer, Roy, and Mitra examined whether occupational physical activity affected food intake and body weight (83). The participants in this study engaged in different occupations that had varying physical activity requirements ranging from very sedentary to very heavy work (83). It was seen that individuals in occupations involving light to very heavy work weighed approximately 118 pounds as compared to an average weight of 140 pounds for individuals with a sedentary job (83). Another interesting finding was that the caloric intake of individuals in light work occupations was the lowest (83). Individuals with the highest caloric intakes were employed in occupations that were sedentary and involved heavy to very heavy work (83). Additionally, beginning at light intensity occupations, caloric intake linearly increased as the intensity of work increased (83). This suggested that appetite is regulated by the level of physical activity over a wide range of occupations (83).

Findings by Heady et al. and Mayer et al. suggest that increasing occupational physical activity from being completely sedentary to maintaining light activity at work may be beneficial in controlling the increasing obesity rates in America (49, 83).

Treadmill Workstations

In 2003, the U.S. Census bureau estimated that approximately 52.4% of employed Americans use a computer at work (59). Because many Americans spend time at work sitting in front of a computer, researchers have identified the work environment as a place to increase NEAT (59, 77). Although the idea of increasing occupational physical activity to prevent weight gain seems logical, it may be very difficult to target sedentary jobs and implement physical activity interventions in ways that are acceptable to employers and employees alike.

The treadmill workstation was first proposed and built 20 years ago by Edelson to reduce inactivity in office workers (35, 36). He proposed that it could solve the hazards of continuous sitting (postural fixity). These hazards included aches and pains, stress, and other illnesses (34, 36).

After briefly disappearing, the concept of the treadmill workstation was reintroduced as a potential strategy for weight loss by Levine and co-workers (77). The treadmill workstation enables the user to alternate between seated work and walking while working. Levine and Miller (2007) examined the energy expenditure of 15 sedentary obese participants at rest, during seated computer work, while standing, and while walking and working at 1mph (77). It was seen that compared to seated computer work (72 $kcal \cdot hr^{-1}$), walking at 1 mph while working expended an additional 119 $kcal \cdot hr^{-1}$. This led them to suggest that replacing 2 to 4 hours of sitting at work with slow paced walking at a treadmill workstation could increase daily energy expenditure by about 500 $kcal \cdot hr^{-1}$ and result in a yearly weight loss between 20 to 30 kg (77).

Treadmill Workstations and Work Performance

Although the treadmill workstation appears to have the potential for weight loss, it could be possible that walking while working may affect work performance. An individual using a treadmill workstation may need to divide attentional resources between treadmill walking and office work, which might compromise work performance. Only one study has measured the effect of walking while working on work performance (38). However, this study examined work performance in a job that is not common among Americans (38). In this study, the interpretations of 100 computerized tomography (CT) scans by two radiologists while sitting and while walking and working were compared to a criterion interpretation of the scans (38). The two participants in this study were allowed to get acclimated (self-selected time frame) to interpreting scans while walking and working. Recall bias was reduced by separating the two interpretation conditions (seated and walking) by a period of one year. Interpretations of the scans for both conditions were classified according to clinical importance by assigning a number from1 to 6 where 1 signified 'unimportant' and 6 signified 'important regardless of clinical history' (38). At the end of testing in both the conditions, all the scans that scored 3 or more were separated and reanalyzed by two external radiologists in consensus (38). The analysis made in consensus by the external radiologists was considered to be the criterion (38). The results of the scans that scored 3 or more by the two participants in the study were compared to the criterion analysis. A total of 459 clinical findings with a score of 3 or more were detected by the criterion method. It was found that both participants in this study detected 99% of the clinical findings identified by the criterion method in the walking condition, and only 81 to 89% of the criterion clinical findings while working seated (38). Based on these results, the authors concluded that it would be feasible

to use a treadmill workstation in interpreting CT scans (38). Since the aforementioned study examined work performance in an uncommon job, there is a need for additional research studying the effects of walking while working on tasks that are more representative of normal or regular office work (38).

Most desk jobs currently involve sitting in front of the computer, using the mouse, and the use of cognitive function (e.g., reading and math). Performing these tasks in conjunction with treadmill walking may reduce processing speed by spreading thin the limited resources of the brain. A study by Grabiner and Troy compared the performance of an attention demanding task in 15 adults during treadmill walking for 10 minutes and in a stationary condition (44). The participants in this study performed the Stroop work-color task, which is a measure of selective attention and processing speed. It was seen that performance was lower during the walking condition as compared to the standing condition (44). However, the decrease in performance was not statistically significant. Additionally, multi-tasking during treadmill walking also affected gait and there was an increase in step width variability as compared to treadmill walking only (44).

Only one study has examined the effect of walking while working on typing speed (36). In this study, Edelson et al. constructed a treadmill workstation and recruited 6 experienced typists (mean typing speed= 61 wpm) as participants (36). The researchers assessed differences in typing speed, stress levels, and musculoskeletal discomfort between a seated condition and an active typing condition, which involved periods of sitting alternated with walking at a treadmill workstation (36). These participants were acclimated to typing while walking on a treadmill prior the testing period. The researchers reported no significant differences in typing speed between

the seated (60.8 wpm) and active (60.3 wpm) conditions (36). Additionally, stress was significantly reduced in the walking condition and the difference in scores for musculoskeletal discomfort although insignificant, was lower for the active condition ($p<0.05$) (36). These results prompted the investigators to conclude that using a treadmill workstation while not hampering typing speed may provide certain physiological and psychological benefits to the user (36). Although Edelson and Danoff did not see any difference in typing speed between the seated and active conditions, it may be possible that differences were absent because of the limited number of participants in their study. Additionally, it may also be possible that walking while working may have detrimental effects in performing other motor movement tasks.

Del Giorno et al. showed that performing a finger tapping task and a test of cognition during submaximal exercise (75% of ventilatory threshold) significantly lowers performance of the tasks ($p<0.05$) as compared to the sitting condition (30). Similarly, decrements in reaction time (motor movement) in response to mild electrical stimulation between a sitting and treadmill walking condition were observed by Regnaux et al. ($p<0.01$) (101).

As in the case of some motor movement tasks, walking while working may hinder an individual's ability to comprehend and understand what he/she is reading (9). Barnard et al. compared the scores of reading comprehension tests between the walking and sitting conditions (9). In this study, 126 participants completed the task of reading a paragraph and answering multiple choice questions on a personal digital assistant (PDA) in both the walking and sitting conditions (9). During the walking condition, the task was completed on pre-determined narrow course that meandered around a room (9). The investigators found that reading comprehension scores for sitting were significantly higher (by 10%) in the sitting condition as compared to

walking (p<0.01) (9). However, this difference may be attributable to the fact that participants from Barnard et al. (2006) walked on a course that was narrow and convoluted and the device used to test reading comprehension had a much smaller screen as compared to the computer monitor in the current study (9).

In conclusion, walking while working may place added demand on the limited resources of the brain required for mental processing and motor control and the increased load could interfere in the performance of the task and lower performance (33, 44, 94).

Consequences of Inactivity

The benefits of regular moderate-vigorous structured exercise with respect to cardiovascular diseases, cancer, and metabolic diseases have been extensively studied and well documented (62, 106, 109). Therefore, this part of the literature review will not delve into the benefits of engaging in regular moderate-vigorous physical activity, but will instead focus on the relatively new fields of the epidemiology of sedentary time and inactivity physiology.

Epidemiology of Sedentary Time

Physical inactivity has been suggested to be one of the most important public health problems of our time (13). Several landmark studies have established the importance of regular moderate-vigorous intensity physical activity in maintaining health and preventing weight gain. However, even though trends suggest that there has been no change in the percentage of people participating in leisure time moderate-vigorous intensity physical activity, there also has been a simultaneous increase in obesity rates (17, 23, 92, 97, 111). This means that the energy balance gap has widened through increased energy intake and a decrease in energy expenditure occurring

in physical activity domains other than leisure time physical activity. It has therefore been suggested that increases in energy expenditure from voluntary leisure time physical activity may be inadequate to prevent the increasing prevalence of obesity (11). Thus, considerable attention is now being devoted to decreasing time spent being sedentary and increasing light intensity activity.

Until recently, most studies simplistically defined sedentary behavior as the absence of moderate-vigorous physical activity and did not specifically examine the ill effects of being sedentary on health and weight status (95). Owen et al. defined sedentary behaviors as engaging in those activities that result in an energy expenditure between 1 and 1.5 METs (e.g., sitting, lying down, TV viewing, etc.) (93). Light physical activities are those that result in an energy expenditure between 1.6 and 2.9 METs (e.g., household activities, light gardening, slow walking, etc.) (95). A recent study by Matthews et al. examined nationally representative data on 6308 adults to determine the amount of time spent by Americans in overall sedentary behaviors (82). The researchers analyzed accelerometer data (Actigraph 7164) and found that Americans spent almost 55% of their waking time being sedentary (82). This study also revealed that, in general, females were more sedentary than males (82). These researchers stated that while maintaining energy intake, Americans would be able to favorably alter energy balance by moderately reducing the time spent in sedentary behaviors (82). Thus, there has been an urgency in studying sedentary behavior as an independent and important risk factor to weight gain and health.

The study of sedentary behaviors has primarily involved examinations of total sitting time. This is because sitting is very ubiquitous in our lives and includes the time spent sitting at work, in front of the TV, and while commuting. Katzmarzyk et al. did a 12-year follow-up study

on approximately 17,000 Canadians between 18 and 90 years of age that examined the effects of time spent sitting on all cause, cardiovascular, and cancer mortality rates (61). Approximately, 75% of adults below the age of 60 years reported being seated almost all the time (61). Sitting time was found to be positively associated with cardiovascular and all cause mortality (61). As compared to individuals who sat for almost none of the time, those sitting almost all the time displayed an increased risk of cardiovascular and all cause mortality by 60 and 67%, respectively (61). Additionally, the researchers also observed gender differences where males (42 to 47% greater risk) sitting all the time demonstrated lower cardiovascular and all cause mortality risk than females (84 to 96% greater risk) as compared to their counterparts who sat almost none of the time (61). Even, physically active individuals who engaged in more than 7.5 $MET \cdot hr \cdot wk^{-1}$ but sat almost all of the time had a 40% increased risk from all cause mortality as compared to those who exercised the same but sat for almost none of the time (61). However, the highest mortality rate was seen in people who were obese ($BMI>30\ kg \cdot m^{-2}$) and sat for almost all of the time (approximately 400% greater risk than obese individuals sitting almost none of the time) (61). The researchers concluded that independent of leisure time physical activity, increased sitting time elevated the risk for mortality and compensating high amounts of sitting time with occasional moderate-vigorous leisure time physical activity does not negate the deleterious effects of increased sitting (61). Similar findings were also observed in women where those sitting for more than 16 hours per day had a 68% greater risk for cardiovascular disease than those who were not (81). Apart from mortality risk, increased sitting time is also associated with the risk for weight gain and other metabolic disorders. The association between weight gain and sitting time was investigated by Brown et al. These researchers reported that middle-aged

Australian women who were seated for more than 4.5 hours per day had a 35 to 50% greater likelihood to gain more than 11 pounds than those sitting for less than 3 hours per day (22). This effect was independent of other variables like habitual physical activity and smoking.

Several studies have used time spent sitting in front of the TV as a marker of sedentary behavior as it may be an indicator of a broader pattern of sedentary behavior, especially in women (112). A study by Healy et al. examining the dose response relationship between television viewing time and physiological markers of metabolic risk (i.e., blood pressure, plasma glucose, and lipid profile) in Australian adults (*N*=4064) revealed a positive association between metabolic risk and increasing TV viewing times (52). Similar relationships were also observed between anthropometric and body composition variables that are considered to be risk factors for obesity and TV viewing times (52). The strongest association between risk variables and television viewing time were observed in adults with viewing times greater than two and a half hours per day (52). Another study by Jakes et al. compared the effects of TV viewing and participation in vigorous physical activity on obesity, and several other physiological and anthropometric variables in 15,515 British adults (58). Men and women who watched less than 2 hours of TV per day and participated in at least of 1 hour of vigorous physical activity per week had a significantly lower BMI than those who watched TV for more than 4 hours per day and did not participate in vigorous physical activity at all (58). This study also showed that among participants engaging in no vigorous exercise, those who viewed TV for more than 4 hours a day had a higher BMI (by approximately 1.5 $kg \cdot m^{-2}$) than those viewing TV for less than 2 hours per day (58). This difference was not statistically analyzed by the researchers. With increasing TV viewing time and time spent in vigorous physical activity, favorable outcomes in blood pressure,

lipid profile, glycosylated hemoglobin, and several anthropometric variables were also observed (58). More evidence suggesting that TV viewing increases metabolic risk in men can be found in a study by Hu et al. where the risk for diabetes showed an increasing pattern with increasing TV viewing time (56). Men watching TV for more than 40 hours per week had a 2.25 fold increased risk for type 2 diabetes compared to men who viewed less that an hour of TV per week (56). In the same study it was also seen that being highly physically active attenuated the risk for type 2 diabetes (56). However, in spite of being highly physically active (least 46 $\text{MET}\cdot\text{hours}\cdot\text{wk}^{-1}$) men viewing TV for more than 15 hours per week still had a 37% greater risk for type 2 diabetes as compared to highly physically active men who viewed TV for less than 3.5 hours per week (56). Similar relationships between TV viewing and the risk for obesity and diabetes were also seen in women (57).

More than 95% of households in America own a television set and the average American watches TV for approximately 2.6 $\text{hrs}\cdot\text{day}^{-1}$ (86, 103). These statistics make it clear that Americans are putting themselves at risk for premature mortality, metabolic and cardiovascular diseases, and weight gain due to increased sedentary time and physical inactivity.

The deleterious effects of prolonged sedentary time can be attenuated by replacing sedentary time with light intensity activity, or by simply disrupting sedentary time through standing or taking a few steps (50, 51). Healy et al. analyzed data collected in the Australian Diabetes, Obesity, and Lifestyle Study to examine the effects of objectively measured light intensity physical activity on 2-hour plasma glucose levels after an oral glucose tolerance test in non-diabetic adults (50). In this study, physical activity was measured using the Actigraph 7164 accelerometer and light intensity physical activity was defined as activity counts between 100

and 1951 $counts \cdot min^{-1}$ (40, 50). The authors found that while increasing sedentary time unfavorably elevated 2-hour plasma glucose levels, the percentage of time spent in light intensity activity was independently associated with 2-hour plasma glucose levels (50). With increasing quartiles of the percentage of time spent in light intensity activity, corresponding significant decreases were seen in 2-hour plasma glucose levels (p=0.006) (50). The same group of researchers demonstrated that taking breaks in sedentary time independently improved anthropometric measurements, lipid profile, and 2-hour plasma glucose after an oral glucose tolerance test (51). In this analysis, a break in sedentary time was defined as a duration of at least one minute where accelerometer activity counts were more than 100 $counts \cdot min^{-1}$ (51). The results of this study showed that as compared to the lowest quartile, the quartile with the highest number of breaks in sedentary time was significantly associated with lowering waist circumference and plasma glucose (p=0.025) (51). Although not statistically significant, BMI and triglyceride levels displayed similar decreasing trends with increasing quartiles of breaks in sedentary time (51).

In conclusion, there is sufficient evidence to conclude that sedentary time is an independent risk factor for poor health and weight gain. It is necessary to interrupt or reduce sedentary time with light intensity physical activity. Recommendations emphasizing the need to reduce sedentary time and increase time spent in light physical activity are necessary.

Measurement of Sedentary Time and Light Physical Activity

Like physical activity, sedentary time can be measured both subjectively and objectively. This section provides brief descriptions of a few instruments that provide measures of sedentary time and light physical activity.

