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COGNITIVE EFFECTS OF EXERCISE IN A WORKPLACE SETTING

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ABSTRACT

Obesity has increased almost three-fold since the 1960s (Ogden et al., 2010). In 1960, 13.4% of the American public ages 20-74 were obese (Ogden et al., 2010). As of 2008, the prevalence of obesity in the United States for adults ages 20-74 has increased to 34.3% (Ogden et al., 2010). A large contributing factor to obesity is that people maintain sedentary lifestyles. People are sitting on their way to the office, all day at work, and they go home and relax by watching TV. One way to increase activity during the day is to incorporate exercise in the workplace setting.

This research investigated the cognitive effects of incorporating exercise into the workplace. For this research, a under the desk elliptical, called the DeskCycle was used (2014, Specifications). Having participants complete cognitive office tasks while using the DeskCycle tested the feasibility of incorporating exercise into the workplace. The participants completed a reading comprehension task and typing task while sitting, pedaling at a low speed (11 mph), and pedaling at a high speed (22 mph). Testing cognition under multiple conditions will determine the effect of exercise on work completed in an office setting. Reading accuracy and Adjusted Words Per Minute (AWPM) was recorded during the experiment.

ANOVA analysis was done on the results of the experiments using Minitab. The result of the one-way ANOVA analysis for the Reading Accuracy versus the Cycling Rate under the three conditions was that there was no significant relationship. The ANOVA analysis of the results of the AWPM versus Cycle Rate also reported no significance. However, when a General Linear Model was completed a significant relationship between AWPM and cycle rate was seen. This research has looked at the cognitive effects of exercise in the workplace, but more research needs to be done with additional participants in order to definitely determine the effects of cycling while completing other cognitive workplace tasks.

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First, I would like to thank my thesis advisor, Dr. Andris Freivalds. It was through his class, Introduction to Work Design, that I become interested in learning further about ergonomics and work design. I have truly enjoyed the opportunity to further this learning experience outside of the classroom. His guidance through the selection of a thesis topic was also greatly appreciated. I am grateful I was provided the opportunity to take part in such unique research project. Dr. Freivalds' constant support was an integral part of the success of my thesis. In addition, I would also like to thank Dr. Paul Griffin. He has always been a knowledgeable and helpful point of contact throughout my time in the Department of Industrial and Manufacturing Engineering.

I would also like to thank PhD candidate in Department of Industrial and Manufacturing Engineering, Jay Cho. He acted as a wonderful mentor and guide throughout the whole process of creating and carrying out the experiment. Dr. Freivalds and Jay Cho submitted and received approval for the experiment from the Institutional Review Board (IRB), therefore, making my thesis possible. Jay Cho also helped create the experimental protocol and worked to gather participants for the study.

Chapter 1

Introduction

1.1 Background Information

The lifestyle of the American office worker has changed over the last three decades. This has been largely in part to the technology that has become available to those working in an office setting. The computer, Internet, and digital technology have transformed the daily patterns of not only those people who work in an office setting, but for anyone who has access to the technology. Americans on a whole spend the majority of their day sitting. In general, the American lifestyle is skewed to more sedentary activities. The sedentary lifestyle coupled with a growing obesity problem in the United States has brought more attention to how people spend their time in the office.

Standards have been created in order to offer a gauge for people to determine if they are healthy. Specifically, there are standards to indicate when people are obese. One index that can be used to determine obesity is Body Mass Index (BMI). In order to calculate BMI, an individual must take their weight in kilograms and divide that by their height in meters squared (kg/m^2) (Ogden et al., 2010). An individual can be classified as being overweight when their BMI is between 25 and 30 kg/m^2 and an individual is considered obese when their BMI is greater than 30 kg/m^2 (Seidell et al., 1997).

People have become more aware of obesity and the effect of obesity on one's health. Despite the more knowledge regarding obesity that is available the American public, obesity is continuing to be a problem in the United States. The prevalence of obesity for U.S. adults from ages 20-74 can be seen in Table **1.1**.

Table **1.1**: Overweight, Obese, and Extreme Obesity in Adults (Ogden et al., 2010)

Sample size and weight status	NHES I 1960-1962	NHANES I 1971-1974	NHANES II 1976-1980	NHANES III 1988-1994	NHANES 1999-2000	NHANES 2001-2002	NHANES 2003-2004	NHANES 2005-2006	NHANES 2007-2008
Sample (n)	6,126	12,911	11,765	14,468	3,603	3,916	3,756	3,835	4,881
Overweight ($25 \leq$ BMI < 30)	31.5	32.3	32.1	32.7	33.6	34.4	33.4	32.2	33.6
Obese (BMI ≥ 30)	13.4	14.5	15.0	23.2	30.9	31.3	32.9	35.1	34.3
Extremely obese (BMI ≥ 40)	0.9	1.3	1.4	3.0	5.0	5.4	5.1	6.2	6.0

Obesity has increased almost three-fold since the 1960s (Ogden et al., 2010). In 1960, 13.4% of the American public ages 20-74 were obese (Ogden et al., 2010). As of 2008, the prevalence of obesity in the United States for adults ages 20-74 has increased to 34.3%. With such a noticeable increase in obesity, there comes a new worry that Americans are not following a healthy lifestyle.

A large indication of health is how active a person is on a day-to-day basis. Americans spend most of their day sitting at a desk working on a computer. Unfortunately, sitting for long periods of time can have adverse affects on someone's health (Owen et al., 2010). Metabolic diseases, like diabetes, and cardiovascular disease can be attributed to a sedentary lifestyle (Owen et al., 2010).

Due to the dangerous effects of sedentary living has on one's health; there has been an increase in research into incorporating exercise into the workplace. One way that this is being done is through walking treadmills. If an obese person would incorporate a walking treadmill into their work setting they could see significant results and improvement in their health. For example, if an obese person were to use a treadmill walking station for 2-3 hr/day, instead of sitting, that person could lose more than 20 kg in a year (Levine et al., 2007). This is the motivation for the research in this thesis.

1.2 Problem Definition

This thesis is investigating the effects of incorporating exercise into an office work setting. Research will be done using an exercise elliptical that is compatible with a desk setting. The elliptical device being used can fit under an office desk. For this research, the DeskCycle is being used (2014, Specifications). The feasibility of incorporating exercise into the workplace is being determined by researching the cognitive effects of exercising while working in an office setting. This research will use human participants to complete cognitive office tasks while using the DeskCycle. The participants will complete a reading comprehension task and typing task while sitting, pedaling at a low speed, and pedaling at a high speed. Testing cognition under multiple conditions will determine the effect of exercise on work completed in an office setting.

1.3 Organization of Thesis

This thesis is divided into five chapters. In Chapter 2 an extensive literature review will be presented. The literature review will first start by investigating the classification of obesity in adults. This is critical to further understand the motivation behind this thesis. Next, sedentary lifestyles and the health effects of living a sedentary lifestyle will be explored. The literature review then covers recent research done to investigate the potential benefits of implementing exercise into the workplace. Finally, the literature review will begin to review the cognitive effects of incorporating exercise into a workplace setting through the use of a walking treadmill.

Chapter 3 will explain the problem statement and hypothesis for the thesis. There will also be an explanation of the experimental procedure created in order to test the cognitive effects of a DeskCycle elliptical in a workplace setting. Chapter 3 discusses the experimental setup created in order to carry out the experiment. Next, the experimental protocol is explained. A step-by-step description of the experiment is explained to demonstrate the tasks and order of that the participants completed the tasks in the study.

Chapter 4 will provide the results of the experiments and the analysis of the study. This will be done through the use of Minitab analysis. Finally, Chapter 5 will summarize the main points of this thesis. Chapter 5 will also provide conclusions for this thesis from the experiments. Chapter 5 will also provide suggestions for future research.

Chapter 2

Literature Review

2.1 Obesity Classification for Adults

Today in the United States obesity is a growing epidemic that affects those in every age demographic. Obesity is the storage of excess body fat. Naturally men and women have body fat. However, there are ranges of body weight that are considered healthy, this amount is based on the weight of the individual. These scales are different for men and women. For a healthy man of a normal weight, their percentage of body fat is between 15-20% (Seidell et al., 1997). For a healthy woman of normal weight, her body fat percentage would lie between 25-30% (Seidell et al., 1997). Body weight is not just the sum of body fat. Therefore, a system is created to determine the health of men and women. A common way to determine health of men and women is through a value determined by height and weight; this is called the body mass index (BMI)(Ogden et al., 2010). To calculate Body mass index take the individuals weight in kilograms and divide that value by their height in meters (kg/m^2) (Ogden et al., 2010). Table **2.1** demonstrates the proposed cut off points for being overweight by the World Health Organization. The table demonstrates the correlation between Body Mass Index and being overweight. As illustrated in the Table **2.1** there are five ranges of body mass index. A body mass index below 18.5 kg/m^2 is classified as underweight or thin (Seidell et al., 1997). A body mass index between 18.5 kg/m^2 and 24.9 kg/m^2 is normal or healthy (Seidell et al., 1997). An individual is first considered obese when their body mass index is between 30.0 kg/m^2 and 39.9 kg/m^2 (Seidell et al., 1997).

Table **2.1**: Body Mass Index Classifications (adopted from Seidell et al., 1997)

Body mass index	WHO classification	Popular description
< 18.5 kg/m^2	Underweight	Thin
18.5–24.9 kg/m^2	—	'Healthy', 'normal' or 'acceptable' weight
25.0–29.9 kg/m^2	Grade 1 overweight	Overweight
30.0–39.9 kg/m^2	Grade 2 overweight	Obesity
≥ 40.0 kg/m^2	Grade 3 overweight	Morbid obesity

Body mass index does not guarantee an accurate gauge of the health of an individual. A women and a man could weigh the same amount, yet the man could be healthy and the women could be obese. In this case the percentage of body fat is different and much higher for the women. Therefore, body fat percentage is a more exact indicator of health for both men and women.

