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The purpose of this study was to provide a real-world test of the relationship between the performance of an acute bout of moderate physical activity (walking) during the lunch hour and subsequent cognitive performance in the workplace. Participants were generally healthy, middle aged (mean age = 45.23), white-collar workers. Participants were randomly assigned to walk or not walk on their lunch break and then complete a battery of computer-based cognitive tests later in the afternoon. On a second day, the same procedures were repeated with the walkers now being the non-walkers and vice versa.

Within subjects analysis revealed significant differences, $p<.05$, for five of the seven response times between the two testing conditions. These results suggest that an acute bout of moderate physical activity during the workday can have facillatory effects on certain cognitive functions.

THE EFFECTS OF AN ACUTE BOUT OF MODERATE INTENSITY EXERCISE ON COGNITIVE PERFORMANCE

by

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Approved by

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APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at the University of North Carolina at Greensboro.

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To my parents who made this opportunity possible, my family for their encouragement, and my friends for their support. Also, to my husband for his continued love, support, and patience.

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CHAPTER I

INTRODUCTION

Physical activity is known to benefit the body and mind in a number of ways. Physiological changes in the body such as increased heart rate, better circulation of blood and nutrients, and the release of endorphins occur as a result of acute exercise (McArdle, Katch, & Katch, 2001). Psychological benefits of acute exercise include better mood states (Arent, Landers, & Etnier, 2000), stress alleviation (Crews & Landers, 1987), and a decrease in anxiety (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991). Exercise has also been found to produce cognitive benefits such as an improvement in attention and concentration, reaction time, and overall mental efficiency (Etnier, Salazar, Landers, Petruzello, Han, & Nowell, 1997, Colcombe & Kramer, 2003).

It has also been shown that people who exercise are generally healthier (Penedo & Dahn, 2005). This has been demonstrated by the fact that they have a decreased risk of coronary heart disease (Blair, 1994), type-2 diabetes (Pearte, Gary, & Brancati, 2004), cardiovascular disease (Wessel et al., 2004), arthritis (Lin, Davey, & Cochrane, 2004), and sexual dysfunction (Esposito et al., 2004). These health benefits result in fewer doctor visits, fewer missed days from work due to illness, and fewer hospital visits. This then suggests that people who exercise spend less of their own, their insurance's, and the government's money on healthcare. One implication of this is that companies that provide their employees with healthcare would save money if their employees were exercising because the employees would then be healthier and have overall lower healthcare costs. Yet few employers are willing to spend money or time upfront to save money in the long run. However, employers that are willing to make changes to accommodate health promotion are seeing the benefits in more ways than just saving money (Pollanshek, 2005).

Pollanshek (2005) suggested that since exercise improves cognitive functioning, employers who allow time for and promote physical activity might get more productivity out of their employees. Aside from employees being at work, as opposed to out sick, they may also get more work done in less time. Their concentration and mental efficiency is predicted to increase as a result of an increase of physical activity.

Participation in exercise does not have to be ongoing to obtain the positive psychological and mental benefits. An acute bout of exercise has been shown to increase creativity (Gondola, 1987), improve reaction time and accuracy, aid in problem solving and information processing (Tomporowski, 2003), and facilitate the distribution of attentional resources (Hillman, Snook, & Jerome, 2003). These benefits have all been observed in laboratory settings, however, have not been examined in the workday with healthy adults. There is currently no quality research evaluating the effects of an acute bout of exercise and the resulting effects on cognitive performance by an individual in the workplace.

With physical activity having so many positive benefits it is difficult to understand why more people do not participate. One of the most frequently expressed barriers to participation in physical activity is time; people claim to be too busy to exercise (Centers for Disease Control, 2005). One way to combat this issue is to find existing free time in the day that is not being used wisely. Taking advantage of breaks at work, especially lunch breaks, to participate in physical activity is a great way to utilize this time.

In 1979, McGlynn, Laughlin, and Rowe provide a quote that clearly explains the rationale behind this study:

> there is a need for research concerning exercise and mental performance which specifically examines the application of findings to business and industry, especially where productivity in sedentary occupations can be improved by exercise…if it can be clearly demonstrated that speed of mental performance is increased by exercise without a decrease in accuracy, exercise programs might be offered during break times and employees encouraged to participate in such programs. (p.413)

Given that performance of physical activity during a natural break in the workday might facilitate adherence and given that it might also impact subsequent cognitive performance, the purpose of this study is to provide a real-world test of the relationship between the performance of an acute bout of moderate physical activity (walking) during the lunch hour and subsequent cognitive performance in the workplace. By testing cognitive performance after an acute bout of walking and also on days when the participants do not walk, it can be seen if there are cognitive changes that result from the physical activity. It is expected that cognitive performance will improve following an acute bout of moderate physical activity.

More specifically, there are certain cognitive improvements that will likely occur as a result of acute exercise in this study. First, response times for the Arrow Reaction

Time Test and the Arrow Flankers Test should improve. It has been shown that reaction time improves as a result of exercise, therefore it is expected that people will respond to a stimulus in less time following acute exercise (Chodzko-Zaijko, 1998; Clarkson-Smith & Hartley, 1989; Tomporowski, 2003). Second, an increase in number of correct responses on the Continuous Attention Test should be seen. Attention has been found to improve after exercise; thus in this task, better attention will be reflected by more correct responses (Gondola, 1987). Third, there should be increases in the number of correct responses for the N Back 1 and 2 Tests. As past research has shown, following exercise participants should perform better on tasks that indicate improvements in working memory (Clarkson-Smith & Hartley, 1989; Molloy, et al., 1988).

CHAPTER II

LITERATURE REVIEW

Exercise and Mental Health

Generally speaking, exercise has a number of mental health benefits. In a review of these benefits, Penedo and Dahn (2005) highlight the positive mental-health outcomes that result from exercise. Exercise reduces the symptoms of depression and anxiety, and may prevent the onset of depression as well (Ross & Hayes, 1988). As previously mentioned, exercise has been found to improve mood states, relieve stress, and reduce negative affect in individuals (Arent, Landers, & Etnier, 2000, Crews & Landers, 1987). In addition, exercise can lead to overall, higher quality of life (Chodzko-Zajko, 1998).

Exercise and Cognition

Participation in physical activity has been associated with changes in mental functioning across the lifespan (Thomas, Landers, Salazar, & Etnier, 2004). The following section will address meta-analyses and literature reviews, cross-sectional studies involving long-term exercise that produce changes in fitness, and research pertaining to acute bouts of exercise. Within each topic, research involving young to middle-aged adults and older adults will be discussed.

General Reviews

In a narrative review of the literature, Tomporowski and Ellis (1986) examined the cognitive changes produced by exercise. To make the bulk of information easier to understand, the studies were categorized based upon the duration and intensity of the exercise sessions as follows: (1) very brief, high-intensity exercise, (2) short duration, high-intensity anaerobic exercise, (3) short-duration, moderate-intensity exercise, and (4) long duration, aerobic exercise. Very brief, high-intensity exercise had differing results depending on the time the cognitive test was administered. Generally, if tested during exercise, scores were higher than pre-exercise. However, if tested immediately following this type of exercise, cognitive scores were lower than at baseline. This may indicate that there is a certain intensity threshold at which the mind experiences the immediate benefits of exercise.

Research involving short-duration (lasting less than 15 minutes), high-intensity anaerobic exercise also yielded conflicting results. A number of different study designs and inconsistencies in outcome goals led to inconclusive findings. Looking at short-duration (less than 15 minutes), moderate intensity exercise, research seems to support the argument that cognitive functioning improves as physical arousal increases. These findings also suggest that the physically fit individuals will perform better than unfit individuals on cognitive tasks during and following exercise. Long-duration, aerobic endurance exercise was found to have facilitating effects on cognitive functioning in both fit and unfit individuals.