Subjective measures

Physical activity scale

This scale is a 24-hour self-report pictograph styled questionnaire aimed at measuring total physical activity in the domains of household, occupation, and leisure time (4). This questionnaire was developed by Aadahl and Jorgensen and comprises of pictures and descriptions of activities in 9 intensity levels ranging from sleep to strenuous activities. The activities are arranged in the order of least intense to most intense physical activity. The user of this questionnaire has to enter the time spent in each of the 9 intensities (4). Scoring of the questionnaire involves the calculation of total $MET \cdot min \cdot day^{-1}$ using estimated MET values for each activity, which was obtained from the Compendium of Physical Activity (4, 6). The measures of sedentary behavior in this questionnaire are several and include daily activities like sleep/lying and resting, sitting quietly, watching TV, sitting while listening to music, reading, eating, or in a meeting, and seated work at a computer or desk (4). Aadahl and Jorgensen validated this instrument against accelerometry and a self report diary in a population of 600 Danish adults between 19 and 60 years of age (4). The questionnaire had poor correlations with accelerometer activity counts (r=0.20) but a significant correlation with the self report diary (r=0.74, p=0.001). The authors stated that the correlation between the questionnaire and accelerometer counts may have been poor because cycling, which is a very frequent activity among the Danes, may have not been captured by the accelerometer. Almost 40% of the participants in this study engaged in bicycling during the study (4)

Canada fitness survey questionnaire

The Canada fitness survey questionnaire is a self report questionnaire that assesses daily, weekly, monthly, and yearly physical activity (96). This questionnaire was adapted from the Minnesota leisure-time physical activity questionnaire (120). The questionnaire has one question on total time spent sitting daily as a measure of sedentary behavior. However, the question classifies the users sitting behavior into one of 5 categories, i.e., almost all the time, about three-quarters of the time, about half of the time, about one-quarter of the time, and almost none of the time (96). This questionnaire has been shown to provide valid (r=0.36, p=0.0001) and reliable (r=0.90, p<0.0001) estimates of energy expenditure (28). Data collected with this questionnaire have been used to determine the effects of sedentary time on cardiovascular and mortality risk in Canadian adults (61).

Bouchard three-day physical activity record

The Bouchard three-day physical activity record questionnaire is a self report questionnaire that assesses physical activity over a period of 2 week days and one weekend day and provides energy expenditure in $kcal \cdot kg^{-1} \cdot day^{-1}$ (96). This instrument gathers information about time spent in sedentary activities such as lying down and sitting in class, while eating, typing or writing, reading, driving, and watching TV (96). Additionally, it also collects data on time spent in light intensity activity involving personal grooming, strolling, and performing manual work like housework (96). This questionnaire has been shown to have excellent test-retest reliability (r=0.96) and has been validated against a cycle ergometer test (r=0.31, p<0.05) (18).

Framingham physical activity index

The Framingham physical activity index is a 24-hour interviewer administered recall questionnaire that documents time spent being sedentary while resting, at work, and during extracurricular activities (96). The questionnaire enables the researcher to calculate a physical activity index score based on physical activity intensity (MET levels) (96). This questionnaire has been compared to several other questionnaires and has shown to provide valid (r=0.55 to 0.63) and reliable (r=0.30 to 0.59) estimates of physical activity (41).

International physical activity questionnaire (IPAQ)

The IPAQ can be administered over the telephone or via self-report. It assesses physical activity in the domains of occupation, transport, household, and leisure over 7 days (27). This questionnaire is unique because it accounts for differences that arise due to nationality and culture and provides internationally comparable measures (27). The IPAQ is scored by multiplying the duration of the activity by its frequency and MET level, which can be obtained from the Compendium of Physical Activities (6, 27). This questionnaire has a long and short form and both these versions allow researchers to determine sedentary time. Validity and reliability of the IPAQ was established in a study that collected data on several participants from 12 different countries over a period of 7 days (27). Criterion validity of the IPAQ was established by calculating Spearman correlation coefficients between IPAQ data and accelerometer counts from the Actigraph 7164 (27). Concurrent validity between the long and short forms was determined by comparing the level of agreement (Spearman correlation coefficients) between the 2 versions that were administered to participants at different times on the same day (27). Similarly, Spearman correlation coefficients were also calculated to establish

test-retest reliability after participants completed the same version of the questionnaire on two separate occasions separated by 3 to 7 days (27). It was seen that there were fair to moderate agreements between the 2 versions of the IPAQ and accelerometer counts (range of pooled ρ=0.30 to 0.33) and reasonable agreement between the two versions of the questionnaire (pooled ρ=0.67) (27). Both the long (ρ=0.80) and short (ρ=0.76) versions of the IPAQ also demonstrated very good test-retest reliability (27).

Objective Measures

This section is a discussion of two activity monitors that are commercially available and feasible for use in the free living environment, i.e., the *activ*PAL™ and the Actigraph accelerometer. The former is a relatively new device while the latter has been extensively used in physical activity research including a large nationally representative study.

activPAL™

The *activ*PAL™ (PAL Technologies Ltd., Glasgow, UK) (20 g, 35 mm x 53 mm x 7 mm) is a motion sensor that can be used to determine free living activity and discriminates between upright activity and seated/lying activities. This device is worn at one third the distance between the hip and the knee on the midline of the thigh and is attached to the skin using PALstickies™. PALstickies™ are self-adhesive patented dual layer hydrogels that are recommended for attachment of the *activ*PAL™. However, the *activ*PAL™ can also be attached to the skin by using hypo-allergenic medical tape (e.g., 3M Tegaderm). The *activ*PAL™ consists of a piezoresistive accelerometer that senses limb position. This monitor has an 8-bit analog to digital converter, a sampling frequency of 10 Hz, and a memory of 4 Mb that allows recording of data in excess of 7 days. The *activ*PAL™ provides output that can be downloaded to a computer

in the form of daily and hourly activity, which is classified as time spent sitting/lying, standing, and stepping. For the stepping periods, this device provides information on the steps taken per day and per hour and also allows the user to identify the intensity of the stepping periods from the output on minute by minute stepping cadence of the walking periods. Additionally, the *activ*PAL™ also provides information on the total transitions from an upright to sitting/lying position and energy expenditure in the form of $\text{MET}\cdot\text{hours}\cdot\text{day}^{-1}$.

The *activ*PAL™ has been shown to be valid and reliable in both laboratory and free living conditions (5, 43, 46, 79, 104). Ryan et al. examined the validity and reliability of the *activ*PAL™ in measuring step number and cadence by comparing *activ*PAL™ output to results from video observation (104). The participants walked indoors on a treadmill at five different speeds, and outdoors at self-selected slow, normal, and fast speeds (104). Irrespective of walking speed, the *activ*PAL™ demonstrated very good reliability (ICC: $r > 0.99$) and validity (absolute percent error <1.11%) for both steps taken and cadence (104). Another study by Grant et al. examined the validity and reliability of the *activ*PAL™ as a measure of posture and postural transition in a simulated free-living condition. The criterion measure in this study was video recordings of the participants performing predetermined activities, which were compared to output from the *activ*PAL™ (46). The participants in this study performed activities of 2 types while wearing 3 *activ*PAL™ monitors, i.e., controlled activities and activities of daily living (46). In the controlled section, measurements were made while participants were seated, standing, and walking for 2 to 9 minutes each (46). In the activities of daily living section, participants performed 6 everyday activities involving sitting, standing, and stepping, which were randomly selected from a list of 19 activities (e.g., doing laundry, cleaning, computer use,

and food and drink preparation) that were predetermined by the investigators (46). As compared to the criterion measure, the *activ*PAL™ demonstrated excellent percentage agreement for the sitting (0.2 to 0.3%), standing (-0.2 to -0.6%), and stepping (-0.7 to -3.6%) tasks in both the controlled and activities of daily life sections (46). The different monitors also demonstrated good to excellent reliability among each other for sitting, standing, and stepping (ICC r=0.79 to 0.99) (46). Godfrey et al. suggested that the study by Grant et al. had several methodological issues and may not be representative of true free living conditions (43). Thus, Godfrey et al. compared free living (6 hour duration) *activ*PAL™ output in 10 participants between 22 and 27 years to that from a validated physical activity logger, which uses two ADXL202 accelerometers (43). These investigators found extremely small percent differences of 0.06% for sitting, 0.50% for standing, and 1.64% for stepping between the *activ*PAL™ and the criterion device (43). For total monitoring time (10 participants x 6hrs), the *activ*PAL™ demonstrated a detection accuracy of 98% for both static and dynamic activities, which allowed Godfrey et al. (2007) to conclude that the *activ*PAL™ is a good measure of activity behavior in the free living environment (43).

Actigraph accelerometers

Actigraph accelerometers (Pensacola, Florida) are commonly used in physical activity research**.** The Actigraph 7164 activity monitor has been used extensively by researchers in laboratory and field-based studies to derive energy expenditure prediction equations and to establish cut-points to distinguish between light, moderate, and vigorous activity (19, 29, 40, 53, 68, 90, 113, 122). These cut-points in turn have been used in several intervention studies and also in a national surveillance study in the U.S. (29, 40, 114). Actigraph discontinued model 7164 and

replaced it with the GT1M model in the early 2000s. However, outputs from both these models are comparable.

Actigraph 7164 and the GT1M have a built-in single axis (vertical) piezoelectric accelerometer capable of measuring accelerations between 0.05 to 2.0 *g* and a frequency response between 0.25 and 2.5 Hz. These accelerometers have a sampling frequency of 10 (7164) and 30 Hz (GT1M) and a memory capacity of 64 kb (7164) and 1 Mb (GT1M) (24, 116). These monitors provide output in the form of activity counts, which are raw accelerations filtered, digitized, and integrated over a given sampling period. Free living data using Actigraph accelerometers are typically collected in one minute intervals (epochs).

Freedson et al. developed activity counts cut-points that corresponded with different physical activity intensities (40). In this study, the investigators measured oxygen consumption in 50 participants who wore an Actigraph 7164 accelerometer at the waist while walking at a slow (4.8 $km \cdot hr^{-1}$) and fast speed (6.4 $km \cdot hr^{-1}$) and while jogging at 9.7 $km \cdot hr^{-1}$ for 6 minutes on a treadmill (40). Using these data, the researchers determined activity cut-points for light (<1952 $counts \cdot min^{-1}$), moderate (1952-5724 $counts \cdot min^{-1}$), hard (5725-9498 $counts \cdot min^{-1}$), and very hard (>9498 $counts \cdot min^{-1}$) intensity exercise (40). These cut-points were determined based on the corresponding MET levels for light (<3.00 METs), moderate (3.00-5.99 METs), hard (6.00-8.99 METs), and very hard exercise (>8.99 METs) (40). Recently, studies examining the effects of objectively measured (Actigraph 7164) light intensity exercise on metabolic risk used the Freedson cut-points to distinguish light intensity activity from activities of higher intensity (50). The Actigraph 7164 was also used to distinguish sedentary time in a study that examined the effects of taking breaks in sedentary time on metabolic risk (51). In this study, the researchers

used a previously used pragmatic cut-point of <100 counts·min^{-1} to define sedentary behavior (27, 51).

Inactivity Physiology

Currently, there is a growing emphasis on increasing light intensity activity, which is one option for increasing overall physical activity levels (50, 72). The idea is to decrease time spent being inactive and to substitute sedentary time with light activity (e.g., standing, slow walking, etc.). Similar to physiological adaptations due to training, the human body also adapts to detraining or complete inactivity. It has been suggested that continuous sitting may produce specific cellular signals involved in the regulation of disease risk factors. Therefore, several researchers are turning their focus to the study of inactivity physiology, i.e., primarily a study of specific molecular, physiologic, and biochemical responses that could lead to metabolic disorders and ill health.

Hamilton and colleagues have been very active in the study of inactivity physiology, primarily focusing on lipoprotein lipase activity (LPL) in response to chronic inactivity and how it responds to light intensity walking after periods of chronic inactivity (47, 48). LPL is an enzyme that binds to circulating lipoproteins and facilitates the hydrolysis of lipoproteins into triglycerides, which are used as an energy source. So far, the 3 published studies examining inactivity physiology of lipoprotein lipase have utilized animal models. Bey and Hamilton conducted a study to test whether LPL activity in muscle is decreased with physical inactivity and restored with subsequent physical activity (12). This study had two parts, i.e., a chronic part and an acute part. Both parts had a control group and a treatment group. In the chronic part, rats in the treatment group were suspended by their tails to deny contact of the hind limbs on the cage

floor for a period of 11 days (10 $hrs \cdot day^{-1}$) with only their fore limbs in contact with the cage floor. In the acute study, rats in the treatment group were not allowed to use their hind limbs for 12 $hrs \cdot day^{-1}$ via the same technique (12). The rats in the control group for both parts were allowed to continue normal cage activity (12). In the acute study, after the 12 hour period, rats from both the control and treatment groups were made to ambulate for four bouts of 30 minutes on a treadmill in 4 hours (12). At the end of both parts, the animals from both groups were sacrificed and LPL activity in the soleus muscle was determined (12). For the chronic part, significantly lower LPL activity was seen in the treatment group as compared to the control group ($p<0.01$) (12). For the acute part, it was seen that after the intermittent walking (at 8 $m \cdot min^{-1}$) bouts of 30 minutes per hour for 4 hours, LPL activity in the treatment group that had reduced during hind limb suspension was restored to levels that were observed in the control group (12). A corresponding decrease in triglyceride uptake with a decrease in high density lipoprotein levels were observed in the suspended rats for both the chronic and acute parts (12). Thus the researchers concluded that high LPL levels that are favorable for enhanced lipid metabolism are lowered during prolonged inactivity. However, light intensity activity for short durations of time after long periods of inactivity can reverse the detrimental effect of being sedentary on LPL levels (12). Encouraged by these findings, Hamilton and colleagues proposed that the physiological effects of physical inactivity have detrimental effects on many specific cellular and molecular processes and these may be reversed with light intensity activity (47).

Based on their findings, Hamilton and colleagues in a recent review suggested that increased sitting time must be considered as a distinct class of behavior and that it could contribute to increasing risk factors related to metabolic diseases through specific cellular and

molecular processes different from those observed in exercise physiology (48). Physical inactivity also increases inter-muscular adipose tissue stores (80). A recent study examined whether reduced lower limb activity altered inter-muscular adipose tissue stores in young adults, and whether increased adipose tissue stores would affect muscle strength (80). It was seen that after four weeks of inactivity, muscle volume decreased by 7.4 and 7.8% in the thigh and calf respectively. Significant increases in inter-muscular adipose tissue stores were observed in both thigh (24 cm^3) and calf (6 cm^3) (80). A corresponding significant loss in strength was also observed at both sites. These findings support the suggestion by Hamilton and colleagues that physical inactivity hinders the uptake of plasma triglycerides by down regulation of LPL, which alters fat oxidation rates resulting in increased inter-muscular adipose tissue stores (48, 80).

Another consequence of continuous sitting or sedentary behavior is increased musculoskeletal discomfort (99). Musculoskeletal discomfort could be the result of 'postural fixity,' which means maintaining the same posture or position for extended periods of time without moving (34). Individuals who sit for more than 95% of time at work experienced greater musculoskeletal discomfort than those who were able to vary their posture (8). In addition, continuous sitting also increases load on the inter-vertebral discs of the lumbar spine (119). Increased pressure in the lumbar spine causes chronic low back pain (119). Prolonged sitting also increases mechanical stresses on the musculature of the spine (118).

Summary

The rapidly rising obesity rate in America can be attributed to an imbalance in the rates of energy intake and energy expenditure. Currently there is an abundance of energy dense foods and an environment that does not favor physical activity. Although time trend studies show no decline in leisure time physical activity, there has been a marked decline in occupational and transportation NEAT. The benefits of moderate to vigorous intensity activity are well established, but current research on inactivity physiology also shows that light intensity activity has a favorable effect at a molecular and sub-cellular level on biochemical mechanisms. Thus, there is an increased emphasis on increasing physical activity as opposed to only increasing structured exercise participation. This increase in physical activity can be brought about by increasing light intensity activity and other forms of NEAT. Light intensity activity can be promoted through the use of treadmill workstations, since they do not interfere with work performance in a major way and result in higher energy expenditure than simply sitting at work.

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PART II

Effect Of Using A Treadmill Workstation On The Performance Of Simulated Office Work Tasks

Part II is a journal article by the same name that will appear in the September 2009 issue of The Journal of Physical Activity and Health. The authors for this article are Dinesh John, David R. Bassett, Dixie L.Thompson, Jeffrey T. Fairbrother, and Debora R. Baldwin.