Body mass index can be used to determine body fat percentage in adults. The equations to find body fat percentage are as follows (Seidell et al., 1997):

Body Fat Percentage: 1.2(Body Mass Index) + .23(Age) – 10.8(Gender) – 5.4

In the equation above, 1 should be inserted for gender when it is a male and 0 should be inserted for gender when it a female (Seidell et al., 1997). Generally, body mass index is a more easily determined; therefore, this is the most common method to measure obesity cutoffs.

Another simple method that can be used to show obesity ranges is waist circumference. There is a direct correlation between waist circumference and obesity (Seidell et al., 1997). Table **2.2** shows the cutoffs measurements for men and women. The alerting zone for women is 32 inches and for men is 37 inches (Seidell et al., 1997). These measurements demonstrate the numerical value that requires a lifestyle change. At those measurements and higher could result in diseases and severe health repercussions.

Table **2.2**: Measurements for Waist Circumference (adopted from Seidell et al., 1997)

	Level 1 ('alerting zone')	Level 2 ('action level')
Men	⩾ 94 cm (∼ 37 inches)	⩾ 102 cm (∼ 40 inches)
Women	⩾ 80 cm (∼ 32 inches)	⩾ 88 cm (∼ 35 inches)

Being overweight often becomes more prevalent in people as the age. Concerns of becoming overweight are extremely likely in both men and women at least up till 50 to 60 years of age. When the genders were compared there were higher rates of obesity in women after 50 then that seen in men (Seidell et al., 1997).

All of the indicators of obesity displayed in this section are not foolproof and without problems. There is no determining factor or set of qualities that will guarantee with complete certainty that a person is obese or healthy. However, they offer insight into a person's health and can act as a warning of poor health in the future. The next section will expand on lifestyles that can lead to being overweight or obese.

2.2 Sedentary Behavior and Health Effect

It is found that there is a relationship between sedentary behaviors and premature mortality (Owen et al., 2010). Sedentary actions are generally described as anything action that involves sitting. Sedentary activities can also be classified by the intensity level, which is described by the rate of energy expenditure as defined by METs (Ainsworth, 2000). A MET is the ratio of work metabolic rate to a standard resting metabolic rate of an action (Ainsworth, 2000). Sedentary activities normally fall in between 1.0 and 1.5 METs (Owen et al., 2010).

There are many different ways that a person can contribute to living a sedentary lifestyle. Advancements in technologies in areas of communication, transportation, and in the workplace have conveniences that never before existed (Owen et al., 2010). These advancements in technologies have translated into a society that spends the majority of their day sitting. Adults in the United States start their day sedentary in the car on the way to work and then spend the majority of their day sitting at desk. On most days physical exertion is limited. Adults also take part in sedentary activities during their leisure time. For example, adults often spend their leisure time watching television or spending time on the computer or Internet. All of these sedentary activities can lead to adverse health affects. A lifestyle that is mostly sedentary can influence the occurrence of obesity and metabolic conditions, for example diabetes (Owen et al., 2010).

In an Australian study that tracked women and men's sitting time throughout their day it was uncovered that women who worked full time sat for approximately 7.5 hours a day (Brown et al., 2003). These women fell into the group who had the highest sitting time (Brown et al., 2003). The women in the study were analyzed separately from the men. It was concluded that the sitting time variable had an influence over what body mass index category that the women were in; as the mean total sitting time increased so did the BMI category (Brown et al., 2003). The sitting was the variable that had the largest impact on BMI in the study (Brown et al., 2003). The BMI category that a woman fell into was only significantly altered when a woman exercised over 150 minutes a week (Brown et al., 2003). Men who partook in the study displayed similar results to the women (Brown et al., 2003). A smaller proportion of the men who fell in the range of the highest amount of time sitting were also in the healthy weight range (Brown et al., 2003).

The correlation of a full time work schedule and sitting for women shows the pattern that those who work longer hours spend more of their time sitting throughout the day in comparison to part-time workers and stay at home parents (Brown et al., 2003). Every hour spent sitting can have an adverse affect on an individual health. The amount of sitting time can increase the risks of different diseases. Even those who exercise consistently increase their risk of having a cardiovascular disease if they are sedentary for large portions of their day (Owen et al., 2010).

The connections between mortality and sedentary lifestyles are also very apparent. It was found that for each additional hour of TV watched there was an increased risk of cardiovascular disease mortality (Owen et al., 2010). Also, those who watched more than four hours of TV per day had an 80% increased risk of cardiovascular disease mortality over an individual who watched less than 2 hours of TV per day (Owen et al., 2010). An important note is that this information excluded risk factors like smoking and blood pressure (Owen et al., 2010).

The correlation between a sedentary lifestyle and heath risks like cardiovascular disease are apparent. However, heath risks can be minimized with breaks in prolonged sedentary periods (Owen et al., 2010). In a National Institute of Health publication a group of people were tracked for movement using an accelerometer (Owen et al., 2010). A group of participants took breaks throughout their sedentary day and moved (Owen et al., 2010). A sedentary period of time was considered to be over if a person raised their accelerometer count to 100 counts per minute (Owen et al., 2010). These breaks in the sedentary time could be the result of standing or walking. A relationship was found between those who would take breaks in their sedentary day and those who continued to sit for prolonged periods of time (Owen et al., 2010). Figure **2.1** illustrates the waist circumference of those who sat for prolonged periods of time and for those who took breaks in sitting throughout the day (Owen et al., 2010). There was a 6 cm difference in waist circumference between those who took the least amount of breaks and those who took the most amounts of breaks throughout the day (Owen et al., 2010). As demonstrated in section **2.1**, the waist circumference of the individual can determine the health of a person. Breaks in sitting can reduce the waist circumference of a person, therefore, leading to a reduced risk of cardiovascular disease and premature mortality (Owen et al., 2010).

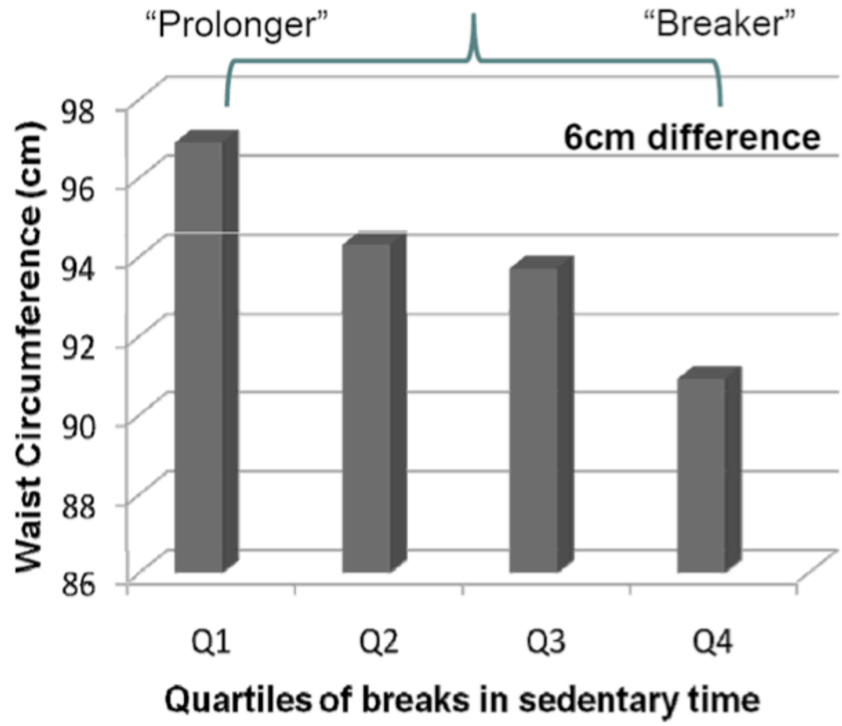

Figure **2.1**: Breaks in Sedentary Activity (adopted from Owen et al., 2010)

Breaks in sedentary behavior also had benefits outside of waist circumference. It was found that breaks in sitting had positive effects on BMI, triglycerides, and 2-h plasma glucose (Owen et al., 2010). These positives affects illustrate the correlation between sitting a decrease in metabolic health. The next section will show methods of breaking up sedentary activity.

2.3 Exercise in the Workplace

With the increased prevalence of obesity across the United States there have been programs put into place in order to reduce the risk of the obesity. There are different lifestyle choices and health factors that attribute obesity. It is difficult to determine the exact cause of obesity; however, a connection between obesity and physical activity has been identified. Those who spend a large portion of their day sedentary often have higher tendencies toward obesity.

More specifically, it was recorded that obese individuals sit on average 2.5 hours per day more then lean individuals (Levine et al., 2007).

In response, offices and workplaces are providing walking treadmills to increase the health of its workers. Exercise is being incorporated in the workplace to combat the increase of work being done at computers over the past two decades. The intention of these walking treadmills with desk capabilities is to increase the amount of physical activity a person takes part in throughout their workday.

In a study by James A. Levine and Jennifer M. Miller published in a 2007 issue of the British Journal of Sports Medicine the walking treadmill desk was tested. The walking desk, displayed in Figure **2.2**, was created to simply fit over a treadmill (Levine et al., 2007). The walking desk featured rubber wheels so the desk could be easily wheeled over the treadmill (Levine et al., 2007). The user would then be able to complete work that would be done at a desk while walking.

Figure **2.2**: Walking Desk to Fit with Treadmill (adopted from Levine et al., 2007)

In the study all of the recruits were asked to complete a series of tasks, each of the tasks would last 20 minutes and they would be slightly different to obtain and record the energy expenditure of each individual (Levine et al., 2007). First, the individual was asked to lay still with their head at a 10° tilt, while still remaining awake (Levine et al., 2007). This first task was completed in order to understand the energy expenditure that a person would have when they were perfectly at rest. The next test that was completed was to emulate the energy expenditure of a person who was working a desk job (Owen et al., 2010). The second test called for the individual to sit a supported office-chair and type a document throughout the 20 minutes (Levine et al., 2007). The third test called for the individual to stand with their legs six inches apart completely still, yet relaxed (Levine et al., 2007).