Overall, this review displays a number of inconsistencies within the existing research at the time. Among other variables, the results differ largely depending on the intensity and duration of the exercise. However, positive results on cognitive functioning have consistently been found resulting from longer duration, lower intensity exercise.

A meta-analytic review on the influence of physical fitness and exercise on cognitive functioning conducted by Etnier et al. (1997) aimed to clarify the mixed results of a number of narrative reviews on the subject. The meta-analysis yielded an overall effect size of 0.25 for 873 effect sizes. After excluding outliers, the adjusted mean for the effect sizes was 0.29 for 852 effect sizes, which is significantly different from zero. This suggests that exercise has a small, nonetheless, positive effect on cognition. By taking a closer look, it can be seen that effect sizes were largest when cross-sectional methods were used (ES=0.53), second largest for chronic fitness training programs (ES=0.33), and the smallest for acute bouts of exercise (ES=0.16). This means that there is a significant association between acute exercise and cognition. Although significant, the effect size was small. This may be attributed to group size and gender makeup. In groups of 20 people or more, the ES=.61, and in mixed gender groups the ES=.70. Thus, based on these findings, it is reasonable to expect that a study involving large numbers of people from both genders who perform an acute bout of exercise will produce a larger effect size. Overall, this meta-analysis shows that exercise does seem to benefit cognitive performance, yet is unable to provide direct evidence explaining the physiological mechanisms between exercise and cognition.

Colcombe and Kramer (2003) conducted a meta-analysis looking at randomized controlled exercise interventions and cognitive function in older adults. With subjects aged 55-80 yrs, it was found that chronic exercise had the greatest effect on executive processes, which include coordination, planning, and scheduling tasks. Executive processes are those highest levels of cognitive processes that enable one to have anticipation, judgment, decision-making, and goal-directed problem solving. Controlled processes and visuospatial processes also showed improvements from fitness training. Regardless of the particular type of cognitive task, fitness training caused an increase, on average, of ½ a standard deviation in performance. Also, relatively brief training programs were as beneficial as moderate-length training programs, yet neither were as advantageous as long term training programs. Short bouts of exercise (15-30 min) showed no major impact on cognitive function, but moderate (31-45 min) to long (46-60 min) bouts of exercise were found to be significantly beneficial. Middle-old (age 66-70 years) participants experienced the most benefits from exercise. In general, the meta-analysis shows that fitness training in older adults does increase cognitive performance. In addition, fitness training can produce results in cognition similar to intellectual training.

The previously mentioned meta-analyses all support a positive association between physical activity participation and cognitive performance. The effect sizes however, depend on the design of the study. For this reason, it is important to examine different study designs and their findings in more detail.

Physical Fitness

Older Adults

Physical fitness has an impact on the lives of older adults as well. Based on empirical data, researchers have concluded that lack of fitness, not age, causes the decline in performance on cognitive tasks (Stacey, Kozma, & Stones, 1985). Also, depressed older adults who increased their fitness level had an increase in memory and executive functioning (Khatri et al., 2001). Tomporowski's (1997) review of physical training on the mental abilities of older adults found that fluid intelligence, information processing, and attention were specific cognitive functions that improved as a result of an increase in fitness.

Chodzko-Zajko (1998) summarized the benefits of physical activity for older persons. The immediate benefits include relaxation, a reduction in stress and anxiety, and elevations in mood. The authors also stressed long term effects such as improvements in a number of aspects of psychological functioning, improved mental health, the postponement of age-related declines in processing speed and reaction time, and an increase in ability in new skill acquisition.

In a cross-sectional study, Clarkson-Smith and Hartley (1989) found that elderly subjects who participated in exercise regularly performed better in tasks involving reasoning, working memory, and reaction time than did their sedentary counterparts. Similarly, Colcombe et al. (2004) found that high-fit, compared to low-fit, older adults were more efficient at executive functioning. Also, high cardiovascular fitness was linked to greater activity in the cortical regions in the brain (the areas that should be engaged in the specific tasks used in the study), and less activity in the anterior cingulate cortex (the area of the brain that shows the need for adaptation in the control processes). These findings were interpreted as indicative of more efficient cerebral functioning by the fit, older-adults than the unfit, older adults.

Young-Middle Aged Adults

Similarly, young and middle-aged adults have been found to experience related cognitive benefits from a 16 session running program, one of these being creativity (Gondola & Tuckerman, 1985). This is important because creativity is involved in many forms of cognitive processing, especially flexible thinking and alternate responses. In addition, Blomquist and Danner (1987) demonstrated that information processing efficiency increases with cardiovascular fitness in adults 18-48 years old. Similarly, El-Nagger (1986) found that physical fitness (assessed by maximum oxygen uptake, resting heart rate, and systolic and diastolic blood pressures) and mental fitness (assessed by performance on eight cognitive processing tests) were positively related in men aged 25-65 years.

In a cross-sectional study, Malmstrom, Wolinsky, Andresen, Miller, and Miller (2005) explored the relationship between cognitive ability and physical performance in middle-aged African Americans. Global cognitive function (measured by the MMSE and Animal Naming Test) was strongly related to physical performance (measured by chair stand, semi-tandem stand, tandem stand eyes open, tandem stand eyes closed, one-leg stand, preferred gait speed, and grip strength). While this study does not look at exercise and its effect on cognition, it is reasonable to presume that a physically active person would perform better than a non-active person on tests of physical performance and therefore perform better on the global functioning tests.

Consistent with previous findings, Lochbaum, Karoly, and Landers (2002) found that in a population of 53 university students (mean age of 24.35 yrs) active (reported exercising 3 times per week, for 45 min at a moderate intensity, for the previous 6 months) participants showed greater performance on tests of fluid intelligence than did non-active (reported no fitness training for the previous 6 months) participants.

Acute Exercise

The present study will be concerned with the effects of acute exercise on cognition. The following research studies focus on acute exercise rather than long-term exercise and explore the relationship with cognitive performance.

Older Adults

In a study of older adults suffering from chronic obstructive pulmonary disease, Emery, Honn, Frid, Lebowitz, and Diaz (2001) found that acute exercise yielded an increase in cognitive performance, specifically verbal processing. In addition, Molloy, Beerschoten, Borrie, Crilly, and Cape (1988) also displayed evidence that after acute exercise, elderly subjects experienced an increase in areas of memory, cognitive function, language and mental capacity.

The decline in cognitive performance that often comes with aging may hinder the speed of the central nervous system, which is involved in cognitive tasks such as reaction time. Exercise is thought to preserve the efficiency of the central nervous system. For this reason, it is logical that participation in exercise, and its stimulation of physiological functioning, will enhance the cognitive performance in the elderly. In a review of literature looking at exercise and the psychological state of institutionalized elderly, Netz and Jacob (1994) concluded that there is an increase in cognitive functioning following acute moderate exercise. Clarkson-Smith and Hartley (1989) found that elderly subjects who participated in acute exercise performed better in tasks involving reasoning, working memory, and reaction time than did their sedentary counterparts.

Young-Middle Aged Adults

In 20 undergraduate students, Hillman, Snook, and Jerome (2003) found that specific executive control processes, tasks that require an increase in conscious effort and control, are affected the most by an acute bout of cardiovascular exercise. They asked participants to exercise at a hard, but submaximal level running on a treadmill for 30 minutes. The benefits to executive control functions from exercise were hypothesized to be due to the increase in the distribution of attentional resources resulting from overall increases in general arousal.

Furthermore, Gondola (1987) found that after a single bout of aerobic dance performed at a moderate to strenuous effort (based on post-exercise heart rate) for 20 minutes, women ages 19-35 years experienced an increase in attention and energy arousal. In addition, they had a decrease in anxiety.