Abstract

Although using a treadmill workstation may change the sedentary nature of desk jobs, it is unknown if walking while working affects performance on office-work related tasks. **Purpose:** To assess differences between seated and walking conditions on motor skills and cognitive function tests. **Methods:** Eleven males (24.6 ±3.5yrs) and nine females (27 ±3.9yrs) completed a test battery to assess selective attention and processing speed, typing speed, mouse clicking/drag-and-drop speed, and GRE math and reading comprehension. Testing was performed under seated and walking conditions on two separate days using a counterbalanced, within subjects design. Participants did not have an acclimation period before the walking condition. **Results:** Paired t-tests ($p<0.05$) revealed that in the seated condition, completion times were shorter for mouse clicking (26.6 ±3.0 *vs.* 28.2 ±2.5s) and drag-and-drop (40.3 ±4.2 *vs.* 43.9 ±2.5s) tests, typing speed was greater (40.2 ±9.1 *vs.* 36.9 ±10.2 adjusted words.min^{-1}), and math scores were better (71.4 ±15.2 *vs.* 64.3 ±13.4%). There were no significant differences between conditions in selective attention and processing speed or in reading comprehension. **Conclusion:** Compared to the seated condition, treadmill walking caused a 6 to 11% decrease in measures of fine motor skills and math problem solving, but did not affect selective attention and processing speed or reading comprehension.

Introduction

Currently, two-thirds of American adults are either overweight or obese (29). Obesity rates are rapidly increasing in most modern and industrialized nations (2, 29). The obesity epidemic has been attributed to the increased availability of inexpensive energy-dense foods in conjunction with a modern environment that has reduced opportunities to be physically active (1). To combat this epidemic, there has been an emphasis on increasing physical activity through structured exercise regimens. More recently, it has been suggested that an increase in non-exercise activity thermogenesis (NEAT) may help control weight (25). In 2003, the U.S. Census bureau estimated that approximately 52.4% of employed Americans use a computer at work (21). Because many Americans spend time at work sitting in front of a computer, researchers have identified the work environment as a place to increase NEAT (21, 26).

The treadmill workstation was first proposed and built twenty years ago by Edelson to reduce inactivity in office workers (14, 15, 28). It was touted to solve the hazards of continuous sitting (postural fixity). These hazards included aches and pains, stress, and other illnesses (13-15, 28). Treadmill workstations allow users to alternate between sitting and walking while working during a regular workday. Treadmill workstations consist of a conventional motorized treadmill that slides under a height adjustable sit-to-stand table. A regular office chair allows the user to sit, if they choose.

After briefly disappearing, the treadmill workstation concept was reintroduced as a potential weight loss strategy by Levine and co-workers (26). They suggested that if an obese individual walked two to four hrs/workday at a treadmill workstation, he/she would increase daily energy expenditure by about 500 $kcal.day^{-1}$ (26). They estimated that this could translate to

a yearly weight loss in the range of 20 to 30 kg (26).

Although the treadmill workstation seems to have the potential for weight loss, the effects of this approach on work performance still need to be assessed. An individual using a treadmill workstation may need to divide attentional resources between treadmill walking and office work, which might compromise work performance. It remains to be seen if slow walking at a treadmill workstation affects performance in work related variables. The results of such a study would establish the feasibility of the treadmill workstation as an effective strategy for weight control. Thus, the purpose of this study was to determine if walking while working at a treadmill workstation affects selective attention and mental processing speed and the performance of simulated office work tasks involving 1) fine motor movements (typing and mouse movements) and 2) mathematical and verbal reasoning.

Methods

Workstation

The treadmill workstation consisted of a sit-stand table (501-11; Conset A/S, Denmark), height adjustable office chair, treadmill (T1450; Vision Fitness, Lake Mills, WI), and a computer. These components were purchased separately and assembled in the Applied Physiology Laboratory (Department of Exercise, Sport, and Leisure Studies) at the University of Tennessee. The table used in the current study could be lowered to a minimum height of 76 cm for seated work and raised to a maximum height of 113 cm above the treadmill deck during walking. The recommended heights while performing normal sitting and standing work are 70 to 78 cm and 95 to 115 cm, respectively (9). The treadmill workstation was constructed in a way

that the user could alternate between treadmill walking and sitting by simply stepping off the treadmill, sitting on the chair, and adjusting the table to a desired height by means of an electronic switch. The computer screen was placed on the table surface and could be moved to suit treadmill walking or sitting.

Participants

Eleven male (24.6 ± 3.5 yrs) and 9 female (27 ± 3.9 yrs) graduate students from the University of Tennessee volunteered to participate in this study. Ability to participate in the study was assessed using a medical history questionnaire (Appendix D). All participants provided written, informed consent (Appendix B). Although all participants were familiar with treadmill walking, none were used to continuous, slow treadmill walking at 1mph or had previously used a treadmill workstation. The experimental protocol was approved by the University of Tennessee Institutional Review Board. As a safety precaution, a one-meter lanyard was attached to the participant's clothing that would automatically turn off the treadmill if they moved more than one meter away from the treadmill control panel during walking. Height and weight of each participant was measured using a stadiometer and physician's scale, respectively. Participant characteristics are shown in table A-1[1].

Test Battery

Participants had to complete a test battery comprising of five tests to assess selective attention and processing speed, cognitive function and fine motor movement. The paper-and-pencil form of the Stroop Color and Word Test (Stoelting Co., Wood Dale, IL.) was used to measure selective attention and processing speed (17). The Stroop test activates an automatic

[1] All tables in Appendix A

verbal interference that impedes the task of color naming (42). This test is valid and reliable in identifying individual differences in the allocation of attentional resources caused by interference (27). The test had three sections of 100 items each and participants had 45 seconds per section to complete as many items as possible. During testing, participants had to verbally identify each item so that the test administrator could verify if items were being correctly identified. The first section required participants to read the names of colors printed in black ink. The second section had items represented by four consecutive ‘X’ symbols printed in red, blue, or green and participants had to identify the color of the print. Items in the third section were names of colors (‘Red’, ‘Blue’, and ‘Green’) printed in a color not represented by the word. Participants had to identify the color of the printed word rather than simply read the word. For instance, if an item on the test were the word ‘Red’ printed in green ink, the correct answer to this item would be green. The number of correct items for each section were recorded and used to determine t-scores. The method of obtaining t-scores is described in the product manual that accompanies the Stroop Color and Word Test (17).

Fine motor movement performance was assessed with a typing and two computer mouse proficiency tests. These tests were conducted on a Dell™ OptiPlex™ GX260 desk top computer with an Intel Pentium® 4 processor (2.40 GHz) and 256MB RAM. The ‘Mavis Beacon Teaches Typing 17’ (Riverdeep Inc., San Francisco, CA.) computer program was the standard typing exercise for all participants. In this test, participants had to replicate sections of text displayed on the screen. On completion of the assigned paragraphs, typing speed, excluding any errors made, was recorded in adjusted words per minute (AWPM). This software has previously been used in research studies to assess typing speed (16, 40). Computer mouse proficiency was assessed using

a visual basic program. In this test, participants were instructed to perform a mouse clicking and a drag-and-drop task (38). In the mouse clicking task, the participant had to click on one of 25 icons that randomly turned red in color until all icons were clicked. The drag-and-drop task involved dragging and dropping 25 icons one at a time (when red) into a larger black box. An icon stayed red until successfully dropped into the box, after which another random icon on the screen turned red. The time taken to complete each task was recorded.

Paper-based graduate record examination (GRE) math and verbal (reading comprehension only) sections were used to assess cognitive function of the participants. These sections were obtained from the official source for GRE review guide (Educational Testing Services) that contain examples of actual GRE tests. The GRE is used to predict academic performance by measuring the basic developed abilities related to success in graduate school (24). Mathematical reasoning and reading comprehension tests from the GRE have been used in previous research studies examining cognitive function (7, 37). For the verbal section, each participant was instructed to read a long (600 words) and short paragraph (200 words), and to answer 11 related questions in 18 min. The reading comprehension part of the GRE is designed to measure the ability to analyze, evaluate, and synthesize information. For the math section participants had to answer 30 questions in 30 min. This section of the GRE measures the participant's ability to reason and solve quantitative problems under a time constraint. Scores for both GRE tests were calculated as the total percentage of correct responses from each test.

Study Design

Data collection was conducted at the treadmill workstation during two visits separated by two days. During their first visit, the study protocol was explained to the participants and they

completed the test battery for either the sitting or treadmill walking (with no prior acclimation) condition. The test battery for the remaining condition was completed during the second visit. Participants were allowed to adjust the table to a desired height for both conditions. During the treadmill walking condition, participants underwent testing while walking at 1 mph (27 $m.min^{-1}$). Participants were allowed to warm up at this speed for a few minutes before the test began. The intensity of level walking at 1 mph is less than 2 METS (4). To avoid a testing effect, two different versions of the GRE and typing test paragraphs were used. A counterbalanced, within-subjects design was used to avoid confounding due to order effects.

Statistical Procedures

Statistical analyses were conducted using SPSS version 14 for windows (SPSS Inc., Chicago, IL). The independent variable in this study was the treadmill workstation condition (seated *vs.* treadmill walking). The dependent variables were scores for the Stroop task (t-scores), typing test (AWPM), mouse clicking and drag-and-drop tests (completion time), and GRE math and reading comprehension (percentage of correct answers) tests. Test results are presented as means ± standard deviations. Paired samples t-tests were used to examine differences between test results from treadmill walking and the sitting conditions. Repeated measures ANOVAs on test versions were performed to determine if GRE test versions had a confounding effect on the results from the two conditions. Statistical significance for all analyses was set at 0.05.

Results

Significant differences between the two conditions were observed on the typing, mouse proficiency, and GRE math test scores. In the sitting condition, participants displayed better

scores on the typing (t_{19}= -3.161, p=0.005), recorded lower completion time on the mouse clicking (t_{19}= 2.747, p=0.013) and drag-and-drop tests (t_{19}= 3.839, p=0.001), and scored higher on the mathematical reasoning test (t_{19}= -2.169, p=0.017). Figures A-1, A-2, and A-3[2] illustrate performances on the Stroop and typing test, mouse proficiency tests, and cognitive tests, respectively. Mouse clicking and drag-and-drop scores (in seconds) for the walking condition were lower by 8% and 6% respectively. Typing (AWPM) and math scores for the sitting condition were 9% and 11% greater than scores for the walking condition, respectively. There were no significant differences between the walking and sitting conditions for the Stroop and reading comprehension tests. However, repeated measures ANOVA showed a significant condition x version interaction for reading comprehension (p<0.05). In other words, the group that took version one while walking and version two while sitting scored better in the sitting condition, and the group that took version two while walking and version one while sitting scored better in the walking condition. However, there was no overall significant difference in reading comprehension between the sitting and walking conditions.

Discussion

Test Results

The results of the current study indicate that walking while working decreases scores on tests of typing and mouse proficiency, and math solving ability by approximately 6 to 11%. This may be because the added task of walking puts an increased load on both mental processing and

[2] All figures in Appendix A

motor control (12, 18, 31). An increased load causes interference in one or both tasks, thereby lowering task performance (18).

Significantly lower performances on fine motor movement tests during the walking condition may have resulted from the increased complexity of performing multiple motor tasks (walking and typing/mouse tasks) that require a more complex interaction with cognitive abilities, and increased recruitment of attentional resources (12, 33). Similarly, performing a cognitive function like math problem solving and treadmill walking simultaneously may have increased complexity and thereby placed a higher than normal demand on attentional resources. This may have resulted in lower scores on the mathematical reasoning tests during the walking condition. Research by Del Giorno et al. showed significantly lower performances ($p<0.05$) on a finger tapping task and a cognitive test during submaximal exercise (75% of ventilatory threshold) as compared to performances in a sitting condition (11). Although the exercise intensity in the study by Giorno et al. was much higher than the current study, a similar trend of decreased performance during dual task performance was observed in both studies (4).

Findings on the typing tests from the current study were different from those by Edelson and Danoff (15). They found no significant difference in typing performances between walking and sitting while working at a treadmill workstation (15). In contrast to this finding, the current study determined that typing speed decreased slightly (3.3 $\pm$ 4.7 AWPM) while walking. This discrepancy may have resulted from the fact that participants in Edelson and Danoff's study had an average seated typing speed of 61 AWPM in comparison to only 40 AWPM in participants from the current study (15). The average typing speed of the current participants was similar to the average speed (40 AWPM) of 3475 participants from Ostrach's study (30). Results from

Ostrach would classify participants tested by Edelson and Danoff in the 2^{nd} decile and the current participants in the 5^{th} decile (30). Therefore, the difference between findings from Edelson and Danoff and the current study may have resulted from the fact that participants in the former study were more experienced typists than those in the current study. In addition, Edelson and Danoff examined only five participants and their study may have lacked the statistical power required to show a significant difference.

Unlike fine motor movement and GRE math tests, results from the Stroop tests were not significantly different between walking and sitting conditions. During the Stroop test, participants utilize their working memory to resolve a mental conflict between word reading and color naming (23, 42). In the walking condition, participants also had to simultaneously process the task of walking. Findings from the current study were similar to those by Grabiner and Troy who did not report a significant difference (p=0.052) in Stroop test results between a stationary condition (standing) and treadmill walking (18). However, they reported a significant decrease in step width variability during treadmill walking while performing the Stroop test (18). They concluded that voluntary gait changes occur to compensate for the reduced visual resources allocated to walking while performing the Stroop test (18). The current study did not assess step width variability. In general, it can be said that walking while performing tasks that invoke a mental load similar to the Stroop test, does not affect an individual's performance on the mental task.

Like the Stroop test, reading comprehension scores in the sitting condition were not significantly different than scores in the walking condition. These results are in contrast to those of Barnard, Yi, Jacko, and Sears where reading comprehension scores for sitting were

significantly higher ($p<0.01$) than those for walking (6). Unlike Barnard et al. who reported a 10% difference between scores, reading comprehension scores while sitting were only 4% higher than treadmill walking in the current study. This difference may be attributable to the fact that participants from Barnard et al. walked on a narrow course that meandered around a room as compared to the simpler task of treadmill walking in the current study. In addition, the device used by Barnard et al. was a personal digital assistant (PDA) and had a much smaller screen as compared to the computer monitor in the current study (6). In summary, reading comprehension may not place as high a demand on attentional resources as other tasks, and thus is not affected by treadmill walking.

Practical Implications of Lowered Performance

Although performance during the walking condition was statistically lower for the typing, mouse proficiency, and math tests, this section of the paper attempts to examine how these results could potentially impact real-life work productivity. In this study, average typing speed decreased from 40.2 while sitting to 36.9 AWPM while walking. According to Ostrach, the average typing speed lies between 38 and 43 AWPM (6). It can be speculated that, because the reduced typing speed during the walking condition falls out of the average typing speed by just one AWPM, there may be a marginal impact on typing while walking and working in an office setting. To substantiate the previous argument, we could consider the example of emailing, which is a popular form of electronic communication (35). A study that examined email communication between physicians and their patients showed that patient emails and physician replies averaged 139 and 39 words, respectively (35). If we compute the time taken to compose an email by these individuals based on average typing speeds from Ostrach's study (sitting: 40

AWPM) and the current study (walking: 36.9 AWPM), patients and physicians using a treadmill workstation would take only 17.5 and 4.9 s longer to compose an email, respectively. In addition, according to the International Organization of Standardization (ISO) ergonomic standard for computer visual display terminals, if a standard keyboard is replaced with a different kind that may cause a decrease in typing speed, the speed obtained using the new one must lie within 0.75 standard deviations of the speed for the standard keyboard to be acceptable (36). Although we did not compare different keyboards in our study, we can apply ISO standards to our results because we induced an experimental condition that decreased typing speed. Typing speed during the experimental walking condition (36.9 $\pm$ 10.2 AWPM) was within the acceptable range (33.4 to 47 AWPM) as per ISO specifications.

The use of a computer mouse depends mainly on the type of job being performed. In this study we examined the effect of walking while working on clicking and drag-and- drop tasks only. A previous study examining computer mouse use in office workers showed that an employee moves and clicks the mouse approximately 78 times per hour (22). In the current study, time taken to move the mouse and click an item took 1.06 and 1.12 s while sitting and walking, respectively. Therefore, moving the mouse and clicking 78 items in an hour while walking and working would require only 4.68 s more than sitting, which may not have a substantial effect on overall work productivity. In general, the task of dragging-and-dropping items using a mouse at work is less frequent than clicking.