After the tests that had the individual completed at rest, the individual was asked to complete a series of walking tests. The first grouping of walking tests had the participant walk at 1, 2, and 3 mph, each for 15 minutes (Levine et al., 2007). This test was completed to show the change in energy expenditure as walking speed increased (Levine et al., 2007). The final test took place after 15 minutes of rest and incorporated the walking desk into the activity after being oriented and familiar to the workstation (Levine et al., 2007). To begin the individual was asked to starting typing about their previous day while standing still. After 5 to 10 minutes of acclimation on the workstation the individual was asked to pick a speed in which they could continue working normally (Levine et al., 2007). For this last task the individual walked for an hour while working, however, the energy expenditure was measured and recorded during the 15-35 minute of the hour (Levine et al., 2007).

Due to the tasks completed throughout the study it was hypothesized that as a task became more physically exhaustive the energy expenditure would also increase (Levine et al., 2007). The analyses of the results demonstrate a similar outcome. The walking tasks proved to expend the most amount of energy; the participant increased the velocity by each increment energy expenditure increase significantly (Levine et al., 2007). Table **2.3** shows the energy expenditure for each task completed by the participant. The energy expenditure, in terms of kcal/hour, increased to 307 kcal/hour when walking at 3 mph (Levine et al., 2007). There was even a significant amount of energy expenditure when the participant was walking and working (Levine et al., 2007). The participant expended 191 kcal/hour when walking and working (Levine et al., 2007). This was 2.65 times more energy expended then when the participant was sitting and working.

Table **2.3**: Energy Expenditure of Participants (adopted from Levine et al., 2007)

	Energy expenditure (kcal/h)	Energy expenditure/ fat-free mass (kcal/kg/h)*
Resting	65 (9)	1.60 (0.20)
Sitting	72 (10)	1.75 (0.28)
Standing	82 (12)	2.01 (0.37)
Walking: 1 mph	198 (28)	4.83 (0.68)
Walking: 2 mph	254 (44)	6.20 (1.02)
Walking: 3 mph	307 (62)	7.45 (1.18)
Walk-and-work desk	191 (29)	4.65 (0.68)

This study is an important indicator of how the health of not only obese people can be affected with the incorporation of movement into their daily lives. Walking treadmills, more specifically, can in utilized in a work environment to promote better health. For example, if a treadmill walking station was used 2-3 hr/day by an obese person instead of sitting that person could lose more than 20 kg a year (Levine et al., 2007). In the next section the cognitive effects of using a physical exertion during work will be investigated.

2.4 Cognitive Effects of Exercise in the Workplace

Due to the increase of stress and obesity in the United States there has been an increase in exercise options in the workplace. These include at work gyms, fitness classes, and facilitated exercise devices like a walking treadmill. With the increase in prevalence of walking treadmills and similar exercise devices, there has been more research done in order to see the effects of the exercise has on an individual work output in an office setting.

Initial effects of exercise from a walking treadmill on workplace activities was researched by Dinesh John, David Bassett, Dixie Thompson, Jeffrey Fairbrother, and Debora Baldwin. In the study, 11 males ages 24.6 ± 3.5 years old and 9 females ranging in ages 27.0 ± 3.9 years old, completed tasks while using a walking treadmill (John et al., 2009). All participants were not accustomed to walking on a treadmill at a pace of 1 mph while simultaneously completed office work tasks (John et al., 2009). In order to be able to fully understand the effects of exercising on the walking treadmill while completing office tasks the participants completed the tasks while sitting as well (John et al., 2009). The tasks given to the participants covered a range of different actions that are common in a workplace setting (John et al., 2009). All of the participants completed a typing task. Using the Mavis Beacon Teaches Typing 17 test, the participants were given a passage on the computer screen and had to replicate the passage; at the completion of the task, typing speed, excluding any typing errors, was recorded in adjusted words per minute (AWPM) (John et al., 2009). The task was completed using the walking treadmill and then at a comfortable seated position (John et al., 2009). Figure **2.3** shows the mean typing speed in words per minute from all of the participant trials. The mean typing speed was calculated for when the participants were using the walking treadmill and for when the participants typed the task in a seated position (John et al., 2009).

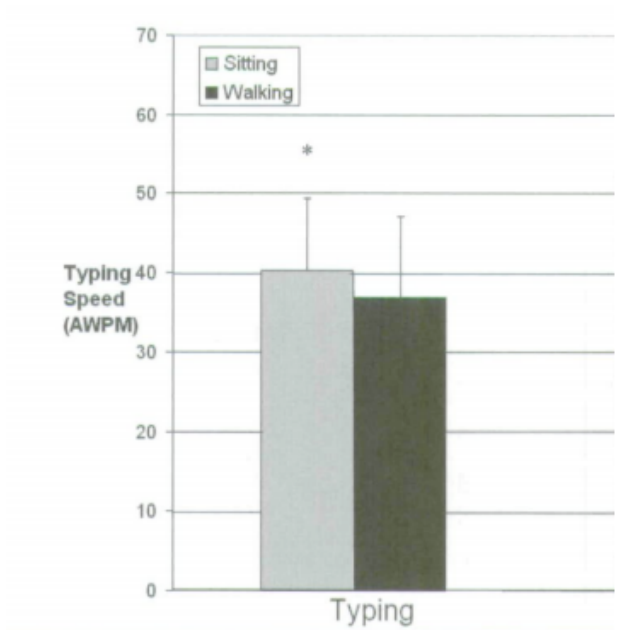

Figure **2.3**: Mean Typing Speed in Works per Minute (adopted from John et al., 2009)

The typing test indicates that the typing speed decreases slightly when the participant was asked to complete the task on the walking treadmill (John et al., 2009). In a seated position the mean typing speed was 40 AWPM. When the participant was asked to complete the typing passage on the walking treadmill the speed was recorded at 37 AWPM (John et al., 2009). Therefore, showing that the walking treadmill slightly inhibits the productivity of the participant.

The participants also completed tasks to assess computer mouse efficiency (John et al., 2009). There were two tests completed, the first was a mouse-clicking task, the second was a drag-drop task (John et al., 2009). The mouse-clicking task had the participant click on 25 icons, as they turned red, until they were all red and clicked (John et al., 2009). The drag and drop task had the participant drag an icon, as it turned red, into a black box until all 25 icons were in the black box (John et al., 2009). Figure **2.4** shows the mean results of how long, in seconds, it took for a participant to complete the clicking and drag-drop task (John et al., 2009). The mouse efficiency tasks saw similar results to the typing task.

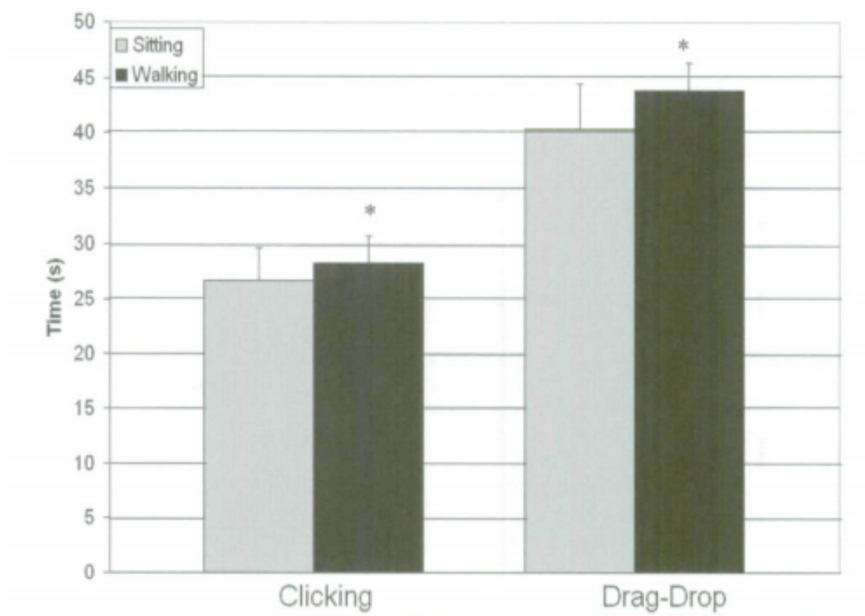

Figure **2.4**: Mean Scores for Mouse Efficiency Tasks (adopted from John et al., 2009)

For both the clicking and drag-drop task the participant took longer to complete the task when they were walking then when they were seated (John et al., 2009). The seated participant took approximately 26 seconds to complete the clicking task and 40 seconds to complete the drag drop task (John et al., 2009). When the participant was completing the clicking task on the walking treadmill it took them 27.5 seconds to complete the task and 44 seconds to complete the drag-drop task (John et al., 2009). The increase in mean time indicates that the walking treadmill has an effect on mouse-efficiency or tasks that have fine motor skills involved.

The participants also completed paper based graduate record examination (GRE) tests; one of the tests was on math and the second was on reading comprehension (John et al., 2009). These tests were given in order to focus more on the cognitive function of the participants when seated and when using the walking treadmill (John et al., 2009). The reading comprehension test had the participant read a long passage (600 words) and a short passage (200 words) and then answer 11 questions in 18 minutes (John et al., 2009). The math test had the participant complete 30 questions in 30 minutes (John et al., 2009).

Figure **2.5** shows the mean percent correct from all of the participants on the math test and the reading comprehension test (John et al., 2009).