Lichtman and Poser (1983) discovered that after an acute bout of vigorous exercise (45 minutes of jogging and other physical activity), adults aged 16-45 showed improvements on mood scales and cognitive processes. The exercisers reported an increase in alertness summarized by “feeling better.” Similarly, in a study of males aged

18-42 years, Hogervorst, Riedel, Jeukendrup, and Jolles (1996) concluded that acute strenuous physical exercise (a bicycle ergometer endurance test) enhanced performance on simple mental tasks and complex cognitive functions. This was thought to occur due to the increased activation of the central nervous system.

Mild cardiovascular adaptation, which occurs as a result of moderate, acute, physical activity, appears to stimulate mental states causing increased cognitive performance. In a study utilizing young adults ages 19-21 years, Gupta, Sharma, and Jaspal (1974) found that acute physical activity done prior to mental work increased mental states causing better performance on mental tasks. However, this only occurred to an extent. The study revealed that physical exercise of 10 minutes or more caused a decrease in mental performance. There is no mention of the participants' intensity; calculated, observed, or perceived (self-reported). It is possible that the participants were exercising at too high of an intensity leading to exhaustion. To be in agreement with other research, participation in moderate intensity activity should most likely produce an increase in performance on mental tasks, not a decrease.

More specifically, participation in an acute bout of exercise has also been shown to result in improved cognitive functioning. In a narrative review of exercise literature, Tomporowski (2003) found that exercise can selectively facilitate certain cognitive processes in adults. He confirms that depending on the type and duration of exercise performed, exercise has the ability to enhance response speed and accuracy, accelerate processes involved in problem-solving and goal-oriented tasks, and help in particular stages of information processing. More specifically,

> Following aerobic exercise people are better prepared to engage in action, concentrate, and solve complex problems than they are prior to exercise…Demonstrating that relatively short bouts of submaximal exercise have salutary effects on information processing and cognition has direct application to those involved in work environments…(p.19)

Most promising are submaximal aerobic exercises between 20 and 60 minutes long.

The present study will focus on an examination of an acute bout of moderate intensity exercise performed by working adults. There is no existing research that has tested the relationship between acute exercise and cognition in the normal, working adult population in a real-world setting. It is hypothesized that performance of an acute bout of moderate intensity exercise will benefit cognitive performance for several hours following the exercise bout. Thus, if the results of this study support the hypothesis, the findings will provide an additional rationale for the promotion of exercise in the workplace.

Physical Activity Programs in the Workplace

General Reviews

In a literature review of worksite wellness programs, Shepard (1999) found a number of benefits resulting from participation in work-site wellness programs. Participants subjectively reported an increased sense of overall wellness and improved productivity. Also, data show that workplace fitness programs tend to lure new employees who possess a positive outlook on work and health, reduce the amount of sick days taken by employees, reduce employee turnover, generate small increases in productivity, and lower healthcare costs. In addition the following have been observed in some of the studies on worksite fitness programs included in the review: a decrease in body mass, decrease in body fat, increase in aerobic power, increase in muscle strength and endurance, increase in flexibility, improved cardiac health, decreases in blood pressure, cholesterol, and cigarette smoking, and increased life satisfaction and overall well-being.

In another review, Gebhardt and Crump (1990) describe the different types and levels of employee health and fitness programs. Level I programs are those that create awareness among employees and are more educational than hands on in nature. Level II programs consist of lifestyle modification by both education and hands on classes that last a minimum of 8 to 12 weeks. For example, they often offer instruction to help employees change negative health habits and also require the employees' direct participation in some type of fitness classes. In Level II programs, the company does not necessarily provide these fitness services. Level III programs take wellness to another level by providing the necessary fitness equipment, center, and locker rooms, and by making healthy food choices available. Level II and III programs, which often run simultaneously to be more beneficial, were more successful at getting employees to begin and continue exercising than were Level I programs. Level II and Level III programs also resulted in the greatest reductions in body weight, body fat, and systolic blood pressure, decreased cholesterol, and resting heart rate. These factors all lead to reduced health care costs, fewer injuries, less employee turnover, less absenteeism, and increases in job performance, productivity, and mood in the workplace.

Only one study could be found directly investigating a workplace fitness program and its effect on mental task performance. Wilson and Wheeler (1991) conducted a study investigating the relationship between participation in a worksite fitness program and mental task performance and reaction time. The fitness program included aerobic activity, resistance training, and stretching and participants were tested on grammatical reasoning and reaction time. Exercisers were those who exercised at lunchtime on Mondays, Wednesdays, and Fridays, while non-exercisers were those who did not exercise on any day of the week. Participants were tested Monday through Thursday during their morning and afternoon breaks. Exercisers were found to have significantly better reaction times, however, no differences were found between the two on the grammatical reasoning test. This study has a number of limitations and rather poor design. For example, the response buttons were wired incorrectly so all "false" responses were not recorded. Also, the timing of the tests were set for convenience, not when it would be most appropriate to see changes in cognitive functioning as a result from participation in exercise. The only cognitive functions the study looked at were grammatical reasoning and reaction time. More importantly, however, was the design limitation of relying on a cross-sectional design, which makes the determination of cause and effect impossible. For these reasons, the results should be viewed with caution.

The following studies examine additional benefits of physical activity and/or fitness programs in the work setting. Burton, McCalister, Chen, and Edington (2005) conducted a study investigating the differences between fitness center participants and non-participants in individual health status and productivity. They found that fitness center participants reported less work impairment (such as health related limitations for time-management, physical work, output limitations, and overall work impairment) than fitness center non-participants. This suggests that there is a positive association between productivity and participation in worksite fitness. Also, the fitness center participants had significantly lower claims of short-term disability (absenteeism) due to health problems than non-participants.

In a study looking at varying levels of participation in an employee fitness program and its effect on absenteeism, Lechner and de Vries (1997) found that greater participation was associated with fewer absences. Participants were classified into high participation, low participation, and no participation groups. The high participation group showed a decline of 4.8 sick days per year. While this decline did not prove to be statistically significant, if proven reliable, this difference in absenteeism could save a company a large amount of money in lost time.

Pronk et al. (2004) conducted a study to examine the relationship between lifestyle-related modifiable health risks, specifically physical activity, cardiorespiratory fitness, and obesity, and work functioning. They found higher levels of physical activity to be correlated with higher self-reported overall job performance. Cardiorespiratory fitness was also found to be predictive of the amount of work performed and the amount of extra effort required to complete a task. Obesity was found to relate to a number of work-related decrements. For example, obesity was associated with problems with interpersonal relationships (getting along with coworkers), more missed days from work, and high health care costs.

Robin (2003) discusses the movement of Canadian companies offering comprehensive wellness programs to their employees. These programs may include a variety of options such as an onsite gym/fitness center, yoga classes, smoking cessation courses, nutrition information, and mental and spiritual health sessions. One company reported a $3 to $4 return for every dollar invested stemming from reduced absenteeism, less extended health benefits, and fewer disability payouts. Another company showed that employees who used the health program and also were members of the company gym took an average of 4.3 sick days compared to 6.34 sick days taken by employees who did not participate. This gave them a 4 to 1 return on their investment. A third company saved $6 million in insurance payments and has seen a 5% decrease in employees who smoke as a result of the implementation of their wellness initiative.

Thus, existing data support the implementation of fitness centers for factors related to employee performance, however, no well-designed study has examined the use of fitness centers and/or physical activity and their relationship with cognition.

In summary, research to date has found that both chronic and acute exercise improves overall mental health and has cognitive benefits for young/middle aged adults as well as for older adults. Also, fitness center participation is related to improved employee performance. By tying these two concepts together, the relationship between acute exercise and performance on everyday, work-specific tasks can be examined.