The third test that showed significantly different results between sitting and walking conditions was the GRE math test. To accommodate errors in the measurement process, Educational Testing Services defines a ‘meaningful difference between scores’ as a value greater

than 2 times the standard error of measurement (SEM) of score differences. In the current study, the difference between sitting and standing conditions for the math test was 2.48 times the calculated SEM of score differences and thus meaningful (1). However, the margin that renders the walking GRE math score to be meaningfully different from that obtained while sitting is very small. In other words, the score obtained while walking (64.3%) would not have been meaningfully different from the score obtained while sitting (71.4%) if it was between 65.6 and 77%.

The differences between scores for the sitting and walking conditions on the typing, mouse proficiency, and the GRE math tests could be reduced through acclimation (34, 41). In light of the potential benefits of using a treadmill workstation, the benefits may outweigh the differences observed.

Restoring Energy Balance.

Current data indicate that in the past forty years, there has been an increase in the average American's caloric consumption and a concurrent decrease in energy expenditure (3, 8). As a result, the average American adult gains 1.8 to 2 $\text{lbs} \cdot \text{year}^{-1}$ (20). Levine and Miller suggested that walking while working at a treadmill workstation increases energy expenditure by approximately 165% in obese individuals as compared to sitting at a desk (26). They speculate that the treadmill workstation may be effective in preventing weight gain or lowering obesity rates in office workers.

Hazards of Sitting

Occupations involving continuous seated work result in increased musculoskeletal discomfort (32). Individuals who sit for more than 95% of time at work experienced greater

musculoskeletal discomfort than those who were able to vary their posture (5). In response to a subjective assessment of musculoskeletal discomfort, users of the treadmill workstation report that walking while working helped reduce back problems associated with continuous sitting (39). In addition to musculoskeletal discomfort, sedentary behaviors like continuous sitting also affect the body at a molecular level. Hamilton, Hamilton, and Zderic proposed that prolonged hours of sitting may upregulate specific molecular, physiologic, and biochemical responses (also known as 'inactivity physiology') that could lead to metabolic disorders (19). A specific example of molecular adaptations to reduced low-intensity activity is the transcription of an inhibitory gene that induces LPL suppression through a posttranslational mechanism (19). Hamilton et al. state that inactivity (sitting) and low nonexercise activity may produce serious health problems that cannot be explained by exercise deficiency alone (19). In other words, maintaining higher levels of low-intensity activity independent of the recommended moderate-vigorous physical activity can lower several metabolic risk factors (19).

Strengths and Limitations

A limitation of this study is that it was not conducted in a proper office setting. In addition, the participants in this study were graduate students and not actual employed office workers. The results of this study may not be comparable to results from an office setting because the duration of a single testing session (60 min) was less than the recommended duration of two to four hrs/day. More importantly, the participants may not have had sufficient time to acclimatize to walking and working. Acclimation may reduce or eliminate the marginal lowering of work performance observed initially. Research examining interference due to dual task performance suggests that acclimating to performing dual tasks can reduce or even eliminate

interference, thereby resulting in improved task performance (34, 41). In addition, other factors that may potentially affect work performance are not discussed in this study. One such factor could be variability in distance from the area of work due to selected conditions (sitting and walking). Assessing the effect of all potential factors that may affect work performance was beyond the scope of this study.

On the other hand, the current study is the only of its kind to have examined the impact of using a treadmill workstation on the performance of tasks that simulate office work. The selected tasks involved cognitive and motor skills that are a requirement in today's work environment. The current study also established that walking while working did not greatly affect work performance.

Conclusion

The treadmill workstation aims to replace 2 to 4 hours of sitting at work with low-intensity physical activity that may help obese office workers achieve a negative energy balance and reduce obesity related costs (10, 26). Using a treadmill workstation could also attenuate musculoskeletal discomfort, reduce metabolic risk factors associated with continuous sitting, and lower stress levels (15, 19). The current study compared the effects of using a treadmill workstation on simulated office work tasks. Walking while working was associated with a minor 6 to 11% decrease in math problem solving, mousing, and typing performance. It is possible that this decrease in performance could be eliminated through acclimation to walking while working. It is imperative to investigate work performance in a proper office setting after participants are used to walking and working for at least 2 to 3 hrs/day. Future studies should examine if using

the treadmill workstation helps lower body weight, reduce fat mass, and lower employee health care costs. If these benefits can be shown, it may be possible to convince employers that the benefits of treadmill workstations justify the costs.

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PART III

Treadmill Workstations: An Obesity Intervention?

Abstract

Purpose: To determine if using of a treadmill workstation favorably influences anthropometric, body composition, cardiovascular, metabolic, musculoskeletal, and mental stress variables in overweight and obese office workers. **Methods:** Twelve (5 males and 7 females) (mean age= 46.2 $\pm$ 9.2 yrs) overweight/obese sedentary office workers (mean BMI=33.9 $\pm$ 5.0 $kg \cdot m^{-2}$) volunteered to participate in this 9 month study. Baseline measurements included anthropometric measurements, body composition, resting heart rate and blood pressure, serum lipid profile, plasma glucose, insulin, glycosylated hemoglobin, and bone mineral density. Postural allocation and $steps \cdot day^{-1}$, musculoskeletal discomfort, and mental stress variables were also measured. Once the baseline measurements were made, treadmill workstations were installed in the participants' offices. All measurements were then repeated after 3 and 9 months of the study. Differences among the outcome variables measured at the 3 time-points were compared using repeated measures ANOVAs or non-parametric Friedman's Rank Tests. **Results**: Between baseline and 9 months, significant increases were seen in the median times spent standing (146 to 203 $min \cdot day^{-1}$), stepping (52 to 90 $min \cdot day^{-1}$) and total $steps \cdot day^{-1}$ (4351 to 7080 $steps \cdot day^{-1}$). Correspondingly, the median time spent sitting/lying decreased (1238 to 1150 $min \cdot day^{-1}$) ($p<0.05$). Using the treadmill workstation significantly reduced waist (by 5.5 cm) and hip circumferences (by 4.8 cm), low density lipoproteins (LDL) (by 16 $mg \cdot dL^{-1}$), and total cholesterol (by 15 $mg \cdot dL^{-1}$) during the study ($p<0.05$). **Conclusion:** Using a treadmill workstation significantly decreased sedentary time and increased standing and stepping time in our participants. This additional energy expenditure favorably influenced waist and hip circumferences and lipid and metabolic profiles in overweight and obese office workers.

Introduction

The obesity rate among American adults has increased from 13.4% in 1960 to 34% in 2006 (17, 42). The current obesity epidemic has been attributed to an increase in the rate of energy intake and a decrease in the rate of physical activity energy expenditure (1, 11, 66). The modern environment promotes an inactive lifestyle through sedentary jobs, motorized transport, and inactive forms of entertainment (11, 40).

Over the past several years, American jobs have become more inactive. For example, between 1950 and 2000, the percentage of adults employed in high-activity occupations declined by 33% and the percentage of adults employed in sedentary occupations increased by 76% (11). Additionally, in 2000, almost 50% of the American workforce was employed in seated jobs (11). The increase in the obesity rate among American adults corresponds with the shift from highly active to more sedentary jobs (11, 17). Because American adults spend almost 50% of their waking hours at work and that occupations with higher levels of physical activity reduce the risk for being overweight or obese, researchers are targeting the workplace as an avenue to introduce weight loss interventions (10, 26, 30, 32, 51, 53).

A potential worksite obesity intervention involves the treadmill workstation. The treadmill workstation consists of a motorized treadmill that slides under a height adjustable sit-to-stand table. A regular office chair can be accommodated next to the treadmill if the user chooses to sit. In 1989, Edelson and Danoff first proposed this concept as a solution for the hazards of continuous sitting at the workplace, i.e., musculoskeletal discomfort (MSD), mental stress, and low alertness. In 2005, Levine and Miller hypothesized that the treadmill workstation could be a potential weight loss intervention. They showed that obese individuals walking at 1

mph while working expended 198 $kcal \cdot hr^{-1}$ as compared to only 72 $kcal \cdot hr^{-1}$ during seated work (32). Additionally, studies have reported that obese individuals are upright for approximately 150 $min \cdot day^{-1}$ less and sit for around 120 $min \cdot day^{-1}$ more than lean individuals (7, 28, 31). Thus, Levine and Miller speculated that, if obese individuals replaced 2 to 4 hours of seated work per day with walking while working, they could lose approximately 20 to 30 kg of their body weight per year (32).

Although the treadmill workstation shows potential as a weight loss intervention, empirical studies are needed to determine the anthropometric, body composition, and physiological effects of using a treadmill workstation in sedentary overweight/obese office workers. Therefore, the purpose of this study was to determine if using of a treadmill workstation favorably influences anthropometric, body composition, cardiovascular, metabolic, musculoskeletal, and mental stress variables in overweight and obese office workers.

Methods

This study was approved by the University of Tennessee Institutional Review Board and the University of Tennessee Graduate School of Medicine Institutional Review Board.

Participants

Twelve University of Tennessee faculty and staff members (5 males and 7 females) (mean age= 46.2 $\pm$ 9.2 yrs) were recruited for this study. Table A-2 contains baseline demographic characteristics of the participants. All participants were recruited through an advertisement in an online university newsletter. To take part in the study, volunteers needed to be between 20 and 65 years of age, have a body mass index (BMI) above 28 $kg \cdot m^{-2}$, have an

office with an area of at least 49 square feet, be engaged in seated office work for most of the day, and be able to walk continuously for 60 minutes. Women who were pregnant were not eligible to participate.

Respondents to the advertisement were contacted on a first come, first served basis. Investigators personally interviewed the respondents to determine eligibility and whether potential participants were willing to use a treadmill workstation Participants were then screened using a 2-page health history questionnaire to determine any contraindications to exercise (Appendix D). Participants who checked "yes" to any past history or current symptoms item on the questionnaire were required to produce a letter from their personal physician giving approval for their patient to participate in the study. All selected participants provided written informed consent (Appendices C1 and C2).

Workstation

The treadmill workstation consisted of a rectangular sit-stand table (Series-5 AdjusTable Height Table, Details, Grand Rapids, MI) and a treadmill (T1450; Vision Fitness, Lake Mills, WI). These components were purchased separately and assembled in the Applied Physiology Laboratory. The height adjustable table had a work surface measuring 152 x 74 cm, which could be lowered to a minimum height of 65 cm for seated work and raised to a maximum height of 116 cm above the treadmill deck. The recommended table heights for performing normal sitting and standing work are 70 to 78 cm and 95 to 115 cm, respectively (13). The treadmill console was modified to fit on a sliding tray on the underside of the table top to allow users easy access to the treadmill controls. The treadmill workstation was constructed in a way that would allow the user to alternate between treadmill walking and sitting by simply stepping off the treadmill

and sitting on the chair after adjusting the table to a desired height by means of an electronic motor. The workstations were installed in the offices of the participants after all baseline measurements were completed. If desired, the participant's LCD computer monitor was mounted on a flexible flat panel radial arm (FLEXmount™, Innovative Office Products, Easton, PA), which was clamped on to the edge of the table top that was opposite to where the user would walk/stand/sit and work. This radial arm suspended the LCD monitor above the table and enabled the participant to move it anywhere above the work surface to suit working while walking, standing, or sitting. Participants were not given any recommendations on the duration ($hr \cdot day^{-1}$) or speed (mph) of walking at the treadmill workstation. In other words, participants were allowed to walk at self-selected speeds and durations at the treadmill workstation during the course of the study.

Study Protocol

The total duration of the study was 9 months. All variables were measured prior to the installation of the treadmill workstation in the participants' offices (baseline), 3 months after the installation, and a final measurement at the end of the study. Participants visited the Applied Physiology Laboratory at the University of Tennessee on the aforementioned 3 occasions. During these visits, anthropometric variables, body composition, bone mineral density, and resting heart rate and blood pressure were measured. Participants were asked to avoid participating in strenuous physical activity and consuming any food 4 and 2 hours prior to testing in the laboratory, respectively. The total testing time was approximately 75 min per laboratory visit.

Physical Activity Measurement

A piezoresistive motion sensor called the *activ*PAL™ (PAL Technologies Ltd., Glasgow, UK) (20 g, 35 mm x 53 mm x 7 mm) was used to objectively measure physical activity. The *activ*PAL™ detects accelerations of the limb and distinguishes limb position. It provides output in the form of time spent sitting/lying, standing, walking, and the total number of $steps \cdot day^{-1}$. Additionally, the monitor also measures energy expenditure in the form of $MET \cdot hours \cdot day^{-1}$. This monitor has an 8-bit analog to digital converter, a sampling frequency of 10 Hz, and a memory of 4 Mb that allows recording of data in excess of 7 days. Data from the *activ*PAL™ was downloaded to a computer using a software provided by the manufacturer (PAL software, version 5.8.2.2, PAL Technologies Ltd., Glasgow, UK). Participants wore the *activ*PAL™ on the midline of the thigh, one-third of the way between the hip and the knee prior to their lab visits for a period of 2 days. The monitor was attached to the skin with hypo-allergenic medical tape (Tegaderm™ HP, 3M Health Care, St. Paul, MN) or by using self-adhesive dual layer hydrogels called PALstickies™ (PAL Technologies Ltd., Glasgow, UK). All measured variables were averaged to obtain mean hours per day values, which were used in the statistical analyses.

Anthropometric Measurements

Anthropometric measurements included height, weight, and waist and hip circumferences. Height was measured using a stadiometer and weight was measured using an electronic scale, which was calibrated using a weight that was certified by the National Institutes of Standards and Technology. Circumferences were measured while the participants were standing with a spring loaded Gulick tape (M-22C, Creative Health Products, Plymouth, MI), which reduces skin compression and improves measurement consistency (64). Waist

circumference was measured at the narrowest part of the torso between the xiphoid process of the sternum and the umbilicus. Hip circumference was measured at the maximal circumference of the buttocks (64). Duplicate measurements were made at both circumference sites. If these measurements differed by more than 5 mm, additional measurements were made (64). The average of the closest two measures (within 5 mm) at each site was used to represent the circumference measures (64).

Body Composition

Body composition was obtained using whole body air displacement plethysmography (BodPod®, Life Measurement Inc., Concord, CA). The BodPod® has been shown to be a valid and reliable method to estimate percent body fat (38). Prior to use, the BodPod® was calibrated on the morning of the day of testing according to manufacturer specifications. During testing, participants wore lycra/spandex swimwear and a swim cap and did not have any metal or jewelry on their person. Each participant was seated inside the sealed chamber of the BodPod® and underwent 2 to 3 measurement trials. The BodPod® derives body volume and calculates body density and percent body fat using the Siri two-compartment model equation (59). The output from the BodPod® also provides information on total fat and lean mass of the participant. Additionally, truncal fat (subcutaneous and intermuscular fat in the trunk) was also obtained using dual energy x-ray absoptiometry (DXA) (GE Lunar Bone Densitometer 8547, GE Lunar Corp., Madison, WI) (67). DXA procedures are detailed below.

Bone Mineral Density

Total bone mineral density was obtained using the DXA. On the morning of the day of testing, a qualified technician performed a quality assurance check for the DXA as per

manufacturer specifications. During testing, participants wore clothing that was free of metallic components or buttons and removed all jewelry and metallic objects from their person. The DXA emits a low dose radiation beam containing x-rays of a high (100-140 kV) and low (45-70 kV) energy level that are absorbed differently by soft and bone tissue. After a digital transformation of the x-ray images, bone mineral density is calculated using the software provided by the manufacturer (enCORE 2002, version 6.70.021, GE Lunar Corp., Madison, WI).

Hemodynamic Measurements

Resting heart rate and blood pressure were measured in all participants in the seated condition. Heart rate was measured using the palpation technique. After a 5 min rest, the investigator palpated the participant's radial pulse and counted the number of beats for a 30 s interval and multiplied it by 2 to obtain heart rate in beats$\cdot$min^{-1} (25). After the heart rate measurement was completed, blood pressure was measured using the auscultation technique with a stethoscope and a mercury sphygmomanometer in accordance with the American Heart Association recommendations (50).

Lipid and Metabolic Profiles

Participants underwent a 12-hour fasting blood draw at the University of Tennessee Medical Center Outpatient Clinic. Approximately 10 ml of blood was withdrawn from the participant's antecubital vein. Blood assays to determine lipid and metabolic profile were conducted. Serum lipid profile variables included LDL, high density lipoproteins (HDL), very low density lipoproteins (VLDL), total cholesterol, and triglycerides. Metabolic variables included plasma glucose, insulin, and glycosylated hemoglobin.