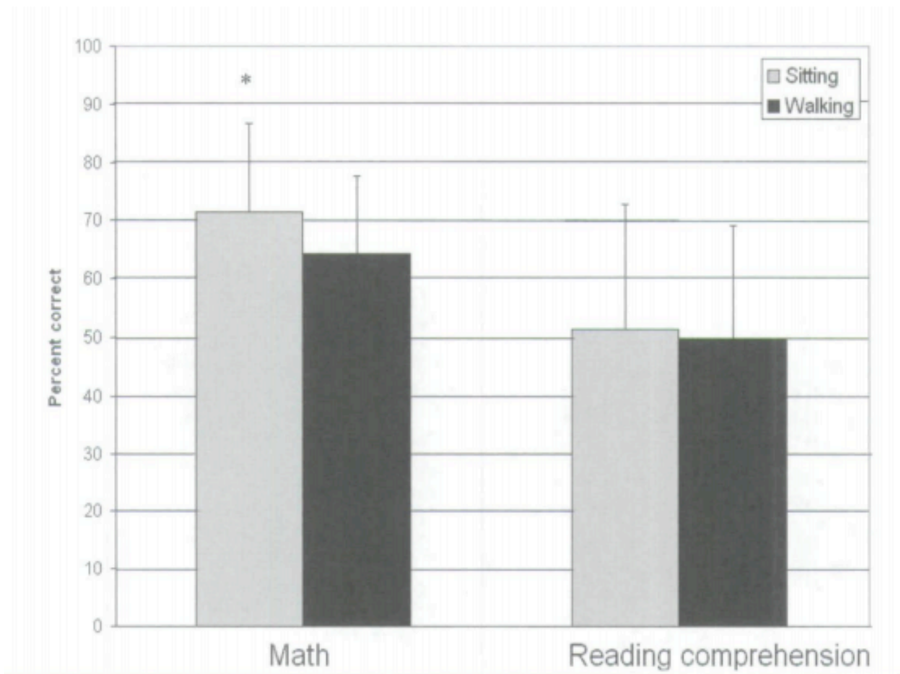

Figure **2.5**: Mean Scores for Math and Reading Comprehension Tests (adopted from John et al., 2009)

The walking treadmill did have an effect on the results on the math and reading comprehension tests. The mean math scores went from 70.5% percent correct when completed seated to 64% correct when completed on the walking treadmill (John et al., 2009). There was not as large as a discrepancy in scores for the reading comprehension test. In a seated position the mean score was 51% correct and on the walking treadmill the score was 50% correct (John et al., 2009).

These results show that the walking treadmill did in fact have an adverse affect on workplace tasks. However, with more research there are new ways developing of how to incorporate exercise into the workplace, one of them being a seated elliptical device. Therefore, more research needs to be done to investigate the cognitive effects of incorporating a seated elliptical exercise device into the workplace.

Chapter 3

Experimental Design

3.1 Problem Statement and Objectives

With development of new technologies, like the computer and the Internet, the modern person's lifestyle has become more sedentary. Sedentary activities are growing and so is the concern of obesity in the United States. Understanding the correlation between spending numerous hours a day sitting and obesity is critical to understanding the health of individuals. In order to reduce and reverse obesity and its effects on one's health, physical exertion machines are finding their way into the office. Walking treadmills are being implemented into workplaces with growing popularity. These treadmills allow any individual to complete their work, yet still receive exercise throughout the day. More recently, elliptical devices are being created. The elliptical machines are placed under desks. The goal of the device is similar to the walking treadmill, and that is to incorporate movement and exercise into an otherwise sedentary activity. It is important to understand the effects of these physical exertions devices, specifically, the elliptical device.

It is important that the elliptical device provide health benefits. However, the use of the machine should not hinder the user from completing the same quality of work than if they were not using any physical exertion machine. Therefore, cognitive changes while using the device at different exertions must be tracked.

The hypothesis that this research addresses is that moderate exercise in a seated position will cause an individual to have no change in their accuracy or time to finish workplace tasks. Also, a person's accuracy and speed will increase from a baseline test of them solely sitting when completing the task. But, as the participant approached high intensity exercise the cognitive ability of the participant will no longer increase. This hypothesis was tested through having the participants in the study complete two cognitive tasks, a typing task and a reading comprehension task. The participants completed the tasks under three conditions: seated, low physical exertion at 11 mph, and at high physical exertion at 22 mph. The results and analysis of the research will be discussed.

3.2 Experimental Protocol

The workstation setup and the experimental method will be discussed below.

3.2.1 Experimental Workstation Setup

In order to simulate a workstation that a person would encounter in an office setting many aspects were considered. The setup consisted of an adjustable desk, adjustable chair, standard desktop setting, and DeskCycle. The desk setting was created in order to offer the greatest amount of variation. Therefore, providing comfort for the participant. Figure **3.1** shows what the desk workstation setup looked like. The participant could change many different settings of the desk setup. Using two crank tables and having a solid board resting on top of each crank table the desk was created. The purpose of utilizing the two industrial crank tables was to ensure that each participant would be comfortable in the set up and to reduce the chance that an uncomfortable work setting would alter the results of the typing and reading comprehension test. Each participant was asked for their preferred desk setting before each round of testing. The change in desk height was achieved by using the crank desks until the desk reached a height that the participant found appropriate for the task.

Figure **3.1**: Workstation Desk Setup

The next alteration to the desk setting that could be made was the seat height. Figure **3.2** is the chair that was used for all experimental testing with the participants. The ergonomic Aeron chair from Smart Furniture offers the participant to have a comfortable seat with adequate support for the back and legs. The participant would also be able to adjust the seat height to even further customize the seat to match their preferred setting when working in office desk setting. Arms are displayed on the chair in Figure **3-2**. These arms were lowered to the lowest setting. The armrests were lowered in order to prevent the participant from resting their arms on them. The motivation behind removing the armrest feature from the setup was to reduce variability and promote proper posture.

Figure **3.2**: Workstation Chair Setup (adopted from 2014, Aeron Chair)

The exercise elliptical that was selected for the participants to use during the tests was the DeskCycle. The DeskCycle's is a pedal exercise device that fits under a desk workstation. The DeskCycle weighs 23 lbs making it an easy and accessible option for a person to utilize when they are work (2014, Specifications). There are 8 different resistance settings that change the difficulty of pedaling for the participant (2014, Specifications). All testing done for this experiment was completed at a resistance level of 2. The elliptical machine is 24 inches long, 20 inches wide by the front leg, 15 inches wide from the back leg, and 10 inches from the top of travel point of the pedal (2014, Specifications).

The DeskCycle was also customized for each participant. The participant had the opportunity to tighten or loosen the Velcro pedal loop so that each foot was secure on the pedal. A Velcro loop was also used to secure the chair to the DeskCycle machine. Depending on the height, weight, and anthropometric measures of the participant the distance of the chair to the DeskCycle would have to be change to optimize comfort during pedaling. The setup of the Velcro loop, chair, and DeskCycle can be seen in Figure **3.3**.

Figure **3.3**: DeskCycle Setup (adopted from 2014, How To Use The DeskCycle)

The experiment called for each participant to pedal at two different speeds. There was a low and high speed. The low speed was at 11 miles per hour and the high speed was at 22 miles per hour. A standard display accessory was used in order to allow the participant to be aware of the speed that they were pedaling. The standard display can be seen in Figure **3.4**. The screen on the standard display is 2.42 inches long and 1.5 inches along the diagonal (2014, Accessories). The standard display was placed to the right of the computer monitor. The standard display was programmed so that the speed would be displayed in miles per hour. Miles per hours were used because participants would be able to recognize that form of measurement more easily over watts. On the bottom half of the screen the time, calories, and distance would scan throughout the pedaling tasks.

Figure **3.4**: DeskCycle Standard Display (adopted from 2014, Accessories)

The workstation desktop was created in order to best match an office work setting. The desktop held a monitor, wireless mouse, and a keyboard. The monitor used was a 24-inch monitor. The monitor was connected to a computer controlled by the experiment facilitators. This was done in order to reduce the variation and remove the extra expectations and work for the participant. Each time the reading comprehension task and typing task was completed it was brought to the screen by the facilitators.

3.2.2 Experimental Method

The objective of this study was to investigate the effects of incorporating a desk elliptical exercise device in an office workstation setting. The study was completed to answer the question following question: does physical exercise affect the cognitive performance of an individual in an office workstation setting? In order to answer this research question an experiment was completed with human participants.

The experimental protocol was developed in conjunction with Jay Cho, a Penn State graduate student. Twelve participants were recruited, 7 were male and 5 were female. All of the participants were ages 19-26, with 7 out of the 12 participants being either 20 or 21 years old. These participants were selected based on NHANES records published by the National Center for Health Statistics. The experiment protocol created for Penn State graduate student, Jay Cho, required the participants to be in the 5th, 50th, or 95th percentile of their gender for height in inches. The specified heights for each height for women can be seen in Table **3.1**.

Table **3.1**: Height in Inches for Women (adopted from Fryar et al., 2012)

Table 10. Height in inches for females aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and ethnicity and age: United States, 2007–2010

Race and ethnicity and age	Number of examined persons	Mean	Standard error of the mean	Percentile 5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[1]				Inches								
20 years and over	5,971	63.8	0.05	59.3	60.3	60.9	61.9	63.8	65.7	66.6	67.3	68.4
20–29 years	980	64.2	0.09	59.9	60.6	61.3	62.2	64.1	66.0	67.0	67.6	68.9
30–39 years	1,029	64.3	0.11	59.6	60.9	61.5	62.5	64.3	66.1	67.1	67.9	68.9
40–49 years	1,060	64.2	0.09	59.8	60.8	61.4	62.4	64.0	66.0	66.9	67.6	68.7
50–59 years	873	63.9	0.12	59.6	60.4	61.0	62.0	64.0	65.6	66.6	67.0	67.9
60–69 years	952	63.6	0.10	59.3	60.2	61.0	62.0	63.8	65.3	66.2	66.8	67.6
70–79 years	679	62.6	0.13	58.4	59.3	59.8	60.7	62.8	64.3	65.4	66.1	66.9
80 years and over	398	61.4	0.14	56.9	57.9	58.8	59.8	61.5	62.9	63.8	64.3	65.5
Non-Hispanic white												
20 years and over	2,764	64.2	0.06	59.9	60.8	61.5	62.5	64.2	66.0	66.8	67.5	68.7
20–39 years	824	64.9	0.10	60.6	61.7	62.2	63.2	64.9	66.5	67.6	68.4	69.5
40–59 years	861	64.5	0.11	60.5	61.2	61.9	62.8	64.4	66.1	66.9	67.6	68.7
60 years and over	1,079	63.1	0.09	58.7	59.8	60.4	61.5	63.1	64.8	65.8	66.4	67.2
Non-Hispanic black												
20 years and over	1,154	64.2	0.10	59.9	60.9	61.4	62.3	64.1	66.0	66.8	67.5	68.3
20–39 years	397	64.4	0.13	60.3	61.2	61.8	62.6	64.4	66.2	67.1	67.6	68.4
40–59 years	384	64.4	0.15	60.2	61.1	61.6	62.5	64.2	66.2	67.0	67.6	68.1
60 years and over	373	63.2	0.11	58.9	59.9	60.4	61.4	63.2	64.9	65.8	66.3	67.4
Hispanic[2]												
20 years and over	1,763	61.9	0.07	57.6	58.6	59.1	60.1	61.8	63.6	64.5	65.2	66.3
20–39 years	673	62.3	0.09	58.1	58.9	59.6	60.5	62.2	63.9	64.9	65.6	66.7
40–59 years	580	61.9	0.13	57.8	58.6	59.3	60.1	61.7	63.6	64.4	64.9	65.8
60 years and over	510	60.5	0.12	56.6	57.5	58.1	58.8	60.4	62.1	62.9	63.6	64.8
Mexican American												
20 years and over	1,074	61.7	0.07	57.2	58.4	59.0	59.9	61.6	63.4	64.2	64.9	66.0
20–39 years	427	62.0	0.10	57.4	58.9	59.5	60.3	62.0	63.6	64.5	65.1	66.3
40–59 years	348	61.7	0.16	57.5	58.5	59.0	59.9	61.4	63.4	64.2	64.8	65.7
60 years and over	299	60.4	0.16	56.6	57.4	57.9	58.8	60.3	61.8	62.9	63.5	64.4