CHAPTER III

METHOD

Participants

Current participants from a previously established walking group, Downtown Walking Adventures (a program that promotes physical activity), were asked to volunteer. All participants were currently walking on Monday, Wednesday, and Thursday on their lunch break in downtown Greensboro, North Carolina. All participants were white-collar employees from businesses in the downtown area. Once asked to volunteer, consent was given by their participation and completion of the questionnaire and cognitive testing. The procedures of this study were reviewed and approved by the University of North Carolina at Greensboro Institutional Review Board.

Unfortunately, the level of participant cooperation was not high. An informational email explaining the study and asking for volunteers was sent to approximately 600 individuals. However, it was not possible to determine how many people actually received the message. Out of the 600, only thirty-five individuals expressed interest in participating, and only 6 completed all of the necessary tasks. For this reason, only data from the demographic survey (n=22), the walking test (n=6), and the non-walking test (n=6) were used. Of the 35 original volunteers, 22 completed the demographic survey which revealed that 19 participants were female and 3 were male, with a mean age of 45.8 (SD= 8.77). The sample was predominantly Caucasian (81.8%) and African American (18.2%). Descriptive data was available for 5 of the 6 participants who completed both the walk test and the non-walk test and revealed a mean age of 43.8 (*SD*=11.58), 100% classification as Caucasian, and 4 females and 1 male. This data indicated that 20% (*n*= 1) often and 80% (*n*= 4) sometimes engage in any regular activity long enough to work up a sweat during their leisure time in a 7 day period.

Procedures

Each participant was asked to complete a series of tasks. First, they were asked to complete a demographic questionnaire and to take shorter, practice versions of the cognitive tests to ensure that they understood the directions. Next, depending on their assignment, they were asked to either walk or not walk on their lunch break. They were then supposed to take the cognitive tests two hours after returning from their walk or regular lunch break. Following this the participants were asked to complete a short questionnaire about their daily activities for that day. Participants were then asked later in the week to complete the same series of events, beginning with walking or not walking on their lunch break (which ever they did not do the previous time).

Acute Exercise

The participants in the study checked-in with the Walking Adventures' staff, indicating that they were walking for that day, and received the daily walking route. The walking routes varied in distance from 1.5 to 2 miles depending on the particular day and took and average of 30-45 minutes to complete. Each participant self-selected his or her pace, yet was encouraged to walk at a moderate intensity. Individuals could choose to walk by themselves, with another, or in a group. Participants proceeded to walk the route and then returned back to work.

Materials

Prior to taking the cognitive tests, each participant completed a short electronic questionnaire providing demographic information (see Appendix A). Other descriptive data was collected through the physical activity questionnaire, which provided information for that specific day (see Appendix B). This helped ensure that people who were supposed to walk, or not walk, acted accordingly. This physical activity questionnaire was not analyzed with the other data because very few participants completed the questionnaire.

Both of these questionnaires were designed on Survey Monkey. This program enables one to create unique surveys with a number of different question types, randomize the order of choices, create skip logic (allowing the question order to be determined by a specific response), collect results anonymously, and analyze the results. Access to the tests was sent in a link via email that took the participants directly to the specific survey they needed to complete.

To test cognition, four computerized tests were used. To test reaction time (simple information processing and speed of response selection), the Arrow Reaction Time Test was used. This is a measure of choice reaction time. The program displays an arrow facing left or right and the participant presses the corresponding arrow key on his/her computer. The corrected response time and the percentage of errors were recorded. The percentage of errors served as a quality control measure to ensure that if response speed increased, accuracy did not suffer. If there are no errors made, the corrected response time is simply the average of the response times for all responses. If errors are made, the corrected response time comes from a formula that combines speed and accuracy while imposing a penalty for errors:

$$\text{Corrected RT} = \frac{(\sum \text{RTs of correct responses} + 2(\sum \text{RTs of incorrect responses})}{\text{Number of Correct Responses}}$$

The percentage of errors comes from the following equation:

$$\text{Percentage of errors} = \frac{\text{The number of incorrect responses}}{\text{The total possible number of responses}} \times 100$$

The Arrow Flankers Test was used to test attention (direction and concentration of cognitive resources) with the existence of distraction. This test displays five symbols, four flanker symbols and a center symbol that is always an arrow pointing left or right. The flankers may be shapes, symbols or arrows. The participant presses the corresponding arrow on the keyboard pointing the same direction as the center arrow. Overall mean response time and total number of incorrect responses were recorded. The total number of incorrect responses served as a quality control measure, ensuring that as response speed improved, accuracy was maintained. In addition, the response time to each type of stimulus (the type of flanker) is also recorded separately. There are three types of stimuli: congruent stimuli which are arrows pointing in the same direction as the center arrow, incongruent stimuli which are arrows pointing in the opposite direction as the center arrow, and neutral stimuli which are shapes or symbols not related to the direction of the center arrow. Task complexity increases and reaction time is expected to increase from the congruent trials to the neutral trials to the incongruent trials.

The Continuous Attention Task measures vigilance (the ability to maintain an alert state) by flashing patterns of 3X3 black and white squares on the screen. A response is required when two consecutive patterns are the same. The number of correct responses was recorded.

N-back Test was used to measure working memory (the ability to hold information in memory while actively processing it) by using long sequences of letters. For each letter the participant indicates if the letter is a target or a non-target. The target letter is defined by the condition. For example, if the condition is 1 back, the letter is the target if it matches the previous letter. If the condition is 2 back, the letter is a target if it matches the letter before the previous letter. For example, if the condition is 2-back and the stimulus is 8-3-4-7-2-7-9-1-2-1, the participant should respond on the second 7 and the second 1. Research consistently demonstrates that the task difficulty increases from 1-back to 3-back. For these tests, the number of correct responses and the overall mean response time were recorded. The overall mean response time was a control measure to see if those with a higher number of correct responses were taking an exceptionally longer time to respond.

These four aspects of cognitive function [reaction time, attention with distraction, continuous attention (vigilance), and working memory] were chosen because they are all used in daily work activities and performance on them was expected to decline as the workday progressed. Thus, an improvement of these four abilities would lead to a more productive afternoon at the office. In addition, the literature with acute exercise suggests that these cognitive tasks will be sensitive to the hypothesized facilitory effects of exercise.

Participants accessed the test via a link sent in an email. In each email sent, there was a link with a unique identification number embedded within it. This allowed each set of test results to be linked with the corresponding participant by his/her identification number. The participant identification numbers were different for each time he/she completed the tests. For example, the same participant (id # 01) was identified as 1001 and 2001; the first number of each indicated if this was the first or second time he/she took the test and the last two numbers indicated the participant identification number. Once the tests were complete the program closed and returned the user to his/her previous computer window.

The cognitive tests used came from Penscreen.com. This company, headed by Brian Tiplady, specializes in cognitive test development and deployment. Tiplady's tests have been used in commercial, academic and governmental research projects. They are designed to test changes in cognitive functions such as speed and accuracy of performance, ability to concentrate, memory, understanding, and problem solving.

Statistical Analysis

A within-subjects analysis utilized dependant t-tests to see if there were significant differences between the mean scores of the different testing conditions (walking versus non-walking) for each test within the group of participants who completed each set of tests for both conditions. The t-tests used were one-tailed since only improvements in cognitive functioning were expected as a result of moderate intensity aerobic exercise. Due to the small sample size and the exploratory nature of the study, there was no adjustment made for experiment-wise error.

CHAPTER IV

RESULTS

Table 1 shows the descriptive data of the different testing conditions (walking versus non-walking) for each test within the group of participants who completed all tests for both conditions (n=6). Of the 6 participants, 3 performed the walk condition first and 3 performed the no-walk condition first.