Musculoskeletal Discomfort

Musculoskeletal discomfort (MSD) was measured using a self report questionnaire (Appendix E-1) (15, 34). The questionnaire contains a diagram of the human body and a discomfort level Likert scale ranging from 0 to 10, where 0 represents 'no discomfort,' and 10 represents 'extreme discomfort.' Participants entered their discomfort score in blank boxes that had arrows pointing to each of the 24 body parts (left and right side). In addition to the 3 measurement time points of the study, participants completed the MSD questionnaire 1 week after the installation of the treadmill workstation. This was done to determine the immediate effects of using a treadmill workstation in our participants. To determine if MSD changed during the course of a day, the participants completed questionnaires at 9:00am, 1:00pm, and 4:00pm on each day. Apart from whole body MSD, regional MSD was also determined for (a) the upper body (neck, arms, and shoulders), (b) the back (mid and lower back), and (c) the lower body (buttocks and legs).

Perceived Stress

Cohen's 10-item Perceived Stress Scale (PSS) was used to determine if using the treadmill workstation influenced perceived stress levels among the participants (Appendix E-2) (14). The PSS measures the extent to which a participant feels that his/her life is unpredictable, uncontrollable, and overloaded during the past 1 month (14). Participants answered each of the 10 questions using a scale of 0 to 4, where 0 represented 'never,' 1 represented 'almost never,' 2 represented 'sometimes,' 3 'represented fairly often,' and 4 represented 'very often (14).' There are 4 positively stated questions on the PSS and the scores for these questions are obtained by

reversing the participant's response on these questions (i.e., 0=4, 1=3, 2=2, 3=1, and 4=0) (14). An overall stress score is obtained by summing the sores for each of the 10 questions (14).

Dietary Intake

To examine if there were any changes in caloric intake over the course of the study, a 24-hour dietary recall interview was conducted at baseline, 3 months, and 9 months after installation of the treadmill workstation. Three recalls were randomly conducted on non-consecutive days of the week (2 weekdays and 1 weekend day). Each 24-hour recall was administered using a telephone interview and the Nutrition Data System for Research software (NDSR, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). These interviews were conducted at a time that was convenient for the participants by personnel who were trained and experienced in using the NDSR. The NDSR software prompts the interviewer to obtain specific and quantitative detail of every food or drink consumed during the previous day. Data on the total calories, total fat, saturated fat, and cholesterol were used in the data analyses.

Data Analyses

Data analyses were conducted using SPSS version 17 for Windows (SPSS Inc., Chicago IL). All variables were examined for normality. Data distribution patterns dictated whether we used parametric or non-parametric tests to make comparisons among the variables (48, 63).

Data from the *activ*PAL™ on the total time spent sitting/lying, standing, stepping, total steps$\cdot$day^{-1}, and energy expenditure in MET$\cdot$min$\cdot$day^{-1} measured at baseline, 3 months, and 9 months after installation of the treadmill workstations were analyzed using non-parametric Friedman's Rank Tests.

One-way repeated measures ANOVAs were used to compare mean differences among the anthropometric measures (weight, BMI, and waist and hip circumferences), body composition measures (percent body fat, total fat, fat free mass, and truncal fat mass), hemodynamic measures (resting heart rate and systolic and diastolic blood pressure), bone mineral density, serum lipid (LDL, HDL, VLDL, triglycerides, total cholesterol, and LDL-HDL ratio), metabolic (plasma glucose, insulin, and glycosylated hemoglobin), dietary, and mental stress variables obtained at baseline, 3 months, and 9 months of the study.

The longitudinal and short term effects of using a treadmill workstation on MSD were determined using 3 x 4 repeated measures ANOVAs on scores of total MSD and that for each of body region (upper body, back, and lower body). The independent variables for these comparisons were time of day (9:00am, 1:00pm, and 4:00pm) and the measurement periods during the course of the study (i.e., baseline, 1 week, 3 months, and 9 months).

If any of the ANOVAs detected significant differences, post-hoc pairwise comparisons with Bonferroni corrections were conducted to identify the differences. If any of the Friedman's Rank Tests detected significant differences, non-parametric Wilcoxon Signed Rank Tests were conducted to identify the differences. The level of significance was set at 0.05.

To examine the relationship between the changes in physical activity (if any) between baseline and 9 months on the changes in the outcome variables, Spearman's Rank Correlation coefficients were computed between these variables. The change in $steps \cdot day^{-1}$ was used as the independent variable and the changes in the outcome variables were the dependent variables.

Results

The time spent sitting or lying significantly declined from baseline to 3 (*p*=0.005) and 9 months (*p*=0.006). The time spent standing increased from baseline to 9 months (*p*=0.013). The time spent stepping increased from baseline to 3 (*p*=0.003) and 9 months (*p*=0.003). Steps per day increased from baseline to 3 (*p*=0.003) and 9 months (*p*=0.005). Energy expenditure measured as $MET \cdot min \cdot day^{-1}$ increased from baseline (median=1909 $MET \cdot min \cdot day^{-1}$) to 3 (median=2080 $MET \cdot min \cdot day^{-1}$; *p*=0.002) and 9 months (1977 $MET \cdot min \cdot day^{-1}$; *p*=0.007). Table A-3 shows changes in the physical activity measurements made by the *activ*PAL™.

Statistical analyses detected no significant differences in body weight (*p*=0.083) and BMI (*p*=0.080) of the participants at baseline, 3 months, and 9 months of the study. Although there were no significant effects of using the treadmill workstation on weight and BMI, these variables demonstrated a trend as participants lowered their body weight by an average of 2.5 kg of their weight and lowered their BMI by nearly 1.0 $kg \cdot m^{-2}$ by the end of the study. However, significant differences were observed between baseline and 9 months for waist circumference (*p*=0.001) and hip circumference (*p*=0.001). Figure A-4 **s**hows the changes in the anthropometric variables.

Statistical analyses of body composition variables revealed that although mean percent body fat decreased from 44.4 ± 5.8% at baseline to 42.4 ± 7.4% at the end of the study, this 2% decrease did not attain statistical significance (*p*=0.095). The change in body composition was primarily due to a 2.8 kg mean decrease in total fat mass (*p*=0.067) rather than a 0.4 kg mean increase in fat free mass (*p*=0.276). A non-significant decrease of 1.3 kg was also observed in truncal fat mass between baseline and 9 month measurements (*p*=0.095). The changes in body composition are shown in figure A-5.

There were no significant differences among total bone mineral density measurements made at baseline, 3 months, and 9 months of the study (p=0.80). Similarly, no significant differences were observed among resting heart rate and blood pressure (systolic and diastolic) measurements made at the 3 time points. Using a treadmill workstation significantly lowered LDL (p=0.005) and total cholesterol (p=0.016) between the 3 and 9 month measurements, but had no significant effects on HDL, VLDL, triglyceride levels, and LDL to HDL ratio. Among metabolic profile variables, glycosylated hemoglobin percent demonstrated a statistically significant decrease during the study (p=0.001). Changes in the hemodynamic, lipid, and metabolic variables can be seen in table A-4.

Walking while working did not significantly influence overall MSD during the course of the study or during a particular work day. Similarly, there were no longitudinal or short term regional effects of using the treadmill workstation on MSD scores within the upper body, back, or lower body. These results can be found in table A-5. Likewise, mental stress levels were not significantly affected by using a treadmill workstation, in our participants (p=0.903). Dietary analyses importantly revealed that our participants did not significantly change their energy, total fat, saturated fat, and cholesterol intake during the course of the study (p<0.05). The means and standard deviations of the mental stress, and dietary variables are shown in table A-4. A significant correlation was observed between the increase in steps per day and magnitude of the decrease in systolic blood pressure (ρ= 0.818, p=0.001). There were no significant correlations between the change in $steps \cdot day^{-1}$ and the changes in all other outcome variables. These correlations can be seen in table A-6.

Discussion

Levine and Miller proposed that replacing 2 to 4 hours of seated work with slow walking (approximately 1mph) and working at a treadmill workstation would result in a substantial annual weight loss in overweight and obese office workers (32). The current study, which examined the longitudinal effects of slow walking while working at a treadmill workstation in overweight and obese office workers demonstrated that replacing sedentary sitting time with standing or walking resulted in declines in waist and hip circumferences, while simultaneously improving the lipid and metabolic profiles. However, only marginal reductions in body weight were observed (p=0.083).

Changes in Physical Activity

The *activ*PAL™ identified significant and desirable changes in postural allocation among our participants after the treadmill workstations were installed. At baseline, the time spent sitting/lying in our participants was similar to that reported by Levine et al. and Johanssen et al. (28, 31). As compared to baseline, the median time spent being sedentary (sitting/lying) after 9 months decreased and a corresponding increase in the median values of standing and stepping time were observed. In fact, one participant increased his steps$\cdot$day^{-1} from 3712 steps$\cdot$day^{-1} at baseline to 38,446 steps$\cdot$day^{-1} by the end of the study.

The lower median values after 9 months could have resulted from two factors. Three participants had personal problems, which included the loss of a family member in one participant and medical conditions (unrelated to the use of the treadmill workstation) in the other 2 participants. The second factor was that after approximately 5 to 6 months of using the treadmill workstation, 6 participants complained about a mechanical problem with the treadmill

that prevented continuous walking for prolonged durations. This resulted from the fact that the treadmill was not specifically designed for slow walking over prolonged durations. This problem was overcome by either increasing walking speed above 2 mph, or by using the treadmill for shorter intervals of 20 to 25 minutes when walking speed was lower than 2 mph.

Anthropometry, Body Composition, and Bone Mineral Density

While approaching statistical significance, the average weight loss among the participants in this study was 2.5 kg. More importantly, the mean percent body fat decreased by approximately 2%, due to fat mass decreasing by an average of 2.8 kg. It has been shown that weight loss in excess of 5% of initial body weight substantially improves risk factors for diabetes and heart disease (49). Weight loss among our participants ranged between 0.5 to 10.5 kg. Among the 12 participants in our study, 3 lost in excess of 5% of their initial body weight. Additionally, 6 participants lost 5% or more of their fat mass (range= 3 to 11.7 kg) after using the treadmill workstation.

In a review that examined the role of physical activity as a weight loss strategy, Wing et al. reported that structured exercise alone produces a modest weight loss of approximately 2.4 kg (65). A study by Schnieder et al. prescribed a 10,000 $steps \cdot day^{-1}$ goal in overweight men and women. They reported a mean weight loss of 2.7 kg and a loss of approximately 2% body fat over a period of 9 months (58). McTiernan et al. determined the effects of engaging in 60 minutes of moderate to vigorous intensity physical activity per day on 6 days of the week for one year. These researchers reported an average weight loss of 1.6 kg, a 2.2% reduction in body fat, and an average decrease of 2.5 kg of total fat mass in their participants. Although participants in the current study walked at an approximate speed of 1.5 mph, which is much slower than in the

other studies, the weight loss was still comparable to that reported by Schnieder et al. and McTiernan et al. (39, 58).

The changes in waist and hip circumferences in the current study were greater than those reported previously where a similar amount of weight loss was observed (39, 58). On average, the participants in our study lost 5.5 and 4.5 cm at the waist and hip, respectively. However, in a study by Ross et al. where exercise-induced mean weight loss was 7.5 kg, the mean decreases in waist and hip circumferences were 6.5 cm at both sites (56). Similarly, Mayo et al. reported a mean weight loss of 12.0 kg in obese participants after exercise training, also saw higher than usual decreases in waist (by 14.2 cm) and hip (8.6 cm) circumferences (36). In addition, Ross et al. found a significant decrease of 1.1 kg fat in abdominal visceral fat among their participants (56). Although we did not have a direct measure of abdominal visceral fat, truncal fat measured by the DXA is a fair indicator of abdominal visceral fat (43). In the current study, participants reduced truncal fat by approximately 1.3 kg between baseline and the end of the study. Both Mayo et al. and Ross et al. attributed the large decreases in waist circumferences to the stimulation of lipolysis and oxidation of abdominal fat in response to physical activity in obese individuals (36, 56). We believe it is likely that the increased energy demand of using a treadmill workstation is met primarily by the use of abdominal fat as fuel, which results in a decrease in truncal and visceral fat. Additionally, the results of our study suggest that using the treadmill workstation lowers subcutaneous hip fat, thereby decreasing hip circumference. These changes in the anthropometric and body composition variables are probably due to the increase in light intensity activity since there were no changes in the self-reported caloric intake.

Using the treadmill workstation did not have any significant effects on total bone mineral density. A cross-sectional study by Uusi-Rasi et al. found no significant differences in bone mineral density between active newspaper and mail carriers who walked approximately 6 $km\cdot day^{-1}$ more than sedentary office workers (61). These researchers measured bone density of the spine and the leg bones (61). To allow a closer comparison between our study and that by Usi-Rasi et al., we performed statistical analyses on bone density of the spine and the legs in our participants. Similar to findings by Uusi-Rasi et al., we found no significant differences among bone mineral density measurements of the spine (p=0.523) and legs (p=0.928) at baseline, 3, and 9 months of the study. However, brisk walking has been associated with slowing the rate of bone loss in the spine and legs and the elevation of biochemical markers of bone mineralization (8). However, we did not make measurements of any biochemical markers of bone mineralization.

Hemodynamics

Engaging in light intensity activity through the treadmill workstation did not significantly lower resting heart rate and blood pressure. However, decreasing trends were observed in heart rate and systolic blood pressure. Resting heart rate in our participants was lowered by approximately 7.5 $beats\cdot min^{-1}$. Belardinelli et al. showed that light intensity exercise training (40% of maximal aerobic capacity) for 8 weeks in individuals with a low exercise capacity, is sufficient to lower resting heart rate by approximately 14 $beats\cdot min^{-1}$ (5). As compared to the present study, the greater drop in resting heart rate observed by Bellardinelli et al. may be attributable to a higher intensity of exercise performed by their participants.

A non-significant decrease in systolic blood pressure (approximately 6.6 mmHg), which was quite comparable to that seen in other studies was also observed (47). Eight of the 12

participants in this study were pre-hypertensive or hypertensive at baseline (12). At the end of the study, 4 out of these 8 participants were able to normalize their blood pressure status. A significant correlation between the changes (baseline *vs.* 9 months) in steps per day and systolic blood pressure values suggested that increasing the volume of physical activity caused an increase in the magnitude of the decrease in systolic blood pressure. The ACSM's position stand on exercise and hypertension states that irrespective of the status of baseline blood pressure (normal, pre-hypertensive, or hypertensive), systolic blood pressure decreases by an average of 4.7 mmHg in response to training at exercise intensities above 30% of maximal aerobic capacity (47). Additionally, in the case of hypertensive individuals, the decrease in blood pressure is independent of exercise intensity (47).

Lipid and Metabolic Profile

According to the standards of the National Cholesterol Education Program (NCEP), all our participants had high baseline LDL, total cholesterol, and triglyceride levels (3). The highest recorded mean value for LDL was at the 3 month measurement (131 $\pm$ 36 $mg \cdot dL^{-1}$). These measurements were made in the month of December and it is possible that the holiday season may have contributed to increasing LDL levels in our participants. However, dietary intake data showed no significant differences among the factors associated with increased LDL levels, i.e., dietary cholesterol, total fat, and saturated fat intake. Nevertheless, the elevated LDL level observed at the 3-month measurement was lowered by around 16 $mg \cdot dL^{-1}$ by the end of the study. Additionally, HDL levels increased marginally during the course of the study. The mean total cholesterol level at baseline, classified as 'borderline high' according to the NCEP, was lowered into the 'desirable' classification by the end of the study (3). Our findings are consistent

with previous evidence where long term, low-moderate intensity physical activity has favorably altered LDL, triglycerides, and HDL levels in the elderly and overweight/obese adults (41, 62).

According to the American Diabetic Association's criteria, none of the participants in our study were diabetic and 3 were pre-diabetic (2). By the end of the study, these 3 participants improved their classification status to normal. Although light intensity activity has been associated with improving plasma glucose status, we did not observe any significant trends among our participants (21). However, there was a significant decline in glycosylated hemoglobin from baseline to the end of the study, which suggested some degree of improvement in glycemic control. Glycosylated hemoglobin reflects the average plasma glucose levels over the past 3 months and has been suggested to be a better indicator of long term glycemic control than fasting plasma glucose (19, 54, 55, 57).