There were two women with heights in the 50th percentile. There were also two women with heights in the 95th percentile. The last women participant's height fell around the 5th percentile. Table **3.2** shows the heights of men at the 5th, 50th, and 95th percentile for their gender.

Table **3.2**: Height in Inches for Women (adopted from Fryar et al., 2012)

Table 12. Height in inches for males aged 20 and over and number of examined persons, mean, standard error of the mean, and selected percentiles, by race and ethnicity and age: United States, 2007–2010

Race and ethnicity and age	Number of examined persons	Mean	Standard error of the mean	Percentile 5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[1]						Inches						
20 years and over	5,647	69.3	0.08	64.3	65.4	66.2	67.3	69.3	71.2	72.3	73.0	74.1
20–29 years	895	69.4	0.13	64.4	65.5	66.5	67.4	69.4	71.5	72.6	73.1	74.1
30–39 years	948	69.5	0.14	64.4	65.4	66.3	67.5	69.5	71.6	72.6	73.3	74.2
40–49 years	934	69.6	0.17	64.9	66.0	66.6	67.6	69.6	71.5	72.6	73.5	74.4
50–59 years	938	69.5	0.13	64.5	65.8	66.3	67.7	69.7	71.3	72.3	72.8	74.4
60–69 years	932	68.8	0.10	63.9	64.8	65.7	66.9	69.0	70.7	71.9	72.6	73.6
70–79 years	646	68.2	0.13	63.6	64.6	65.2	66.3	68.2	70.0	70.9	71.9	72.7
80 years and over	354	67.2	0.15	62.5	63.7	64.4	65.3	67.3	69.2	69.9	70.4	71.5
Non-Hispanic white												
20 years and over	2,738	69.8	0.07	65.3	66.4	67.1	68.0	69.8	71.6	72.6	73.3	74.3
20–39 years	797	70.2	0.14	66.2	66.9	67.5	68.2	70.2	72.1	73.0	73.6	74.4
40–59 years	836	70.2	0.11	66.0	67.0	67.6	68.5	70.2	71.8	72.7	73.6	74.6
60 years and over	1,105	68.7	0.09	64.2	64.9	65.7	66.9	68.9	70.6	71.6	72.4	73.4
Non-Hispanic black												
20 years and over	1,091	69.5	0.10	65.1	65.9	66.5	67.6	69.4	71.2	72.2	73.0	74.0
20–39 years	356	69.7	0.15	65.5	66.2	66.9	67.9	69.4	71.4	72.3	73.3	74.0
40–59 years	373	69.6	0.21	65.0	66.1	66.6	67.7	69.6	71.4	72.3	73.2	74.3
60 years and over	362	68.6	0.17	64.2	64.9	65.7	66.7	68.9	70.3	71.5	72.1	73.1
Hispanic[2]												
20 years and over	1,541	67.1	0.13	62.6	63.5	64.1	65.1	67.0	68.9	70.1	70.9	72.4
20–39 years	573	67.4	0.19	62.6	63.6	64.4	65.2	67.3	69.4	70.6	71.6	72.8
40–59 years	577	67.1	0.14	63.0	63.7	64.1	65.1	67.0	68.8	69.8	70.5	71.5
60 years and over	391	65.9	0.18	61.7	62.8	63.2	64.2	66.0	67.4	68.3	68.8	70.0
Mexican American												
20 years and over	990	66.9	0.15	62.5	63.3	63.9	65.0	66.7	68.5	69.8	70.8	72.2
20–39 years	386	67.1	0.24	62.5	63.3	64.0	65.0	66.9	69.1	70.3	71.5	72.8
40–59 years	371	66.7	0.14	62.9	63.5	64.1	65.1	66.5	68.2	69.4	70.0	71.2
60 years and over	233	65.8	0.21	61.9	62.6	63.2	64.2	65.9	67.2	68.2	68.5	69.8

Once the participants were selected the experiment protocol began with the participants receiving an explanation of the experiment. The participants were also given an IRB consent form. The form was explained and the participants were required to sign their consent. The participants were given notice that they would be completing exercise; similar to that of walking, and that they should notify the facilitators if they have any knee or leg injuries.

After the participant signed the consent forms, anthropometric measurements were taken as apart of the experimental protocol for Jay Cho's research. The measurements taken included: weight, stature, trochanteric height, knee height, popliteal height, buttock-knee, buttock-popliteal, elbow rest height, sitting acromial, and foot length. The stature and trochanteric height was taken by having the participant standing erect without shoes. All of the other anthropometric heights were taken with the participant sitting on a wooden box, with their feet flat with no shoes on. The participant also had their arms and knees flexed at 90 degrees. Figure **3.5** demonstrates the proper body stance the participant used in order to obtain the anthropometric measurements.

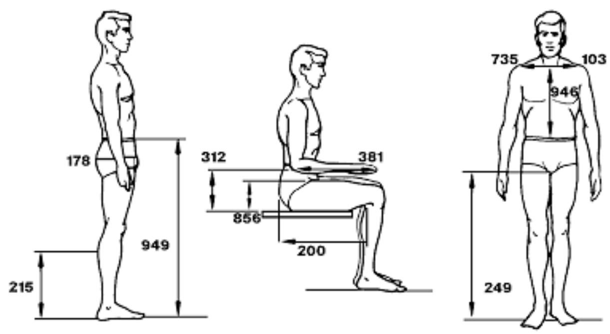

Figure **3.5**: Anthropometric Measurements (adopted from 2008, Anthropometry and Biomechanics)

All of the data was recorded on a paper form created by Jay Cho. The participants were then asked to place their shoes back on.

Once the participant was ready the participant moved to the chair in order to obtain preferred workstation setting measurements. The participant was first directed to adjust the seat so that it was a comfortable height. Then the chair was moved toward the desk cycle, which was placed under the desk. The Velcro loops on the pedals were then adjusted to the participant's specification so that feet would not slip off the pedals. The proper pedaling technique was explained to the participant before they began to pedal. The proper technique has the leg almost fully extended when pedaling, however, the leg is never locked or completely straight. As the participant became more comfortable, the desk height was altered to be the most comfortable for the participant. Each participant was asked if they would like the desk to higher or lower. If the participant wanted the desk to be higher, the facilitators raised the desk until it would a little too high for the participant. Then the facilitators would lower the desk until the participant said the desk height was ideal for them. If the participant indicated that the desk needed to be lowered, the facilitators would lower the desk until it was a little too low, and then raise the desk until the participant found their ideal desk height. In order to find an ideal desk height the participant was asked to consider the best desk height to use the computer desk setup and also so that they could pedal at a fast pace and not have their knees hit the desk.

The next adjustment that was made was the desk depth. The desktop was not secured in one position. Therefore, the participant, with the help of the facilitator, could push or pull the desk toward them in order to reach the point where the participant was the most comfortable. After the participant was happy with the setup of the table, DeskCycle, and chair, measurements of the preferred setting was made. A tape measure was used to measure the seat height. The measurement was taken from the base of the seat to the floor. The desk had a tape measure fastened to side in order to determine the height. Therefore, once the desk was at desired height the measurement was recorded. The desk depth was recorded. This was measured from the front of the DeskCycle to the middle of the chair.

The steps to find the preferred workstation measurements of the desk setting and chair were taken before the tests were completed for each new condition. The reading comprehension test and the typing test were completed under three conditions, sitting, low pedaling speed, and high pedaling speed. At the low speed the participant would pedal at a speed of 11 mph. At the high speed the participant would pedal at a speed of 22 mph. The tasks would be done completed under each condition twice.

After the preferred workstation setting measurements of the desk and chair were recorded the participant was walked through the tasks that they would complete in the experiment. Before receiving specific instructions the participants filled out an informational form on Google Forms asking the following questions:

1. Name
2. Age
3. For what uses do they use the computer (i.e. financial banking, word processing, gaming)

The participant was also asked to type a short paragraph in order to determine if the participant looked at the keyboard when typing.

The participant was then walked through the reading comprehension and typing task. The reading comprehension test was provided through Google Forms. Passages at an 8th grade reading level were selected because the average reading level of an adult in the U.S matches that of an 8th grader (Doak et al., 1995). The participant was showed a passage that was at an 8th grade reading level. All of the passages were from *Reading for Comprehension (8th grade / Level H)*, a book published by the Continental Press. All of the passages had 5 questions to accompany the passage (2007, Reading for Comprehension). A sample passage and samples questions can be found in Figure **A.1** and **A.2** in Appendix A.