Arrow Reaction Time Test. Results indicated that corrected response time was significantly different as a function of condition, $t(5)=2.36$, $p<.05$, with participants performing more quickly after walking (M=436.17, SD=90.66) than on a day when they did not walk (M=460.67, SD=96.98). There was not a significant difference in the percentage of errors, $t(15)=0.96$, $p>.05$.

Arrow Flankers Test. Mean response time for congruent stimuli, $t(5)=2.33$, $p<.05$, mean response time for neutral stimuli, $t(5)=2.43$, $p<.05$, mean response time for incongruent stimuli, $t(5)=2.53$, $p<.05$, and overall mean response time $t(5)=2.73$, $p<.05$ were significantly different as a function of condition. Examination of the means (as seen in Table 1) indicated that the average response time for the walking condition was significantly faster than for the no walking condition. The total number of incorrect responses, $t(5)=-0.42$, $p>.05$, did not significantly differ as a function of condition.

Continuous Attention Test. The number of correct responses, $t(5)=-0.54$, $p>.05$ was not found to be significantly different as a function of condition.

N Back 1 Test. The number of correct responses, $t(5)=1.00$, $p>.05$ and the overall mean response time, $t(5)=-0.19$, $p>.05$ were both not significantly different relative to condition.

N Back 2 Test. The number of correct responses, $t(5)=0.15$, $p>.05$ and the overall mean response time, $t(5)=0.50$, $p>.05$ were not significantly different as a function of condition.

Table 1.

Within Subjects Descriptive Data.

Test	Cognitive Task	Condition	Mean	Standard Deviation	Effect Size
Arrow Reaction Time Test					
	Corrected Response Time				
		No Walk	460.67	96.98	0.36*
		Walk	436.67	90.66	
Arrow Flankers Test					
	Mean Response Time for Congruent Stimuli				
		No Walk	589.50	146.40	0.24*
		Walk	556.67	126.95	
	Mean Response Time for Neutral Stimuli				
		No Walk	604.83	193.16	0.29*
		Walk	554.83	147.90	
	Mean Response Time for Incongruent Stimuli				
		No Walk	660.17	118.87	0.33*
		Walk	611.67	88.87	
Continuous Attention Test					
	Number Correct Responses				
		No Walk	8.00	2.10	0.15
		Walk	8.30	1.97	
N Back 1 Test					
	Number Correct Responses				
		No Walk	11.83	0.41	-0.36
		Walk	11.50	1.22	
N Back 2 Test					
	Number Correct Responses				
		No Walk	10.67	0.82	-0.01
		Walk	10.5	2.35	

Note. n=6, * indicates *walk* and *no walk* means are significantly different, p<.05. Effect sizes calculated using a pooled standard deviation.

CHAPTER V

DISCUSSION

Past research suggests that increases in certain cognitive functions should result from participation in moderate intensity physical activity. However, no quality study has been done in a real-world setting to investigate the effects of an acute bout of moderate physical activity on cognitive functioning. Therefore, the purpose of this study was to provide a real-world test of the relationship between the performance of an acute bout of moderate physical activity (walking) during the lunch hour and subsequent cognitive performance in the workplace. Analyses were conducted to examine within-subject differences in cognitive performances relative to the condition (walking or not walking).

Results from the within subjects analysis supported the hypotheses. Significant differences were found in response time of the Arrow Reaction Time Test and on the Arrow Flankers Test. The Arrow Reaction Time test was designed to assess choice reaction time. Thus, these results are consistent with previously known information that physical activity improves reaction time (Tomporowski, 2003).

The Arrow Flankers Task was designed to assess attention with the existence of a distraction. Findings on this test were remarkably consistent with significant differences in speed of performance being observed for neutral, congruent, and incongruent stimuli, and for overall mean response time in this task. This is also consistent with past research and with reviews demonstrating that there should be improvements in response speed and information processing (differentiating between unlike stimuli and responding accordingly) as a result of participation in acute exercise (Tomporowski, 2003; Wilson & Wheeler, 1991). The Arrow Flankers Test has been used in a number of studies similar to this one. For example, Casey et al. (2000) found that when testing attention with the presence of a distraction, mean response scores were faster for compatible (congruent) trials (*M*=464 msec with a 2% error rate) than for incompatible (incongruent) trials (*M*=508 msec with a 6% error rate). Importantly, the means and errors recorded in this study, which was conducted in a field setting, are similar to past research findings in yielding faster response times for congruent trials (*M*=573.09 msec) than incongruent trials (*M*=635.92 msec) and in demonstrating low error rates (overall percentage of errors =1.04%). The Arrow Flankers Task is also considered to be a measure of executive function; therefore, these results are also consistent with past research (Colcombe & Kramer, 2003; Hillman, Snook, & Jerome, 2003; Molloy et al. 1988) in supporting a positive effect of acute exercise on the performance of executive function tasks.

The Continuous Attention Test has been shown to be a valid measure of vigilance (Tiplady, 1992) with an error rate of less than 4%. The current study found an average error rate of 3.75%, showing equivalent validity in a field setting as well. However, in this study, the results were not significant as a function of exercise.

Performance on the N-Back Tests (designed to assess working memory) did not differ as a function of the performance of physical activity. The N-Back Tests have also been used in past research. In a study looking at the differences in cognitive performance between age groups the N Back test was found to have an error rate of 6.8% for individuals over the age of 60 years old (Dobbs & Rule, 1989). In the current study, the average error rate was only 0.77%, indicating that field administration did not have a deleterious effect on accuracy of performance. Also, the error rate for the current study is most likely lower as a result of a younger sample.

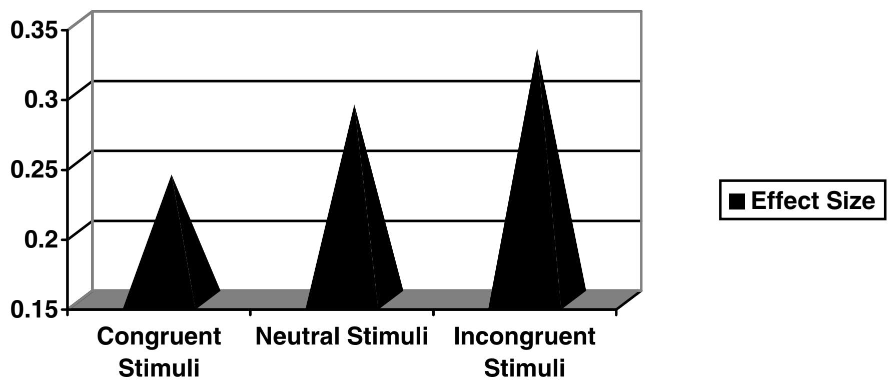
There is no existing literature that has specifically examined physical activity and vigilance, however; generally speaking, attention has been found to improve as a result of exercise (Tomporowski, 1997; Gondola, 1987). Most of the existing literature that demonstrates the positive effects of physical activity on memory does so with older adults (Khatri et al., 2001; Clarkson-Smith & Hartley; 1989, Molloy, et al, 1988). Perhaps the sample in this study was too young to see significant improvements in working memory resulting from the physical activity performed. Since generally healthy young and middle-aged adults do not usually show deficits in working memory it is unlikely that noticeable changes will occur as a result of exercise.

The argument has been made that decreases in cognitive function, specifically memory, come as a result of the decline in physical health associated with age, not necessarily aging alone (Stacey, Kozma, & Stones, 1985). This leads to the decrease in available cognitive resources. Exercise is thought to stimulate the central nervous system, making these resources more readily available (Netz & Jacob, 1994; Brisswalter, Collardeau, & Rene, 2002). For this reason, older adults show stronger improvements in memory resulting from exercise than do young or middle aged adults.