Musculoskeletal Discomfort and Mental Stress

There is evidence that continuous seated work results in musculoskeletal discomfort (4). Individuals who sit for more than 95% of time at work experience greater musculoskeletal discomfort than those who vary their posture (52). Thompson et al. reported that using the treadmill workstation helps reduce back problems associated with continuous sitting (60). Alternating between working in the seated and standing positions also reduces foot swelling, spinal shrinkage, and increases overall comfort of the upper body (23, 45, 46). Edelson et al. (1989) reported non-significant decreases in MSD after their participants used a treadmill workstation (16). Similarly, we did not observe any statistically significant reductions in musculoskeletal discomfort in our participants. However, a visual inspection of table 3 seems to

indicate that over the course of the study, total and regional MSD in the upper body and back decreased.

Physical activity has been positively associated with decreasing mental stress (6, 18). However, the stress levels of the participants in our study did not seem to be affected by the use of a treadmill workstation. Contrary to our findings, Edelson et al. reported a significant decrease in stress and an increase in arousal levels ($p<0.05$) (16). This discrepancy in findings between the 2 studies may be attributable to the differences in the measurement instruments and to the fact that unlike in our study where stress measurements were made while participants were at work, Edelson et al. conducted their study in a laboratory setting.

Practical Implications

The National Health and Nutrition Examination Survey data suggests that on average, Americans spend 55% of their waking time being sedentary (35). Additionally, Levine et al. reported that sedentary time is higher on workdays (37). Obese individuals spend up to 63% of their daily time being sedentary (7, 28, 31). There is growing evidence that sedentary time is an independent risk factor for obesity and chronic diseases (20). Epidemiological evidence has shown that women who sit for more than 4.5 $hrs \cdot day^{-1}$ are at a greater risk of gaining more than 5 kg of weight, as compared to those who sit for less than 3 $hrs \cdot day^{-1}$ (9). Additionally, sitting time is associated with an increased risk of all-cause and cardiovascular mortality (29). Data from the Australian Diabetes Study have also shown that long uninterrupted bouts of sedentary time have a detrimental effect on lipid and metabolic profile (22). Additionally, it has been seen that engaging in light intensity activity favorably alters the metabolic profile (21).

On the whole, our study demonstrated that, sedentary office workers can increase occupational physical activity and significantly reduce sedentary time by using a treadmill workstation. The treadmill workstation provides the option of being more active at work, rather than solely relying on leisure time physical activity. Unlike worksite wellness programs that focus on engaging in moderate to vigorous activity, the treadmill workstation promotes an increase in light intensity activity during regular office hours. Thus, users of the treadmill workstation may find it a more acceptable way to expend energy. It is also possible that light intensity activity at the treadmill workstation may enhance long-term adherence. For example, at the end of the study, 11 out of 12 participants opted to keep the treadmill workstations in their offices.

American adults gain approximately 0.6 to 1 kg a year (24, 27, 33). Hill et al. suggested that increasing energy expenditure by an average of approximately 100 $kcal \cdot day^{-1}$ could prevent weight gain in almost all Americans (24). The participants in our study were able to replace sedentary time with upright time, which not only helped them prevent weight gain, but also resulted in an average weight loss of 2.5 kg. Levine et al. recommend using a treadmill workstation to replace 2 to 4 hours a day of sedentary time with slow walking (1mph). We found some positive results in this study even though our participants did not meet the recommendation by Levine et al. on using the treadmill workstation. Based on the findings that median standing time increased from 146 to 203 $min \cdot day^{-1}$ and the median stepping time increased from 52 to 90 $min \cdot day^{-1}$, we wanted to know how much caloric expenditure would result if we assumed that the treadmill workstation caused people to perform light activity for an additional 95 min/day. Based on theoretical equations (Appendix F), we computed that this additional light intensity activity

would have increased the energy expenditure in our participants by approximately 159 $kcal \cdot day^{-1}$. Thus, it can be speculated that using a treadmill workstation for approximately 3 hours per day would result in an additional energy expenditure of approximately 301 $kcal \cdot day^{-1}$. If the participants in our study expended an additional 301 $kcal \cdot day^{-1}$ on a daily basis, it could have resulted in a significant weight loss over the course of the study.

Strengths and Limitations

The current study had several strengths and limitations. To our knowledge, this is the first longitudinal study to examine the effects of using a treadmill workstation on anthropometric, body composition, lipid, metabolic, MSD, and mental stress variables in overweight and obese office workers. In this preliminary study, we used an objective activity monitor that enabled us to quantify the increase in standing and stepping time attributable to using a treadmill workstation. Multiple 24-hour recalls, the current gold standard for dietary assessment, were used to determine if diet influenced changes in the anthropometric, body composition, and blood lipid variables. Because there were no significant differences in the dietary variables throughout the study, it is likely that the observed changes in physiological variables resulted from using the treadmill workstations.

With regard to limitations, this study had a fairly small sample size. Because this was a pilot study, we had funding to purchase and install only 12 treadmill workstations. The small sample size may have limited our ability to detect significant changes in some of the variables over the course of the study. However, despite having a small sample size, we were able to detect significant effects of using the treadmill workstation on waist and hip circumferences, LDL, total cholesterol, and glycosylated hemoglobin levels. Additionally, decreasing trends were also seen

in weight and body composition measures. We did not perform any gender comparisons because this was only a pilot study of the effects of using a treadmill workstation and we were not on powered to be able to detect a gender difference. We also encountered a mechanical problem with the treadmills of 6 participants, which could have affected the time spent walking at the treadmill workstation. Additionally, we also did not design the study to be a randomized controlled trial. This was because our study was a preliminary study and we were primarily interested in observing the longitudinal effects of using a treadmill workstation in over weight and obese workers with a pre-post design where the participants served as their own controls.

Conclusion

Our study demonstrated that using a treadmill workstation increased the amount of time spent standing and walking over a 9 month period in overweight and obese office workers. This additional physical activity has the potential to increase energy expenditure by approximately 159 $kcal \cdot day^{-1}$, which could be sufficient to prevent weight gain or even result in weight loss in overweight and obese office workers. Treadmill workstations provide users with an option other than leisure time physical activity for expending calories and may also result in long term maintenance for increased occupational physical activity as compared to moderate- vigorous activity. However, the question of adherence was not specifically examined in the current study. Future studies need to determine whether providing a recommendation on daily use of the treadmill workstation leads to improved results. Such studies should also use treadmills that are specially designed for prolonged slow walking and have the capability to record the volume of daily use. Additionally, researchers should determine whether using the treadmill workstation

influences other physical activity domains such as leisure time, transportation, or household activity.

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APPENDICES

Appendix A

Tables and Figures

Table A-1. Characteristics of participants (*N*= 20). Data expressed as mean (SD).

Age (yrs)	26.4 (4.04)
Height (m)	1.69 (0.10)
Weight (kg)	67.05 (15.76)
BMI ($kg \cdot m^{-2}$)	22.98 (3.44)

Table A-2. Characteristics of participants at baseline (*N*=12). Data expressed as mean (SD).

	Male	**Female**
Age (yrs)	47.2 (11.8)	45.6 (7.8)
Height (m)	1.75 (0.05)	1.67 (0.03)
Weight (kg)	103.5 (21.2)	94.4 (15.2)
BMI ($kg \cdot m^{-2}$)	33.7 (5.8)	34.0 (4.9)

Table A-3. Time spent sitting/lying, standing, and stepping and steps per day as measured by the *activ*PAL™ at baseline, 3 months, and 9 months of the study (N=12). Values presented as median (interquartile range). 'p-values' indicate significant results from the Friedman's Rank Tests and 'Trend contrast' represents the z-score (p value) from the Wilcoxon Signed Rank Tests comparing baseline to the 3 and 9 month measures.* Significantly different from baseline (p<0.05).

	Baseline	3 month	9 month	*p*-value	Trend Contrast	
					3 month	9 month
Sit/Lie (min/day^{-1})	1238 (128)	1056 (233)*	1150 (87)*	0.005	-2.824 (0.005)	-2.746 (0.006)
Stand (min/day^{-1})	146 (110)	227 (109)	203 (67)*	0.013	-2.353 (0.019)	-2.473 (0.013)
Step (min/day^{-1})	52 (28)	127 (105)*	90 (39)*	0.001	-2.981 (0.003)	-2.982 (0.003)
Steps per day	4352 (2158)	10463 (6971)*	7080 (3169)*	0.004	-2.981 (0.003)	-2.824 (0.005)

Table A-4. Hemodynamic, lipid, metabolic, dietary intake, and mental stress variables measured during the study (*N*=12). Values presented as mean (SD). * indicates significant differences from the baseline measure and † indicates a significant difference from each other (p<0.05).

	Baseline	3 month	9 month
Resting heart rate (beats·min^{-1})	78.0 (11.0)	73.0 (11.0)	72.0 (9.0)
Resting systolic blood pressure (mmHg)	125.0 (11.0)	119.0 (9.0)	118.0 (9.0)
Resting diastolic blood pressure (mmHg)	77.0 (8.0)	77.0 (8.0)	79.0 (9.0)
LDL (mg·dL^{-1} blood)	123.0 (26.0)	131.0 (36.0)†	115.0 (36.0)†
HDL (mg·dL^{-1} blood)	47.0 (11.0)	47.0 (10.0)	50.0 (8.0)
VLDL (mg·dL^{-1} blood)	35.0 (14.0)	32.0 (11.0)	31.0 (11.0)
Total cholesterol (mg·dL^{-1} blood)	206.0 (31.0)	210.0 (35.0)†	195.0 (36.0)†
Triglycerides (mg·dL^{-1} blood)	177.0 (68.0)	159.0 (54.0)	152.0 (54.0)
Insulin (µIU·ml^{-1})	13.0 (5.0)	13.0 (6.0)	12.0 (9.0)
Plasma glucose (mg·dL^{-1} blood)	95.0 (6.0)	96.0 (9.0)	94.0 (6.0)
Glycosylated hemoglobin (%)	5.7 (0.2)	6.1 (0.4)†	5.3 (0.5)*†
Total caloric intake (kcal·day^{-1})	1889.0 (437.0)	1856.0 (761.0)	1889.0 (515.0)
Total cholesterol intake (mg·day^{-1})	87.0 (99.0)	100.0 (96.0)	192.0 (141.0)
Total fat intake (g·day^{-1})	66.0 (18.0)	67.0 (32.0)	70.0 (29.0)
Total saturated fat intake (g·day^{-1})	20.0 (7.0)	20.0 (8.0)	23.0 (12.0)
Mental stress	19.0 (7.0)	19.0 (8.0)	19.0 (8.0)

Table A-5. Total and regional MSD measured during the study (*N*=12). Values are mean (SD).

Time of day	Measurement	Total	Upper body	Back	Lower body
9:00 AM	Baseline	17 (19)	9 (15)	3 (4)	6 (6)
	1 Week	22 (23)	11 (16)	4 (4)	8 (8)
	3 months	18 (20)	9 (13)	3 (4)	7 (9)
	9 months	16 (13)	6 (9)	3 (2)	7 (7)
1:00 PM	Baseline	20 (18)	9 (10)	4 (4)	7 (8)
	1 Week	24 (20)	12 (14)	3 (3)	9 (8)
	3 months	18 (17)	8 (9)	3 (3)	7 (8)
	9 months	17 (14)	6 (7)	3 (2)	8 (8)
4:00 PM	Baseline	26 (20)	13 (14)	5 (4)	8 (7)
	1 Week	25 (19)	11 (12)	3 (4)	11 (9)
	3 months	18 (17)	8 (8)	2 (3)	8 (8)
	9 months	19 (14)	6 (8)	4 (3)	9 (8)

Table A-6. Spearman's Rank Correlation coefficients between the change in steps·day^{-1} and the changes in outcome variables. * indicates a significant correlation (p<0.05).

Outcome Variable	Spearman's ?	*p* value
Weight	0.133	0.681
Percent BF	0.119	0.712
Total fat mass	0.119	0.713
Truncal fat	0.182	0.572
LDL	0.460	0.132
HDL	0.270	0.397
Total cholesterol	0.434	0.159
Triglycerides	0.042	0.897
Plasma glucose	0.035	0.914
Insulin	0.259	0.417
Glycosylated hemoglobin	0.025	0.939
Resting heart rate	0.325	0.302
Resting systolic BP	0.818*	0.001
Resting diastolic BP	0.354	0.259

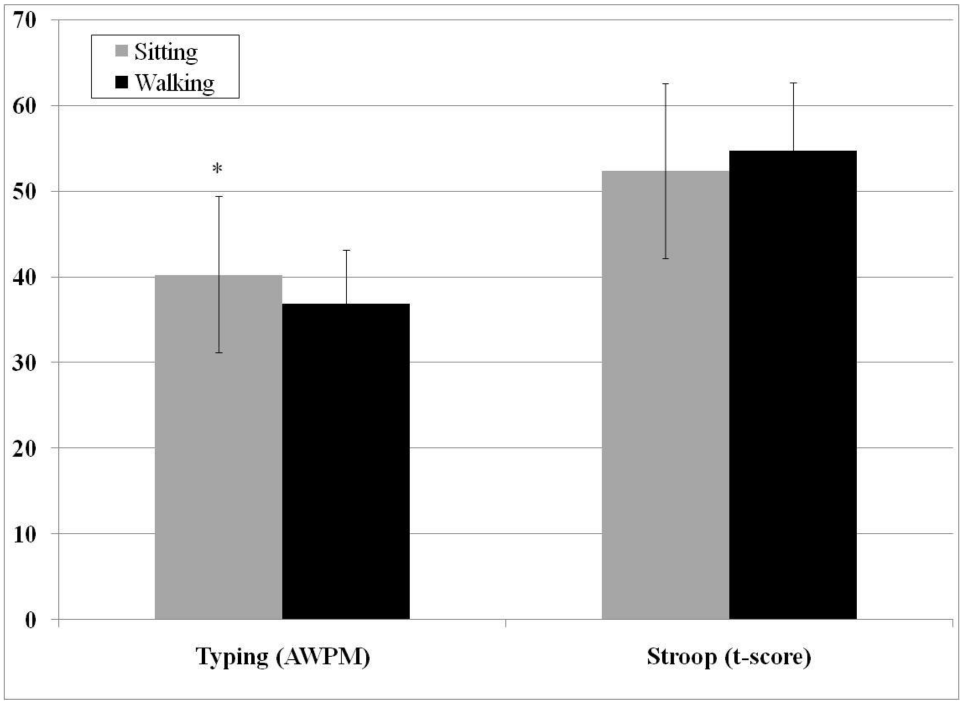


Figure A-1. Mean and standard deviations of scores on the typing and Stroop tests during the walking and sitting conditions (N= 20). * Significant difference between conditions (p<0.05).

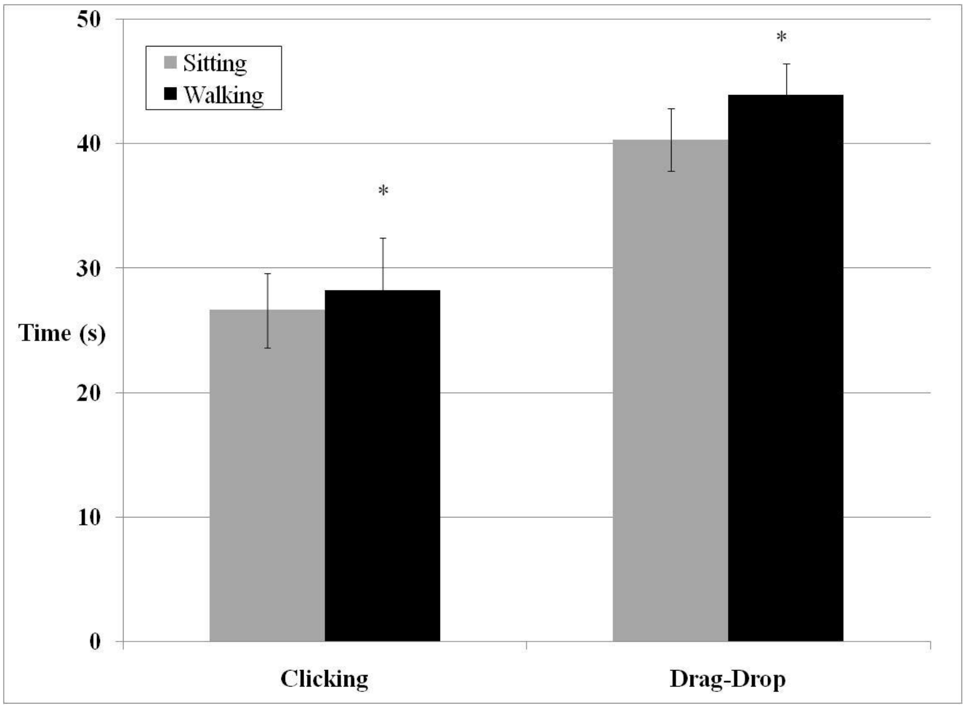


Figure A-2. Mean and standard deviations of time taken to complete mouse clicking and drag-and-drop tests during the walking and sitting conditions (*N*= 20). * Significant difference between conditions ($p<0.05$).