The participant was informed that before starting each reading passage they should start the stopwatch on the iPod touch to the right of the keyboard. This stopwatch was used to measure the length of time it took each participant to finish the reading passage and questions. The facilitator took note of when the participant was done this test and would record the time. The time was recorded when the participant would press next in the Google Form. The Google Form displayed a page telling the participant to go to the typing task when directed by the facilitator. The stopwatch continued to run for four full minutes. The participant was notified that they should continue to pedal at the speed for the full four minutes and continuously pedal throughout the typing task as well.

In order to maintain the correct speed for each condition, low and high, each participant was given a minute to practice pedaling at that speed. The participants also received an audio notification if they were not pedaling at the appropriate speed for that condition. The facilitator would use a bell app on an iPod touch to signal the participant to look at the standard display at their right of the screen when they had an opportunity, and then adjust their speed accordingly. A deviation of 1 mph was allotted at each condition, low and high.

The directions for the typing task were provided next. The facilitator moved the computer screen to the typing test software for the participant. The typing test software used was Typing Master Pro (2014, Typing Master). Typing Master Pro is an electronic keyboard program; the program provides standardized paragraphs for each keyboarding task (Baker et al., 2006). Passages provided by Typing Master Pro are at a fourth-grade reading level (Baker et al., 2006). The participant was informed that they would have 2 minutes to work on the typing passage. The passage would automatically advance as the participant progressed throughout the passage (Baker et al., 2006). It was also explained to the participant that once they press space after finishing a word they would not be able return to that word to make any adjustment. The participant was then given a one-minute practice passage. The normal typing tests would last for 2 minutes.

Upon the completion of the typing test, the facilitator brought the participant back to the Google Form window. There the participant was asked rate their perceived physical exertion on the Borg's scale. The Borg scale is a category scale for perceived exertion that increases linearly with increase in exercise (Borg, 1982). The Borg rating scale can be seen in Table **3.3**.

Table **3.3**: Borg RPE Scale (adopted from Borg, 1982)

Borg Rating	**Exertion Level**
6	
7	Very, very light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Once the participant completed the rating they were asked to move out of the chair to the back of the room. Then the participant would have a 2-minute rest before completing the tasks under the next condition.

The successions of steps were repeated for each condition twice. The conditions of sitting, low, and high were randomly assigned in different orders for each participant. For example, a participant would complete the conditions in the order: sit, low, high, sit, low, high.

Whereas the next participant would complete the conditions in the following order: low, sit, high, sit, low, high. When the participants were completing the tasks under the sit condition they did not wait for the full four minutes for the reading comprehension task. As soon as the finished the reading comprehension task they were directed to the typing task.

After each condition was completed twice the participants set up the workstation setting and the chair for their preferred setting. With the standard display covered, the participant was asked to pedal at the speed that was the most comfortable to them. The facilitators explained that the participant should pick a speed where they would feel like they were exercising, but their work would not be compromised. After practicing that speed for one minute the participant completed the reading comprehension test and typing test like they did for the low or high speed. During the preferred pedaling condition, the facilitators took the speed down every minute for the six minutes that they were pedaling. After completing the task, the study was concluded. The participant was paid and signed a receipt in acknowledgement of the payment.

Chapter 4

Results and Analysis

4.1 Results and Analysis

The raw data from the study can be found in Appendix B in Table **B.1**, Table **B.2**, Table **B.3**, Table **B.4**, and Table **B.5**

4.1.1 Analysis of Reading Comprehension Test

In order to analyze the data recorded from the work exercise study, an analysis of variance (ANOVA) was completed. Minitab, statistical software, was used to complete the ANOVA analysis. First, the ANOVA for reading test accuracy was completed. The ANOVA results can be found in Table **4.1**. The raw data for the analysis was taken from the raw data seen in Table **B.1**. This test analyzed if the cycle rate had a significant impact on the accuracy of the reading test. The raw results for the reading results show numbers of 1, .9, .8, and .7. These numbers correspond to the percentage of questions that the participant scored correctly on. The results seen in the raw data show that the cycling rate (in mph) at sitting, low, and high speeds did not have an effect on the reading accuracy. This is seen in both participant 0 and 1 test results. They both scored 100% on the test under each condition. The results of the ANOVA analysis reiterate this finding.

Table **4.1**: One-way ANOVA, Reading Accuracy vs. Cycle Rate (mph) (Minitab)

One-way ANOVA: Reading Test Accuracy versus Cycle Rate (mph)

```
Source             DF      SS      MS     F      P
Cycle Rate (mph)    2  0.0117  0.0058  0.54  0.589
Error              33  0.3583  0.0109
Total              35  0.3700

S = 0.1042   R-Sq = 3.15%   R-Sq(adj) = 0.00%


                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level   N    Mean   StDev  --+---------+---------+---------+-------
 0     12  0.9083  0.0996   (------------*-----------)
11     12  0.9000  0.1279  (-----------*-----------)
22     12  0.9417  0.0793          (-----------*------------)
                           --+---------+---------+---------+-------
                           0.850     0.900     0.950     1.000

Pooled StDev = 0.1042
```

Table **4.1** shows that there is no significance between cycle rates and reading test accuracy. This is because the p-value was 0.585. A p-value greater than .1 means that there is no evidence to reject the null hypothesis. Therefore, there is no difference in reading accuracy at sitting, low, and high cycling rates. The analysis of the reading accuracy for the reading comprehension test was also analyzed by plotting the main effects. Figure **4.1** graphs the main effects plot for reading acccuracy under the conditions of the participant sitting, pedaling at a low rate of 11 mph, and pedaling at a high speed of 22 mph.

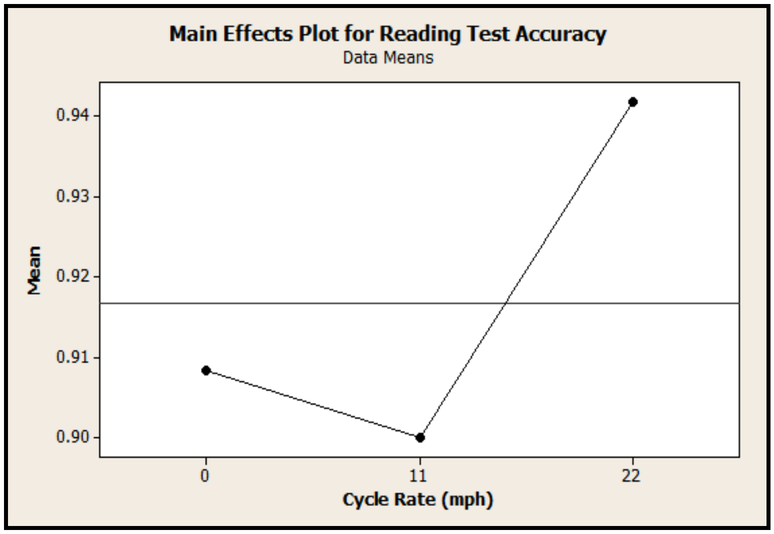

Figure **4.1**: ANOVA, Main Effects Plot for Reading Accuracy (Minitab)

Further analysis was completed in order to ensure that there was no significance between the reading accuracy and cycle rate. A two-way analysis was completed because there is a large variation created by the participants. Therefore, a General Linear model was completed. For this analysis in Minitab the indicator was used to automatically indicate the participant variables. Once this was done a two-way General Linear Model was run for reading accuracy versus the participant and cycle rate. The results of the General Linear Model can be seen in Table **4.2**. The General Linear Model reported the same results of the one-way ANOVA test. The p-value of the reading accuracy versus cycle rate was 0.280. Therefore, the two-way General Liner Model reinforces that there is no significant relationship between the reading accuracy and cycle rate.

Table **4.2**: General Linear Model of Reading Accuracy versus Participant, Cycle Rate (Minitab)

General Linear Model: Reading Accuracy versus Participant, Cycle Rate

```
Factor       Type   Levels  Values
Participant  fixed      12  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Cycle Rate   fixed       3  0, 11, 22


Analysis of Variance for Reading Accuracy, using Adjusted SS for Tests

Source       DF    Seq SS    Adj SS    Adj MS     F      P
Participant  11  0.263333  0.263333  0.023939  5.54  0.000
Cycle Rate    2  0.011667  0.011667  0.005833  1.35  0.280
Error        22  0.095000  0.095000  0.004318
Total        35  0.370000


S = 0.0657129   R-Sq = 74.32%   R-Sq(adj) = 59.15%


Unusual Observations for Reading Accuracy

      Reading
Obs  Accuracy      Fit   SE Fit  Residual  St Resid
 19   1.00000  0.85000  0.04098   0.15000      2.92 R

R denotes an observation with a large standardized residual.
```

The ANOVA for the response factor, reading time in seconds was also completed. The ANOVA results can be found in Table **4.2**. The raw data for the analysis was taken from Table **B.2** in Appendix B. This was analyzed to determine if cycle rate had a significant impact on the reading time in seconds for the reading test. The raw results for the reading time are in seconds. The reading time was recorded for the reading comprehension test taken while the participant was sitting, cycling at 11 mph, and cycling at 22 mph. The raw data seen in Table **B.2** did not show any pattern. Every participant had different reactions to the reading comprehension tests. Participant 1 and 2 both reduced their reading time (in seconds) with each condition. Meaning that their time was the lowest at the high cycling speed, and highest at the sitting condition. Participant 6 reading time results were the opposite of participant 1 and 2. In order to determine if there is a significant relationship between reading time (in seconds) and cycle rate a one-way ANOVA analysis was completed. The ANOVA test results showed that there was no significant difference in reading time at different cycle speeds. The one-way ANOVA test resulted in a p-value of 0.310. Therefore, there is no evidence of a significant relationship between the reading time (in seconds) and the cycle rate (in mph).