In addition, exercise has been found to be most beneficial with highly complex tasks, during which, a number of resources are tapped (Colcombe & Kramer, 2003;

Tomporowski, 1997). This study supports this research. As difficulty increases in the Arrow Flankers Task (from congruent, to neutral, to incongruent) the effect sizes increase as well. These findings suggest that the improvements in cognitive performance resulting from exercise increases in correlation with the increasing difficulty of the task.

Figure 1. Effect Sizes of the mean response times from the Arrow Flankers Test.



Consequently, it is logical to predict that future research investigating increases in cognitive performance resulting from exercise, will find that individuals in highly cognitive jobs might experience the most benefit from exercise during the workday.

Overall, the within-subjects findings suggest that an acute bout of moderate physical activity results in an increase in certain cognitive functions, specifically reaction time and executive function. This is the first study to demonstrate that the effects of moderate physical activity on cognition can be demonstrated in the work-setting, suggesting that the benefits of physical activity for cognition are not limited to laboratory settings. This is extremely valuable to employers looking to get the most out of their employees. It shows that moderate physical activity done during the workday improves performance on cognitive functions that might be important for the performance of everyday work tasks.

Study Limitations

There are a number of limitations in this study. To begin with, a very small sample of people is represented. Due to lack of participation and cooperation, the sample had much lower numbers than anticipated. Time constraints at work, lack of interest, disapproval of supervisor(s), and fear that the results of testing could become available to others are potential reasons that individuals did not volunteer to participate. An email was sent to approximately 600 people explaining the study and asking for volunteers. It was expected that at least 50 people would participate so that a within subjects analysis could be used. These numbers would have yielded stronger statistical power. That being said, it is important to note that even with such small numbers the results indicated that there is some cognitive improvement resulting from moderate physical activity as seen in the within subjects analysis. Demographically speaking, the sample of interest, middle aged, healthy, working adults, was represented.

The main problem that arose was that the volunteers did not complete all of the necessary tasks. In an introductory email, potential participants were given information pertaining to what would be expected of them. Once they agreed to participate, further detail was given about the specific times of the exercise and the tests. Emails were sent every day (as necessary) reminding the participants what was needed of them to complete their part of the study. Nevertheless, for some reason they did not complete everything. Perhaps they did not have the time to complete these tasks in their workday, unexpected events repeatedly came up preventing them to do so, or they simply changed their minds and no longer wanted to participate. Whatever the reason, only one person out of 35 correctly completed all the tasks. In addition, environmental distractions and interruptions while taking the test could not be controlled for.

Another limitation is that most of the participants were somewhat physically active to begin with. As previously mentioned, most of them were walking for 30 to 45 minutes a day, three days a week. Perhaps the results would have been more powerful if the population was sedentary or, conversely, these cognitive benefits related to acute exercise might not be evident in sedentary adults.

All of the correspondence with the participants was done via email, partly due to the fact that the investigator could not physically be in more than one place at a time and several participants needed to be tested simultaneously. However, it was thought that this would be the most efficient way to organize the study; after all, most business professionals are frequently checking their email. In hindsight, maybe this was not the best method for insuring participant compliance with the instructions; since the researcher was not physically present, the participants had little accountability. It is much easier to delete an email reminder than it is to ignore someone standing there.

An additional limitation may relate to the collection of the cognitive data on a computer. A study by Tseng, Tiplady, Macleod, and Wright (1998) investigated the effects of testing modality (the use of Personal Digital Assistants, PDAs, computers, and pen and paper) on anxiety. It was found that computer anxiety can possibly affect the results of cognitive function assessments. However, it can be argued that the participants in the current study have rather low anxiety associated with computer use. The majority, if not all, of their workday is spent working on a computer. In addition, society, as a whole, is much more adapted to computers now than they were in 1998. While it is certainly possible, it seems unlikely that computer anxiety affected cognitive testing scores in the current study. In addition, the performance data obtained in this study is generally similar to findings in the literature from lab-based experiments, thus the integrity of the tests does not appear to have been compromised by the field administration.

Directions for Future Research

It is believed that this study could be redone with the same population and be more successful if perhaps it was done within one corporation with the support of management. This way, participants would not feel guilty about using work time to participate. Also, getting management involved may spark some interest to get such fitness programs established, which is the ultimate goal.

In addition, such a study could be done with any type of moderate physical activity, not just walking. Walking was chosen based on the accessibility of the sample; however, the extant literature would suggest that any form of moderate intensity physical activity should result in cognitive benefits. A variety of activities might provide better compliance and a better appreciation for the aspects of the exercise that are important for cognitive benefits.

The most important concept that needs to be further investigated is the effect of physical activity on certain cognitive functions that are applicable to everyday work tasks. This study begins to show that physical activity improves certain aspects of cognitive functioning that are used in the workplace. There is already a wide array of research pertaining to cognition in a laboratory setting, yet these are not applicable to everyday work tasks and settings. Employers are ultimately responsible for the implementation and promotion of physical activity programs; therefore, they are the ones who need to be shown additional convincing data supporting the validity of such programs.