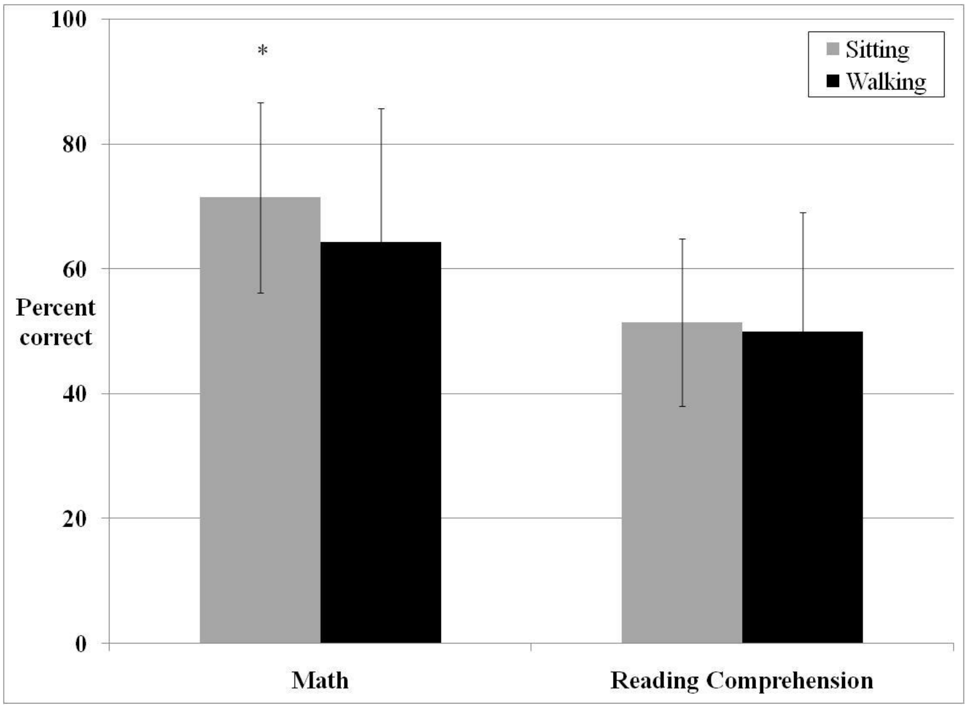


Figure A-3. Mean and standard deviations of scores on the GRE math and reading comprehension tests during the walking and sitting conditions (*N*= 20). * Significant difference between conditions ($p<0.05$).

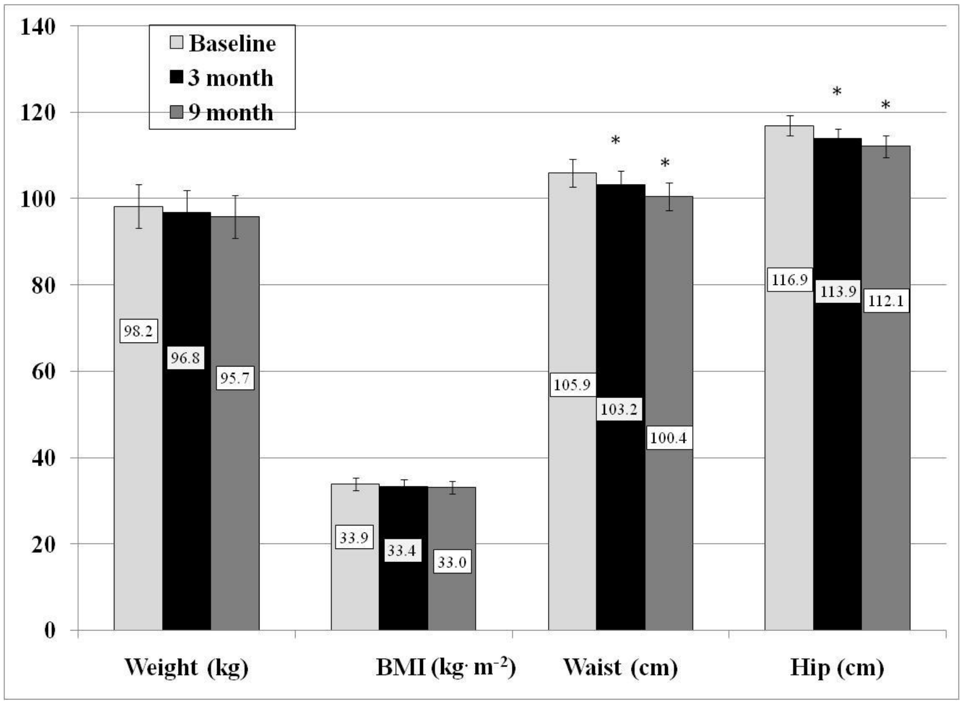


Figure A-4. Mean and standard errors of weight, BMI, and waist and hip circumferences measured during the study (*N*=12). * indicates significant difference from baseline (p<0.05).

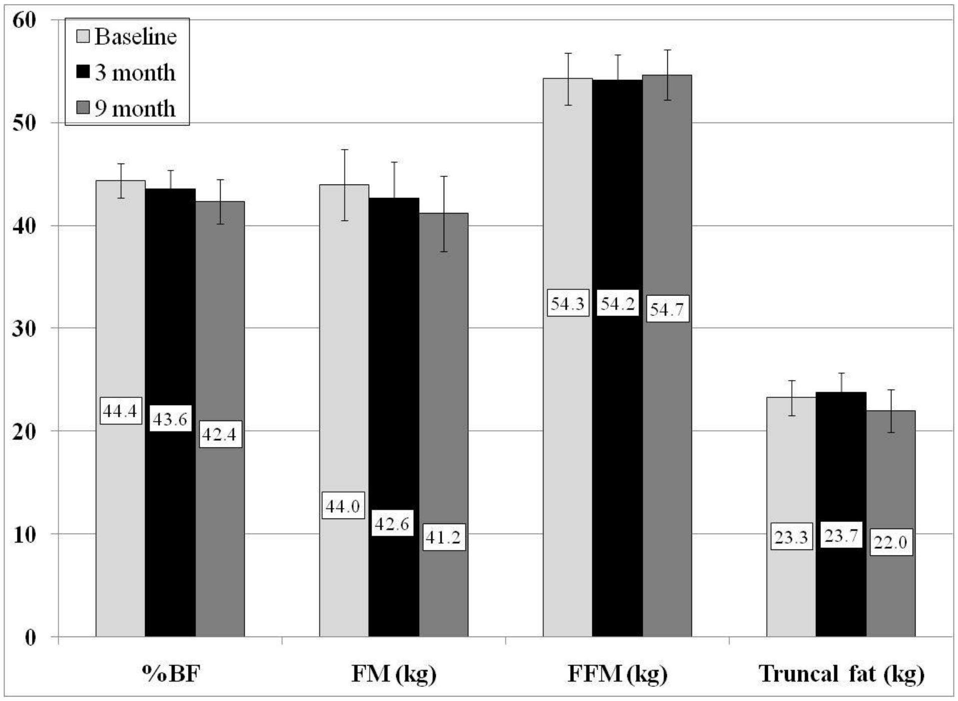


Figure A-5. Mean and standard errors of body composition variables measured during the study (*N*=12). (%BF= percent body fat; FM= total fat mass; FFM= total fat free mass).

Appendix B

PART II-Informed Consent Form

Informed Consent Form

Effect of a Treadmill Workstation on Processing Speed and Selective Attention, Fine Motor Skills, and Mathematical and Verbal Reasoning

Investigators: Dinesh John
David R. Bassett, Jr.
Address: The University of Tennessee
Department of Exercise, Sport, and Leisure Studies
1914 Andy Holt Ave.
Knoxville, TN- 37996
Telephone: 865-974-5091 (Dinesh)
865-974-8981 (Dr. Bassett)

Purpose
You are invited to participate in a research study that examines if working at the treadmill workstation affects: 1) selective attention and processing speed, 2) fine motor skills, and 3) mathematical and verbal reasoning. If you give your consent, you will be asked to undergo the testing procedures listed below.

Procedures
You will have to make 2 visits to room 310 in the Applied Physiology Laboratory (Department of Exercise, Sport, and Leisure Studies) located in the HPER Building. All data collection procedures will be completed in the laboratory at a treadmill workstation and each visit will take approximately 65-75 minutes of your time. You will be tested for 2 conditions at the treadmill workstation, i.e., a sitting sedentary condition and a treadmill walking condition. You will be tested for a randomly selected condition during your first visit and the remaining testing condition will be completed during the second visit. The treadmill workstation consists of a sit-stand height adjustable table, a treadmill, a chair, and a computer. The treadmill will be slid under the left side of the table to enable working on the computer/table and walking at the same time. The chair will be placed towards the right side of the table to enable seated work. A desktop computer will be placed on the height adjustable tabletop.

Prior to testing, you will have to complete a health history questionnaire and all testing procedures will be explained to you. You will be given an opportunity to ask questions if any. For the sitting condition you will complete the required testing procedures while seated in a chair, and for the treadmill walking condition you will complete the same testing procedures while walking on the treadmill at 1.0 mph. The height of the table will be adjusted to a comfortable level indicated by you for both conditions. During both conditions you will complete the following tests:

1) *Processing speed and selective attention tests*
A computerized version of the 'STROOP Color and Word Test' will be used to measure your processing speed and selective attention. During this test, the name of a

color will appear on the screen in a color not similar to what is spelled on the screen. You have to respond with the color of the text and not what the word spells on the screen. The time taken to complete the STROOP test will be recorded. This test will take approximately 5-10 minutes.

2) *Fine Motor Skills tests*

To assess fine motor movement performance, you will have to complete a typing test and a computer mouse control skill test.

- The 'Mavis Beacon Teaches Typing 12' computer program will be used as the standard typing exercise. This test takes approximately 15 minutes to complete where you will be asked to replicate each word beneath the text displayed on the screen. The program will then calculate your typing speed as the total number of words typed correctly.
- To assess your computer mouse control skills, a visual basic program will be used that allows you to perform a clicking and a drag and drop task. In the clicking task, you have to click on one of 25 buttons that randomly turns red in color. In the drag and drop task, you have to drag and drop all of the 25 buttons into a larger black box, one at a time when the color of a button turns red. Time taken to complete the two tasks will be recorded; each test takes less than two minutes.

3) *Cognitive skills tests*

- Reading comprehension aptitude testing- A reading comprehension test similar to that given on the Graduate Record Examination will be administered. This test is designed to assess your ability to analyze, evaluate, and synthesize information obtained from it. You will be given 18 minutes to complete this test.
- Mathematical aptitude testing- A quantitative reasoning question set comprising of approximately 20 questions similar to the Graduate Record Examinations quantitative test will be provided to you. This test measures your ability to reason and solve problems in a quantitative setting. You will be given 20 minutes to complete this test.

Risks and Benefits

The risks associated with this study are minimal and less than those encountered during vigorous exercise due to the slow speed (1 mph). There is a risk of falling during treadmill walking due to the multi-tasking nature of the condition. Precautions will be taken to minimize risks during treadmill walking. The benefits of participation include knowledge of your mental processing speed and selective attention and awareness of fine motor movement performance.

Confidentiality

The information obtained from these tests will be treated as privileged and confidential and will not be released to any person without your consent. However, the information will be used in research reports or presentations, but your name or any other forms of identity will not be disclosed.

Contact Information
If you have any questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study), contact the investigator Dinesh John. If you have questions about your rights as a participant, contact Research Compliance Services of the Office of Research at 865-974-3466.

Right to Ask Questions and to Withdraw
You are free to decide if you want to participate in this study and withdraw from it at any time.

Before you sign this form, please ask questions about any aspects of the study that are unclear to you.
- -

Consent

By signing this paper, I am indicating that I understand and agree to take part in this research study.

________________________________ __________
Your signature Date

________________________________ __________
Researcher's signature Date

Appendix C-1

Part III-Informed Consent Form

INFORMED CONSENT FORM
Treadmill Desks: An Obesity Prevention Intervention

Researchers:
David R. Bassett, Jr.
University of Tennessee
Dept. of Ex., Sport, & Leisure
1914 Andy Holt Ave.
Knoxville, TN 37919
e-mail: dbassett@utk.edu
Phone: 865-974-8766

Dixie Thompson
University of Tennessee
Dept. of Ex., Sport, & Leisure
1914 Andy Holt Ave.
Knoxville, TN 37919
e-mail: dixielee@utk.edu
Phone: 865-974-8883

Purpose
The purpose of this study is to examine the effects of slow treadmill walking (at roughly 1.0 mph) while doing office work, over a period of nine months. If you choose to participate, you will be provided an electric height adjustable sit-to-stand desk with a treadmill on one side and a chair on the other. This will enable you to choose between sitting or walking while you work.

Procedures
The testing will take place in the Applied Physiology Laboratory at the University of Tennessee HPER building (1914 Andy Holt Ave., room 310). On the first day, you will fill out a health history questionnaire, and we will measure your height, weight, resting heart rate and blood pressure. Bone density will be measured using a machine that uses X-rays that involve low-dose radiation. *You must wear clothes without zippers or metal hooks; women must avoid wearing an under-wire bra.* Body fat percentage will be measured using a device called the Bod Pod. This is a sealed chamber with a plexiglass window, and it measures the volume of your body by detecting changes in air pressure. You will need to change into swimwear (provided) in order to ensure accuracy.
A 10-milliliter blood sample (about 2 teaspoonfuls) will be drawn for measurement of glucose, insulin, and blood lipids.

Over the next 1-2 weeks you will be asked to fill out questionnaires to measure physical activity, usual dietary habits, musculoskeletal pain, and stress. We will also ask you to wear a small device to measure how much walking you do over 2 days. (The device weighs only a few ounces and does not interfere with daily activity.) The initial testing will take no more than 3 hours; and these tests will be repeated 3 and 9 months after the start of the study.

At the end of the nine month study, we may ask if you want to volunteer for an additional follow-up study. This would involve leaving the treadmill workstations in your office, and repeating the same physiological measures and questionnaires annually. You may discontinue your participation in the study at any time, but if you do so you must return the equipment.

Risks and Benefits

There are some risks to being in this study; you could fall or strain a muscle while walking on the treadmill. However, since the treadmill is moving slowly (1 mph), that is unlikely. Another risk is that you may find your work productivity declining slightly when you are walking. However, if this should happen, you will have the option of sitting down.

When we measure your bone density, you will be exposed to low-dose radiation. The radiation exposure of one DXA scan is roughly equivalent to that of a transcontinental plane flight; since there are three scans over the course of the one year study, your radiation exposure will be equivalent to three transcontinental plane flights. The DXA machine is only operated by individuals certified to do so by the State of Tennessee. Because there is radiation exposure, you should not participate in this study if there is any chance you may be pregnant. If you become pregnant, you should stop your participation in the study and notify Dr. Bassett or Dr. Thompson immediately.
The risks to the blood sampling include infection and bruising. To minimize those risks, a medically trained individual will withdraw your blood.
There are no known risks to the Bod Pod procedure, or measurements of height, weight, heart rate and blood pressure. There are no known risks to filling out the questionnaires.
The results will help us to understand the possible benefits to low intensity exercise, performed over long durations, in achieving energy balance and weight control. You will receive a free body composition and bone density analysis and exposure to a potential solution to the problems of weight gain and obesity.

Confidentiality

The information from these tests will be treated as private and confidential, and will not be shown to anyone other than the researchers and the research assistants directly involved in the project without your consent. The numbers may be used in research reports but your name will not be used.