Table **4.3**: One-way ANOVA, Reading Time (seconds) vs. Cycle Rate (mph) (Minitab)

One-way ANOVA: Reading Time (seconds) versus Cycle Rate (mph)

```
Source             DF       SS     MS     F      P
Cycle Rate (mph)    2   180600  90300  1.22  0.310
Error              33  2452380  74315
Total              35  2632980

S = 272.6   R-Sq = 6.86%   R-Sq(adj) = 1.21%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level   N   Mean  StDev  +---------+---------+---------+---------
 0     12  158.0   31.3  (------------*-------------)
11     12  310.3  470.2              (------------*------------)
22     12  162.1   29.0  (-------------*------------)
                         +---------+---------+---------+---------
                         0       120       240       360

Pooled StDev = 272.6
```

The analysis of the reading time for the reading comprehension test was also analyzed by plotting the main effects. Figure **4.2** graphs the main effects plot for reading time under the conditions of the participant sitting, pedaling at a low rate of 11 mph, and pedaling at a high speed of 22 mph.

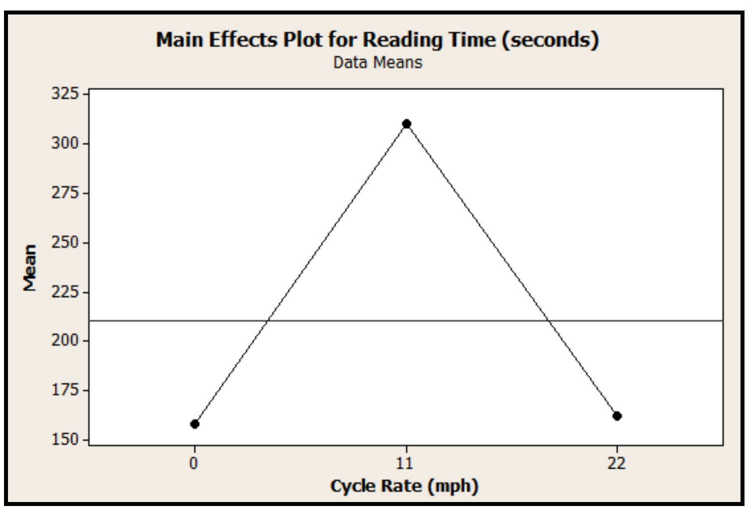

Figure **4.2**: Main Effects Plot for Reading Time (Minitab)

The large variation created by the participants, resulted in a need for further analysis of the reading time. A two-way General Linear Model was completed. Minitab's automatic indicator command was used to indicate the participant variables for the test. The results of the General Linear Model can be seen in Table **4.4**. Similar to the one-way ANOVA test, the General Linear Model showed no significance between reading time and cycle rate.

Table **4.4**: General Linear Model of Reading Time versus Participant, Cycle Rate (Minitab)

General Linear Model: Reading Time versus Participant, Cycle Rate

```
Factor       Type   Levels  Values
Participant  fixed      12  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Cycle Rate   fixed       3  0, 11, 22


Analysis of Variance for Reading Time, using Adjusted SS for Tests

Source       DF   Seq SS   Adj SS  Adj MS     F      P
Participant  11  15552.5  15552.5  1413.9  2.46  0.035
Cycle Rate    2   1940.3   1940.3   970.1  1.69  0.208
Error        22  12626.6  12626.6   573.9
Total        35  30119.3


S = 23.9569   R-Sq = 58.08%   R-Sq(adj) = 33.31%


Unusual Observations for Reading Time

     Reading
Obs     Time      Fit  SE Fit  Residual  St Resid
 10  100.000  144.069  14.940   -44.069     -2.35 R
 12  142.000  191.736  14.940   -49.736     -2.66 R
 22  206.000  161.278  14.940    44.722      2.39 R

R denotes an observation with a large standardized residual.
```

4.1.2 Analysis of Typing Test

The next analysis that was completed was for the typing test. The one-way ANOVA analysis was completed for Adjusted Words Per Minute (AWPM) versus cycle rate at the following conditions: sitting (0 mph), low cycle (11 mph), and high cycle (22 mph). The raw data taken for the AWPM at each of these conditions can be seen in Table **B.3**. The ANOVA results for AWPM versus Cycle Rate can be seen in Table **4.3**.

Table **4.5**: One-way ANOVA, AWPM vs. Cycle Rate at All Conditions (mph) (Minitab)

One-way ANOVA: AWPM versus Cycle Rate (mph)

```
Source             DF    SS   MS     F      P
Cycle Rate (mph)    2   250  125  0.56  0.579
Error              33  7425  225
Total              35  7675

S = 15.00   R-Sq = 3.26%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N   Mean  StDev  -------+---------+---------+---------+--
 0     12  52.38  16.17            (------------*-----------)
11     12  49.79  14.75         (-----------*------------)
22     12  45.96  14.00  (------------*-----------)
                         -------+---------+---------+---------+--
                              42.0      49.0      56.0      63.0

Pooled StDev = 15.00
```

The one-way ANOVA test resulted in a p-value of 0.579. There is no significant relationship between AWPM and cycle rate. The one-way ANOVA was analyzed with the cycle rates at sitting, low cycle (11 mph), and high cycle (22 mph). The raw data showed that there was a difference in AWPM seen at each of the cycling conditions. The average AWPM recorded for the sitting, low cycle, and high cycle condition were 52.375, 49.792, and 45.958 respectively. Given this large variation in AWPM, further analysis was made of the AWPM data.

A one-way analysis was completed for AWPM versus cycle rate (mph) at the following conditions: sitting (0 mph) and high cycle (22 mph). This was done to see if a large significance exists from the change from the sitting to high cycle condition. The results of the one-way ANOVA can be seen in Table **4.4.** The ANOVA one-way analysis resulted in a p-value of 0.310. Therefore, showing that there is no significant relationship between AWPM and cycle rate.

Table **4.6**: One-way ANOVA, AWPM vs. Cycle Rate at Sitting and High (mph) (Minitab)

One-way ANOVA: AWPM versus Cycle Rate (mph)

```
Source             DF    SS   MS     F      P
Cycle Rate (mph)    1   247  247  1.08  0.310
Error              22  5033  229
Total              23  5280

S = 15.12   R-Sq = 4.68%   R-Sq(adj) = 0.35%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N   Mean  StDev  -------+---------+---------+---------+--
 0     12  52.38  16.17           (------------*------------)
22     12  45.96  14.00  (------------*------------)
                         -------+---------+---------+---------+--
                             42.0      49.0      56.0      63.0

Pooled StDev = 15.12
```

The minitab analysis did not show a significance of the relationship between AWPM and cycle rate. However, the raw data showed a large difference between AWPM for the participants at each of the conditions. Further experiments should be completed with more participants to see if a significance will become more apparent.

In order to reduce the effect of the variation created by the participants, a General Linear model completed. The General Linear Model was completed for AWPM versus particpants and cycle rate. The Minitab indicator command was used in order to indicate the participant variables. The results of the General Linear Model can be seen in Table **4.7**. The further analysis show that the one-way ANOVA analysis is not true and there is a significance between AWPM and cycle rate. The p-value of AWPM versus cycle rate was 0.000. Therefore, for the typing test, the AWPM was impacted by the cycle rate.

Table **4.7**: General Linear Model of AWPM versus Participant, Cycle Rate (Minitab)

General Linear Model: AWPM versus Particpant, Cycle Rate

Factor	Type	Levels	Values
Particpant	fixed	12	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Cycle Rate	fixed	3	0, 11, 22

Analysis of Variance for AWPM, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Particpant	11	7285.69	7182.20	652.93	109.68	0.000
Cycle Rate	2	258.53	258.53	129.27	21.71	0.000
Error	22	130.97	130.97	5.95		
Total	35	7675.19				

S = 2.43991   R-Sq = 98.29%   R-Sq(adj) = 97.29%

Unusual Observations for AWPM

Obs	AWPM	Fit	SE Fit	Residual	St Resid
4	83.0000	78.5455	1.5314	4.4545	2.35 R
6	52.5000	48.3788	1.5314	4.1212	2.17 R

R denotes an observation with a large standardized residual.

4.1.3 Analysis of Participant's Preferred Cycling Speed

The study also investigated the preferences of the participant so that they would be able to complete the work to their best ability and still receive exercise. One way to do this was by having the participants indicated their perceived exertion. This was accomplished by having the participant rate their exertion after each condition on Borg's RPE scale (Borg, 1982). This data was important to be able to see the change in exertion from each condition. The average Borg rating at the sitting condition was 6.208. This corresponds to the participants on average using no exertion at all during the sitting condition. At the low cycling rate (11 mph) the average Borg rating was 8.208. This Borg rating corresponds to very light exertion. Then at the high cycling rate (22 mph) the average Borg rating was 10.75. This Borg rating means that the participants on average exerted very light energy when completing the tasks. Therefore, showing that at all three conditions the participants never exceeded a fairly light level of exertion. Higher cycling rates can be tested in order to determine if the higher cycling rates would have a significant effect on the reading time, reading accuracy, and AWPM.

Each participant was asked to blindly cycle at their desired and most comfortable pace while completing the reading and typing task. The cycling speed was taken every minute for the duration of both tasks for each participant. The averages of the cycling speeds for each participant can be seen in Table **4.5**.

Table **4.8**: Average Desired Cycling Rate for Each Participant

Participant	0	1	2	3	4	5	6	7	8	9	10	11
Average Cycling Rate	15.68	19.35	16.37	17.28	16.68	15.07	14.5	18.07	18.57	13.47	18.8	12.6

There was a large deviation for the average cycle speed among the 12 participants. The lowest cycling speed was at 12.6 mph, while the highest cycling speed desired was at 19.35. The majority of the desired cycling rates fell between 15-20 mph. The desired averages indicate that the low and high cycle rates selected for the study were appropriate for a workstation setting. Therefore, showing that the participants can continue to produce quality work products while exercising at a moderate pace.

Chapter 5

Summary, Conclusion, and Future Research

5.1 Summary and Conclusion

Bringing exercise into the workplace is one solution that is being researched in order to solve the obesity crisis that is plaguing the United States. It is widely known that the American public is extremely overweight on a whole. Over the last half century the health of the nation has declined rapidly. This is greatly are result of the sedentary lifestyle that Americans live. Technology have made it possible for many people to never have to leave their desk at work. Computers and the Internet allow the American worker to have any information they need right at their desk in the office.