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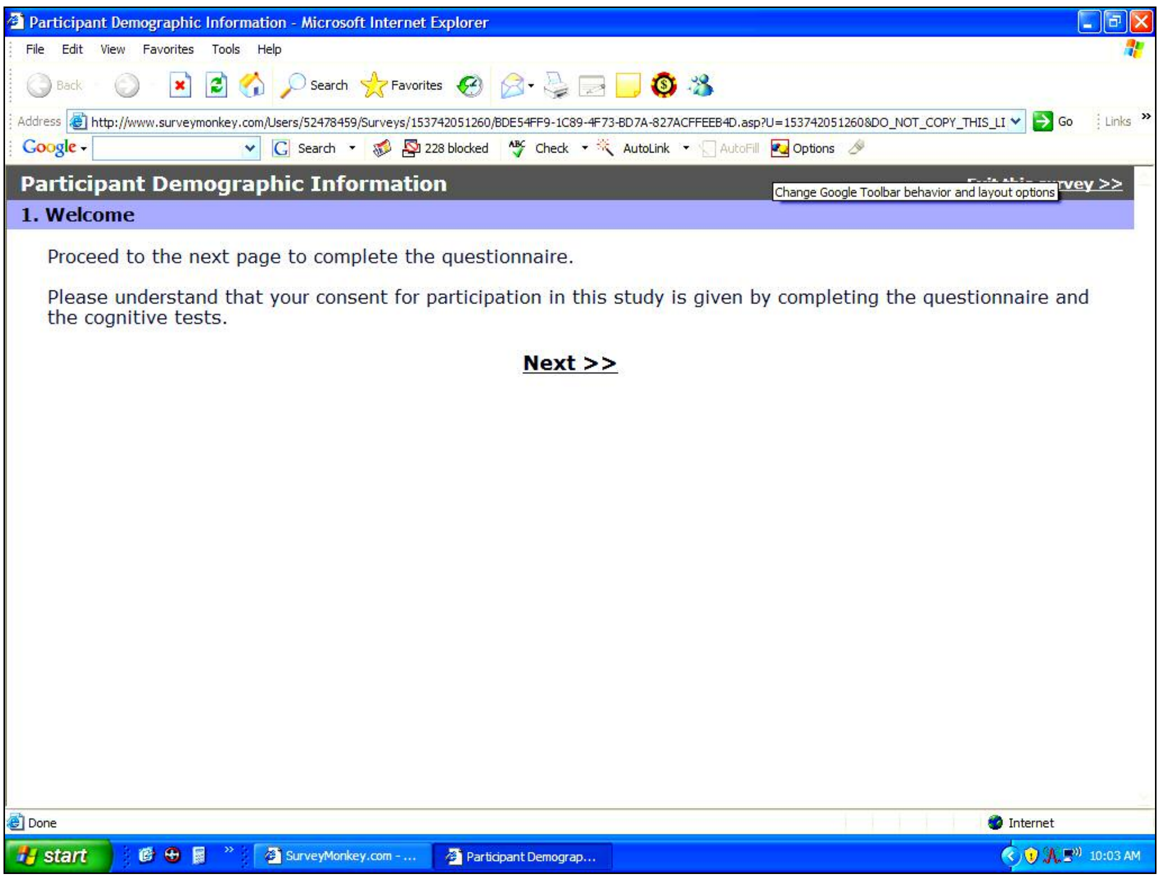
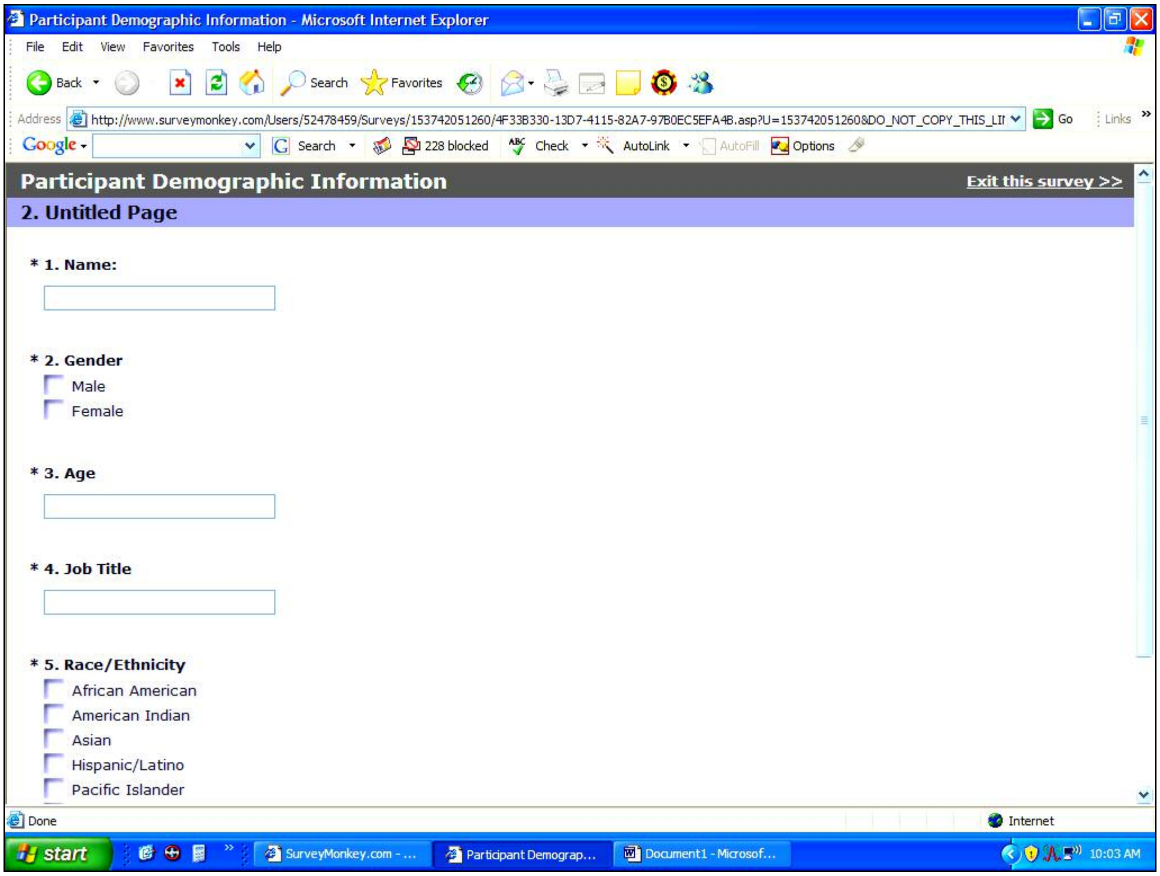
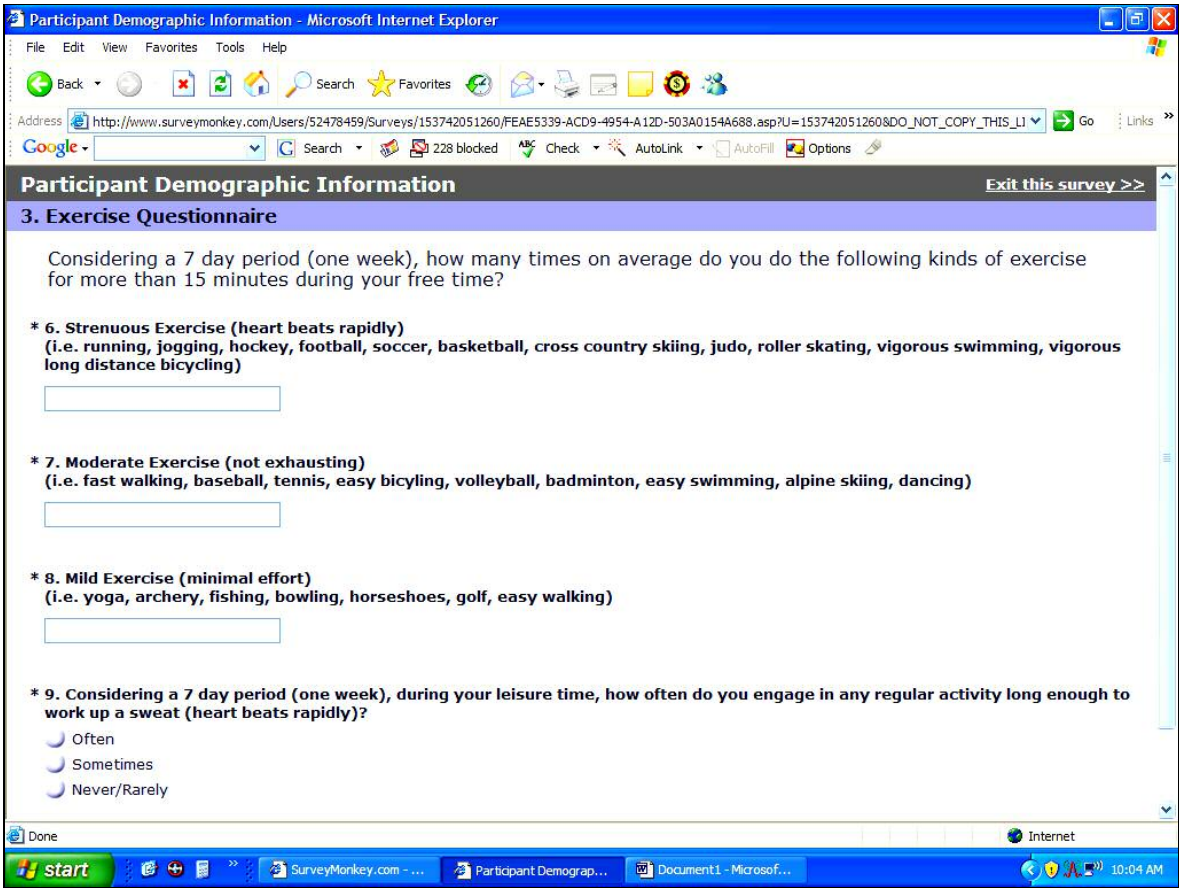
APPENDIX A

Participant Demographic Questionnaire
(taken from website used)