Right to Ask Questions and to Withdraw

You are free to decide whether or not to be in this study and may withdraw from the study at any time. Before you sign this form please ask questions about anything that is unclear to you.

Emergency Medical Treatment

The University of Tennessee does not "automatically" reimburse subjects for medical claims or other compensation. If physical injury is suffered in the course of research, or for more information, please notify the investigator in charge (David R Bassett, Ph.D. Phone: 865-974-8766).

Consent

By signing this paper, I am indicating that I understand and agree to take part in this study.

______________________________________ ___________________

Participant's signature Date

______________________________________ ___________________

Researcher’s signature Date

Appendix C-2

Part III-Informed Consent Form

CONSENT TO TAKE PART IN A RESEARCH STUDY

Treadmill Desks: An Obesity Prevention Intervention

Researchers:
David R. Bassett, Jr.
University of Tennessee
Dept. of Ex., Sport, & Leisure
1914 Andy Holt Ave.
Knoxville, TN 37919
e-mail: dbassett@utk.edu
Phone: 865-974-8766

Dixie Thompson
University of Tennessee
Dept. of Ex., Sport, & Leisure
1914 Andy Holt Ave.
Knoxville, TN 37919
e-mail: dixielee@utk.edu
Phone: 865-974-8883

Purpose

The purpose of this study is to examine the effects of slow treadmill walking (at roughly 1.0 mph) while doing office work, over a period of nine months. If you choose to take part, you will be provided an electric height adjustable sit-to-stand desk with a treadmill on one side and a chair on the other. This will enable you to choose between sitting or walking while you work.

Procedures

The testing will take place in the Applied Physiology Laboratory at the University of Tennessee HPER building (1914 Andy Holt Ave., room 310). On the first day, you will fill out a health history questionnaire, and we will measure your height, weight, resting heart rate and blood pressure. Bone density will be measured using a machine that uses X-rays that involve low-dose radiation. *You must wear clothes without zippers or metal hooks; women must avoid wearing an under-wire bra.* Body fat percentage will be measured using a device called the Bod Pod. This is a sealed chamber with a Plexiglas window, and it measures the volume of your body by detecting changes in air pressure. You will need to change into swimwear (provided) in order to ensure accuracy.

A 10-milliliter blood sample (about 2 teaspoons) will be drawn for measurement of glucose, insulin, and blood lipids.

Over the next 1-2 weeks you will be asked to fill out questionnaires to measure physical activity, usual dietary habits, musculoskeletal pain, and stress. We will also ask you to wear a small device to measure how much walking you do over 2 days. (The device weighs only a few ounces and does not interfere with daily activity.) The initial testing will take no more than 3 hours; and these tests will be repeated 3 and 9 months after the start of the study.

At the end of the nine-month study, we may ask if you want to volunteer for an additional follow-up study. This would involve leaving the treadmill workstations in your office, and repeating the same physiological measures and questionnaires annually. You may discontinue your participation in the study at any time, but if you do so you must return the equipment.

Risks and Benefits

There are some risks to being in this study; you could fall or strain a muscle while walking on the treadmill. However, since the treadmill is moving slowly (1 mph), that is unlikely. Another risk is that you may find your work productivity declining slightly when you are walking. However, if this should happen, you will have the option of sitting down.

When we measure your bone density, you will be exposed to low-dose radiation. The radiation exposure of one DXA scan is roughly equivalent to that of a transcontinental plane flight; since there are three scans over the course of the one year study, your radiation exposure will be equivalent to three transcontinental plane flights. The DXA machine is only operated by individuals certified to do so by the State of Tennessee. Because there is radiation exposure, you should not participate in this study if there is any chance you may be pregnant. If you become pregnant, you should stop your participation in the study and notify Dr. Bassett or Dr. Thompson immediately.

The risks to the blood sampling include infection and bruising. To minimize those risks, a medically trained individual will withdraw your blood.

There are no known risks to the Bod Pod procedure, or measurements of height, weight, heart rate and blood pressure. There are no known risks to filling out the questionnaires.

The results will help us to understand the possible benefits to low intensity exercise, performed over long durations, in achieving energy balance and weight control. You will receive a free body composition and bone density analysis and exposure to a potential solution to the problems of weight gain and obesity. You will not have to bear any cost related to the installation of treadmill workstations or for any of the measurements described in the study procedures.

Injury

If you feel you have been injured by your participation in this study, you should see your physician for treatment and then notify the researchers by calling (865) 974-8766. The research study is not responsible for medical bills related to the treatment of injuries.

You are not waiving any legal rights or releasing the University of Tennessee or its agents from liability for negligence. In the event of physical injury resulting from research procedures the University of Tennessee does not have funds budgeted for compensation either for lost wages or for medical treatment.

Confidentiality

All reasonable efforts will be made to keep your protected health information (PHI) private and confidential. PHI is health information that is, or has been, collected or maintained and can be linked back to you. Using or sharing ("disclosure") of such information must follow federal privacy guidelines. By signing the consent document for this study, you are giving permission ("authorization") for the uses and disclosures of your personal health information. A decision to participate in this research means that you agree to let the research team use and share your PHI as described below.

As part of the study the research team may share the results of study related lab work, bone density scans, measurements or demographics with the groups named below:

- The Federal Government Office for Human Research Protections,
- The University of Tennessee Institutional Review Board
- The University of Tennessee Graduate School of Medicine Institutional Review Board,

Federal privacy regulations may not apply to these groups; however, they have their own policies and guidelines to assure that all reasonable efforts will be made to keep your personal health information private and confidential.
The study results will be retained in your research record for at least six years after the study is completed. They will be stored in a locked file cabinet in room 317 of the UT Health, Physical Education, and Recreation Building (1914 Andy Holt Ave.) and only Dr. Bassett, Dr. Thompson, and Dinesh John will have access to these records. After 6 years, the research records will be destroyed.

Unless otherwise indicated, this permission to use or share your PHI does not have an expiration date. If you decide to withdraw your permission, we ask that you contact David R. Bassett, Jr. in writing and let him know that you are withdrawing your permission. His mailing address is Dept. of Exercise, Sport, and Leisure Studies, The University of Tennessee, Knoxville, 1914 Andy Holt Ave. Knoxville, TN 37996. At that time, we will stop further collection of any information about you. However, the health information collected prior to this withdrawal may continue to be used for the purposes of reporting and research quality.
Your treatment, payment or enrollment in any health plans or eligibility for benefits will not be affected if you decide not to participate. You will receive a copy of this form after it is signed.

Right to Ask Questions and to Withdraw
You are free to decide whether or not to be in this study and may withdraw from the study at any time. Before you sign this form please ask questions about anything that is unclear to you.

Contact Information:
If you have questions about the study you may call David Bassett at (865) 974-8766 or Dixie Thompson at (865) 974-883. If you have questions about your rights as a research subject you may call the UT IRB at 974-7697.

Consent
By signing this paper, I am indicating that I understand and agree to take part in this study.

____________________	____________________	__________
Printed name of participant	Signature of participant	Date & Time
____________________	____________________	__________
Printed name of Investigator	Signature of Investigator	Date

Appendix D

PART II and III-Health History Questionnaire

(Staff Use) ID# ___________	**HEALTH HISTORY QUESTIONNAIRE**	(Staff Use) Date

Name: ____

Address: ____

City: ____ **Zip Code:** _______________

Phone: _______________________ **Date of Birth:** ________________ **Age:** ________

Gender:____ **M** ____ **F** **UT Faculty/Staff:**___ **Y** ___ **N** **Do You Live Alone?** __**Y** __ **N**

Occupation: ______________________________________ **Full Time?** ___**Y** ___ **N**

Marital Status: (circle one) Single Married Divorced Widowed

Education: (check highest level completed)

Elementary____ High School____ College____ Graduate School____

Race: White____ American Indian____ Asian____ Hispanic____ Black/African American___ Native Hawaiian/Pacific Islander____ Other____

Personal Physician:__________________________ **Location:**______________________

Are you taking any prescription or over-the-counter medications? YES____ NO____

Name of Medication	Reason for taking	For how long?

Please turn over

Emergency Contact
Name:____
Relationship:_____________________ Phone- Work:__________________________
Home:_________________________

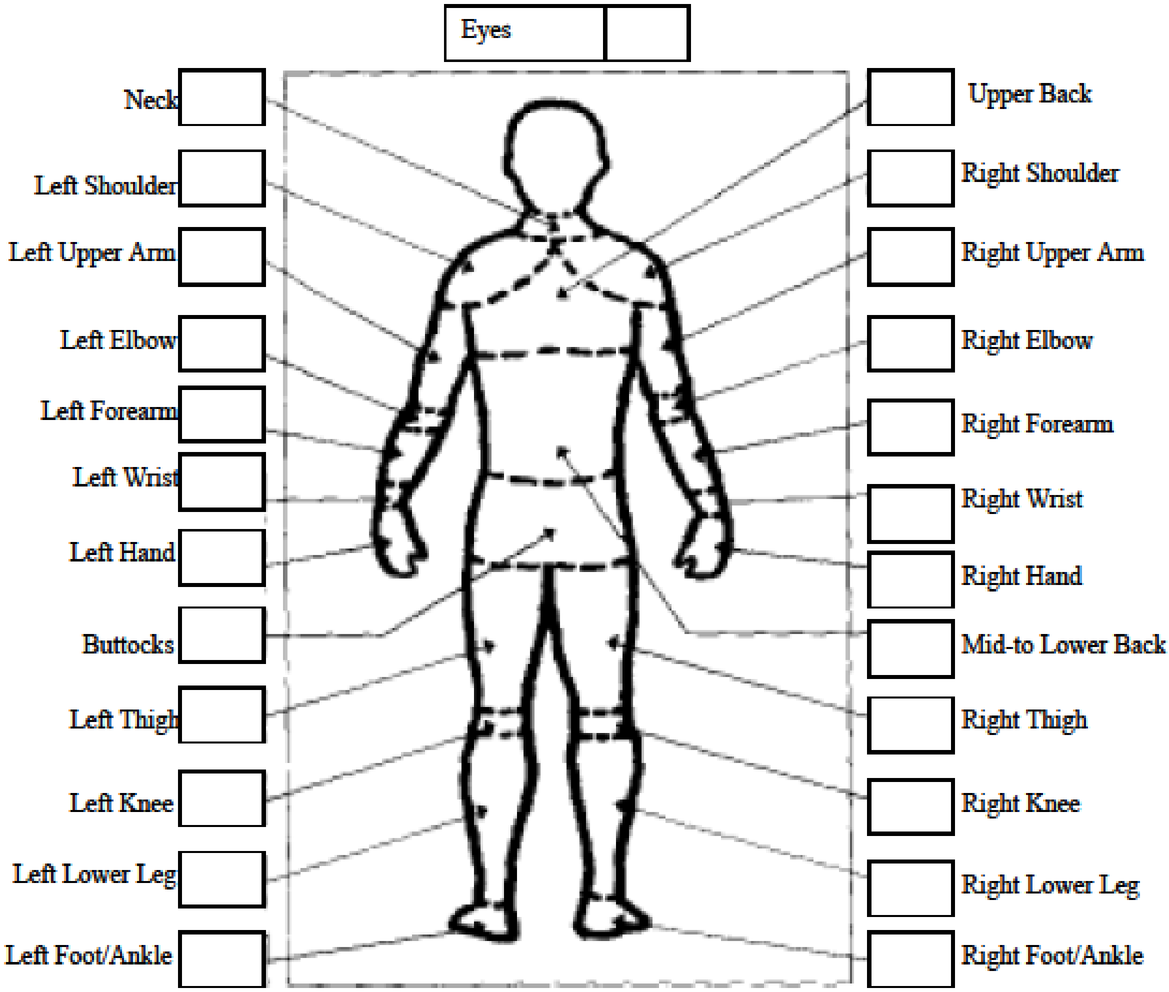
PAST HISTORY	
Have you ever had? (Please check all that apply)	
______ Heart attack	______ Stroke
______ Any heart problems	______ Blood clots
______ Arthritis	______ Cancer
______ Recurring leg pain (not related to arthritis)	______ Liver or kidney disease
______ Any breathing or lung problems	______ Low back or joint problems
______ Diabetes	

PRESENT SYMPTOMS	
Do you currently have? (please check all that apply)	
____ Chest pain/discomfort	____ Cough on exertion
____ Shortness of breath	____ Coughing of blood
____ Heart palpitations	____ Dizzy spells
____ Skipped heart beats	____ Frequent headaches
____Chronic fatigue syndrome	____ Orthopedic/joint problems
____ Diabetes	____ Back pain

Appendix E-1

Part III-Musculoskeletal Discomfort Questionnaire

Musculoskeletal Discomfort Bodymap Pictograph



DISCOMFORT LEVEL

0 No Discomfort
1
2 Fairly Comfortable
3
4
5 Moderate Discomfort
6
7
8 Very Uncomfortable
9
10 Extreme Discomfort

Appendix E-2

Part III-Perceived Stress Scale

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

Name ____ Date __________

Age ________ Gender (*Circle*): **M F** Other ______________________________

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	**0**	**1**	**2**	**3**	**4**
2. In the last month, how often have you felt that you were unable to control the important things in your life?	**0**	**1**	**2**	**3**	**4**
3. In the last month, how often have you felt nervous and "stressed"?	**0**	**1**	**2**	**3**	**4**
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	**0**	**1**	**2**	**3**	**4**
5. In the last month, how often have you felt that things were going your way?	**0**	**1**	**2**	**3**	**4**
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	**0**	**1**	**2**	**3**	**4**
7. In the last month, how often have you been able to control irritations in your life?	**0**	**1**	**2**	**3**	**4**
8. In the last month, how often have you felt that you were on top of things?	**0**	**1**	**2**	**3**	**4**
9. In the last month, how often have you been angered because of things that were outside of your control?	**0**	**1**	**2**	**3**	**4**
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	**0**	**1**	**2**	**3**	**4**

Appendix F

Part III-Energy Expenditure Calculations

A calculation of the additional energy expenditure from increasing upright time is necessary to understand the practical impact of using a treadmill workstation at work. In the current study, median standing and stepping time increased between baseline and the end of the study. Although it is not statistically appropriate to compute the increase in standing and stepping time among our participants as the differential between median baseline and 9 month values, to calculate the additional energy expenditure accrued from increasing upright time, we assume that the differences between the median values is equivalent to the increase in standing and stepping time, i.e., participants increased their standing and stepping time by 57 $min \cdot day^{-1}$ and 38 $min \cdot day^{-1}$, respectively.

Calculations:

- Energy expenditure of seated work from Levine et al.= 0.83 $kcal \cdot kg^{-1} \cdot hr^{-1}$ (32)
- Energy expenditure of standing motionless from Levine et al.= 0.95 $kcal \cdot kg^{-1} \cdot hr^{-1}$ (32).
- Net energy cost of typing using an electronic keyboard is= 0.25 $kcal \cdot kg^{-1} \cdot hr^{-1}$ (44).
- Total energy expended by our participants doing 95 min of seated computer work= 129 kcal.
- Total energy expended by our participants doing 57 min of standing computer work= 112 kcal.
- Energy cost of our participants while walking at 1.5 mph (minimum speed of walking in our participants) and doing computer work= 2.85 $kcal \cdot kg^{-1} \cdot hr^{-1}$ (32, 44).
- Therefore, the total energy expended by our participants walking and working for 38 min was approximately= 176 kcal.
- Thus, the additional energy expenditure from using a treadmill workstation =159 $kcal \cdot day^{-1}$ (energy expenditure of walking and working for 38 min + energy expenditure of standing and working for 57 min – energy expenditure of seated work for 95 min) by using the treadmill workstation.

VITA

Dinesh John was born in Mumbai, India on March 11th 1975. He was raised in Mumbai where he underwent schooling. He completed a Bachelors of Arts Degree from S.I.E.S. College of Arts, Science, and Commerce (University of Mumbai) in May 1995. After working for eight years, he attended Ithaca College, Ithaca where he obtained a Masters degree in Exercise Science in August 2006. In the year 2007, he pursued a Doctor of Philosophy degree in Education in the Department of Exercise, Sport, and Leisure Studies at the University of Tennessee. He graduated with this degree in August 2009. He has accepted a position as a post-doctoral research fellow in the Kinesiology Department at the University of Massachusetts, Amherst.