Currently, there is interest in bringing exercise into the workplace. Walking treadmills have become a popular option for those who are interested in exercising at work. A walking treadmill can have a significant effect on ones health. On average if a person was to replace 2 to 3 hours of sitting with walking on their treadmill at work, that person could lose up to 20 kg in a year (Levine et al., 2007). The introduction of exercise into the workplace is predicted to have a drastic improvement in one's health. This thesis investigated the feasibility of incorporating exercise into an office setting by researching the cognitive effects on office work when exercising.

The hypothesis that this research addressed is that moderate exercise in a seated position will not cause an individual to have any change in their accuracy or time to finish workplace tasks. Having participants complete two tasks, a reading comprehension and typing task tested this hypothesis. These tasks were complete under three different conditions: sitting, cycling at a low rate (11 mph), and cycling at a high rate (22 mph).

The results of the reading test and typing test were analyzed by ANOVA one-way test using Minitab. The results of the reading test were recorded through the accuracy of each participant's answers to the questions. The reading time for the passages was also recorded for each participant. A one-way ANOVA analysis was done for the reading accuracy versus the cycling rate under the following three conditions: sitting, low cycle rate (11 mph), and high cycle rate (22 mph). The results of the analysis showed no significance between the reading accuracy and the cycle rate. A General Linear Model was also completed for the reading accuracy versus the participants and cycle rate. The results of the General Linear Model reiterated the results of the one-way ANOVA analysis; there was no significance between the reading accuracy and cycle rate. An ANOVA analysis was also done for the reading time for the three conditions. Again, the results of the analysis showed that the relationship between the reading time and cycle rate had no significance. These two analyses show that low to moderate exercise, as shown through the cycle rate, has no effect on reading cognition in an office setting. To reduce the effect of the variation created by the participant variable, a General Linear Model was completed. The General Linear Model analysis results also showed that there was no significance between reading time and cycle rate.

The second task completed by the participants' was a typing test. The Adjusted Words Per Minute (AWPM) was recorded for each participant under each of the three exercise conditions. A one-way ANOVA analysis was completed for those results. The result of the analysis was that there was no significance between the AWPM and the cycle rate. However, the raw data showed a wide difference in AWPM averages for each of the three conditions. The average of AWPM recorded for the sitting, low cycle, and high cycle conditions were 52.375, 49.792, and 45.958 respectively. The variation seen in the raw data prompted further analysis. A two-way General Linear Model was completed because of the variation created by the participant variable. The General Linear Model results shows that there was significance between AWPM and cycle rate. The p-value was 0.000. Therefore, the AWPM were affected by the different cycle rates. There is possibility for some variation during the typing task because the participant had to change their eye sight line during this test to check the standard display for their speed. This could have caused some variability in the results.

This research also investigated the preferred exercise level of the participants to complete the reading and typing test. All of the participants had an average preferred cycling rate between 12-20 mph. These cycle rates fall in the range created by the low and high cycle rates. The research shows that the moderate levels of exercise tested in this study are appropriate.

5.2 Future Research

The conclusions presented in this thesis can be applied to any office setting or individual that is considering incorporating a desk elliptical exercise device into their workday. Previous research has shown the benefits of changing the standard sedentary workday and incorporating exercise into the office setting. The research done in this thesis shows that there is no significant effect on reading comprehension tasks when utilizing a desk elliptical at work. The research also showed that there was a significant relationship between the typing task and cycle rate. Therefore, the desk cycle elliptical affected the typing task in a work setting.

Further research can be done on the cognitive effects of desk elliptical exercise in the workplace. In further research it would be important to consider a larger participant pool. A larger number of participants in a future study would provide further insight into how the different cycle rates affect different cognitive tasks. A large number of participants would also help determine if the standard display to the left of the monitor had an affect on the typing test. Future research could try to minimize the effect of the standard display by having a digital display on the monitor screen. This would result in less variation in the typing test because the participant would not have to move their line of sight to see the display. All of these suggestions for future research will help ensure that desk elliptical exercise does not affect cognition in the workplace.

Appendix A

Reading Comprehension Sample Passage

Are you a "lefty" or a "righty"?

1 Get a piece of paper and a pencil. Write down your name. If you are like 90% of Americans, you hold the pencil in your right hand. The other 10%, left-handers, know how difficult living in a right-handed world can be. Almost everything, from scissors to guitars to TV remote controls, is made for right-handers.

2 The hand you are most likely to use is called your dominant hand. You have probably been aware of this since you were very young. But you may not know that you also have a foot, eye, and side of your brain that are dominant.

3 Finding out if you are left-footed or right-footed is easy. Just pretend to kick a ball. There's a test for the eyes, too. Hold one arm straight out from the middle of your body. Point your index finger so it blocks something in the distance. Look at the finger with both eyes open. Then close one eye at a time. If, for example, your finger seems to stay in the same place when you look at it with only your left eye, you are left-eyed.

4 Finding which side of your brain is dominant is a little harder. It depends on how you hold your pencil. Is your hand straight, with the pencil pointing away from you? Or is it hooked, with the pencil pointing toward you? Straight right-handers and hooked left-handers are left-brained. Straight left-handers and hooked right-handers have a dominant right brain.

5 Here's one more experiment with right and left. This one is just for fun, though. On a picture of your face, put the edge of an unframed mirror along the nose. What do you notice when you look at the picture from the right and then from the left?

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Figure **A.1**: Sample Reading Comprehension Passage

Circle the correct answer for questions 1–5.
Write your answer to question 6 on a separate piece of paper.

1. About ______ of Americans are left-handed.
   - **A** 40%
   - **B** 30%
   - **C** 20%
   - **D** 10%
2. Which word in paragraph 3 means "something used to show what other things are like"?
   - **A** example
   - **B** middle
   - **C** finger
   - **D** index
3. Which paragraph tells why life is difficult for left-handed people?
   - **A** 1
   - **B** 2
   - **C** 3
   - **D** 4
4. In the eye test described in the article, if your finger stays the same when you look at it only with your right eye, you are ______.
   - **A** left-eyed
   - **B** right-eyed
   - **C** nearsighted
   - **D** right-handed
5. *Remote* can have the following meanings. Mark the meaning used in paragraph 1.
   - **A** out of the way
   - **B** small in degree
   - **C** operated from a distance
   - **D** far removed in space or time
6. Read the last paragraph of the article again. What do you think you'd see? Why? Try the experiment and describe what happens.

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Figure **A.2**: Sample Reading Comprehension Questions

Appendix B

Data from Research Study

Table **B.1**: Reading Accuracy in Percent for Reading Comprehension Test

Participant	Age	Gender	No Cycling	Low Level Cycling	High Level Cycling
0	21	m	1	1	1
1	20	f	1	1	1
2	19	f	1	0.9	1
3	19	f	0.9	1	1
4	21	m	1	1	1
5	20	m	1	0.9	1
6	19	f	0.8	1	0.8
7	26	m	0.8	0.8	0.9
8	21	m	0.9	0.8	0.9
9	22	f	0.7	0.6	0.8
10	20	m	0.9	1	0.9
11	20	m	0.9	0.8	1
Average			0.908	0.9	0.9416
Standard Deviation			0.0996	0.1279	0.07929

Table **B.2**: Reading Time in Seconds for Reading Comprehension Test

Participant	Age	Gender	No Cycling	Low Level Cycling	High Level Cycling
0	21	m	157	162.5	161
1	20	f	172	170	166
2	19	f	160	149	146.5
3	19	f	147.5	164	153.5
4	21	m	153	149	149.5
5	20	m	145.5	144.5	131.5
6	19	f	156.5	162	172.5
7	26	m	136	180.5	116.5
8	21	m	211	215	189
9	22	f	100	206	147.5
10	20	m	216	172.5	185.5
11	20	m	142	228	226.5
Average			158.0416	175.25	162.125
Standard Deviation			31.2929	27.235	28.995

Table **B.3**: Adjusted Words Per Minute from Typing Task

Participant	Age	Gender	No Cycling	Low Level Cycling	High Level Cycling
0	21	m	68	66	64.5
1	20	f	71	67	61
2	19	f	50	49.5	42.5
3	19	f	83	74	69
4	21	m	49	49	43.5
5	20	m	52.5	42	41
6	19	f	59.5	63	57.5
7	26	m	38	37	34
8	21	m	53	49	45
9	22	f	25.5	27	24
10	20	m	42.5	36.5	36
11	20	m	36.5	37.5	33.5
Average			52.375	49.79166667	45.95833333
Std Dev			15.47999381	14.11922202	13.40779987

Table **B.4**: Perceived Exertion Expressed by Participants on Borg's Scale

Participant	No Cycling	Low Level Cycling	High Level Cycling
0	6	7.5	11
1	6	9	11.5
2	6	7	8
3	6	11.5	13.5
4	7	9	11.5
5	6	8	11
6	6	6	9
7	6	7	8
8	6	6.5	7.5
9	6	8.5	13
10	7.5	8	9.5
11	6	10.5	15.5
Average	6.208333333	8.208333333	10.75
Standard Deviation	0.49810246	1.616088619	2.463367983

Table **B.5**: Desired Pedaling Rates For Each Participant in Miles Per Hour

Participant	0	1	2	3	4	5	6	7	8	9	10	11
1st record	15.3	18.8	16.5	17	17	15.2	14.9	18.3	18.8	13	20.2	13
2nd record	16.5	19.3	16.8	17.6	17.1	15.6	14.8	18.1	18.4	14	18.2	12.9
3rd record	14.7	19.5	17.1	18.6	16.3	15.3	14.5	18.1	18.5	13.4	19.9	12.5
4th record	15.8	18.5	17.3	18.1	17.7	14.8	14.9	19.1	19.7	13.7	18.7	12.7
5th record	16.1	19.9	15.9	16.3	16.2	14.8	14.6	17.8	18.1	13.2	18.7	13.1
6th record		20.1	15.7	16.1	15.8	14.7	13.3	17	17.9	13.5	17.1	12.2
7th record			15.3									11.8
Average	15.68	19.35	16.37	17.28	16.68	15.07	14.5	18.07	18.57	13.47	18.8	12.6

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