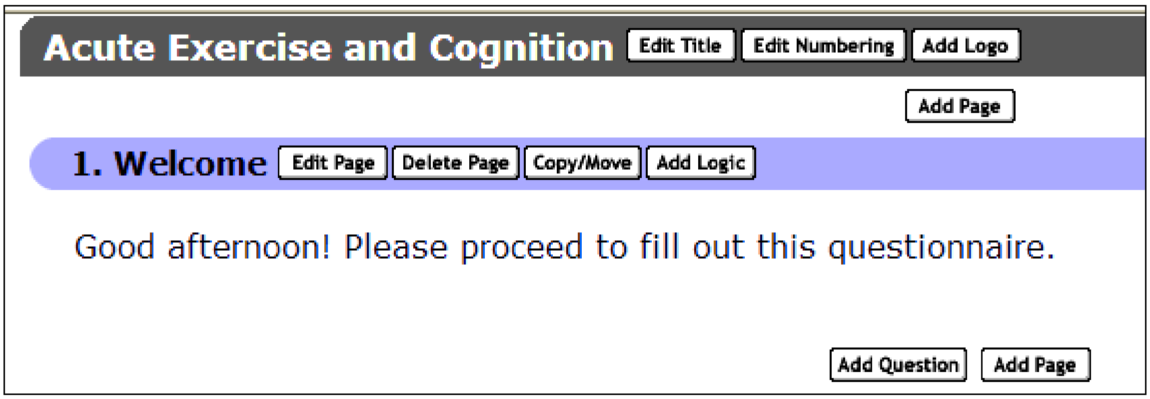



Participant Demographic Information - Microsoft Internet Explorer
Participant Demographic Information
Exit this survey >>
2. Untitled Page
* 1. Name:
* 2. Gender
Male
Female
* 3. Age
* 4. Job Title
* 5. Race/Ethnicity
African American
American Indian
Asian
Hispanic/Latino
Pacific Islander


Participant Demographic Information - Microsoft Internet Explorer
Participant Demographic Information
Exit this survey >>
3. Exercise Questionnaire
Considering a 7 day period (one week), how many times on average do you do the following kinds of exercise for more than 15 minutes during your free time?
* 6. Strenuous Exercise (heart beats rapidly)
(i.e. running, jogging, hockey, football, soccer, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)
* 7. Moderate Exercise (not exhausting)
(i.e. fast walking, baseball, tennis, easy bicyling, volleyball, badminton, easy swimming, alpine skiing, dancing)
* 8. Mild Exercise (minimal effort)
(i.e. yoga, archery, fishing, bowling, horseshoes, golf, easy walking)
* 9. Considering a 7 day period (one week), during your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?
Often
Sometimes
Never/Rarely

APPENDIX B

Participant Daily Activity Questionnaire
(taken from website used)

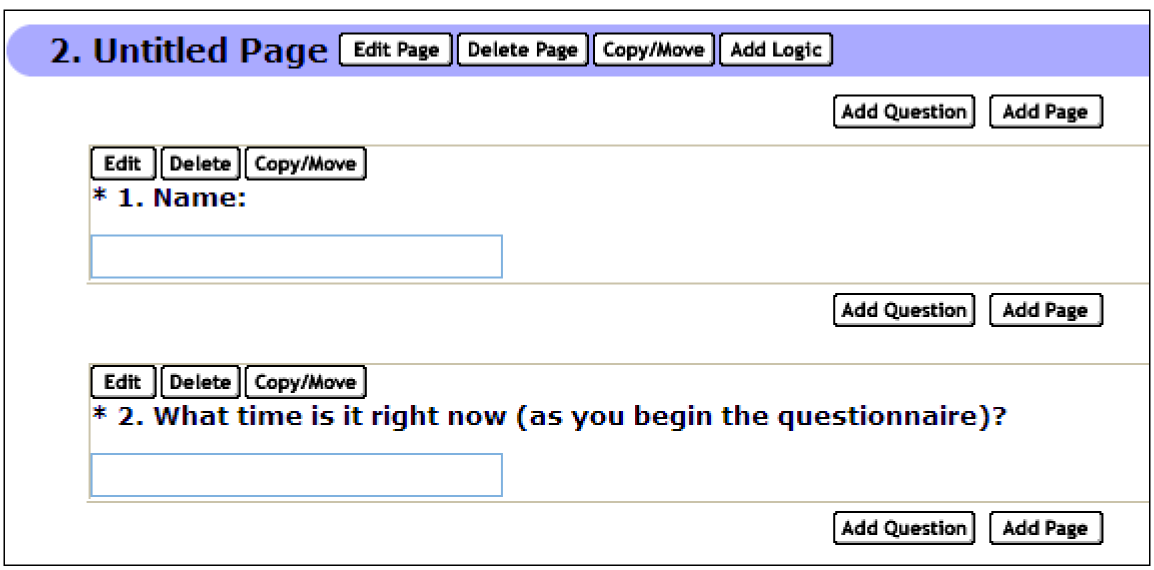

Acute Exercise and Cognition Edit Title Edit Numbering Add Logo

Add Page

1. Welcome Edit Page Delete Page Copy/Move Add Logic

Good afternoon! Please proceed to fill out this questionnaire.

Add Question Add Page


2. Untitled Page Edit Page Delete Page Copy/Move Add Logic

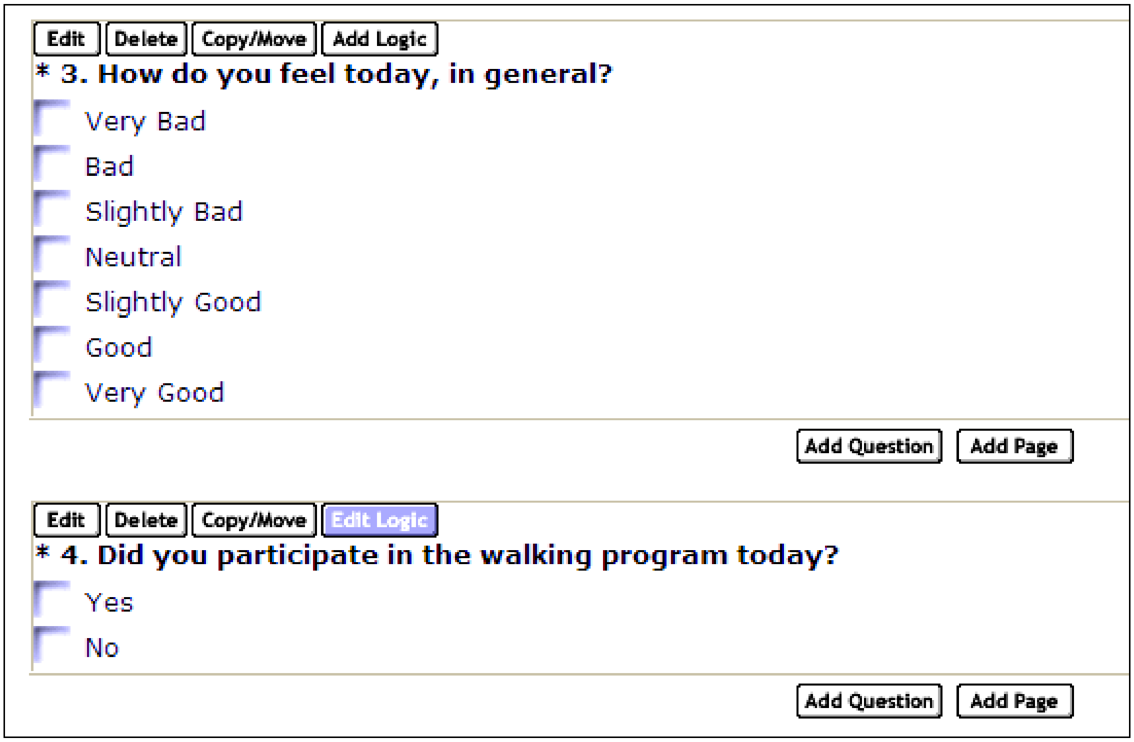
Add Question Add Page

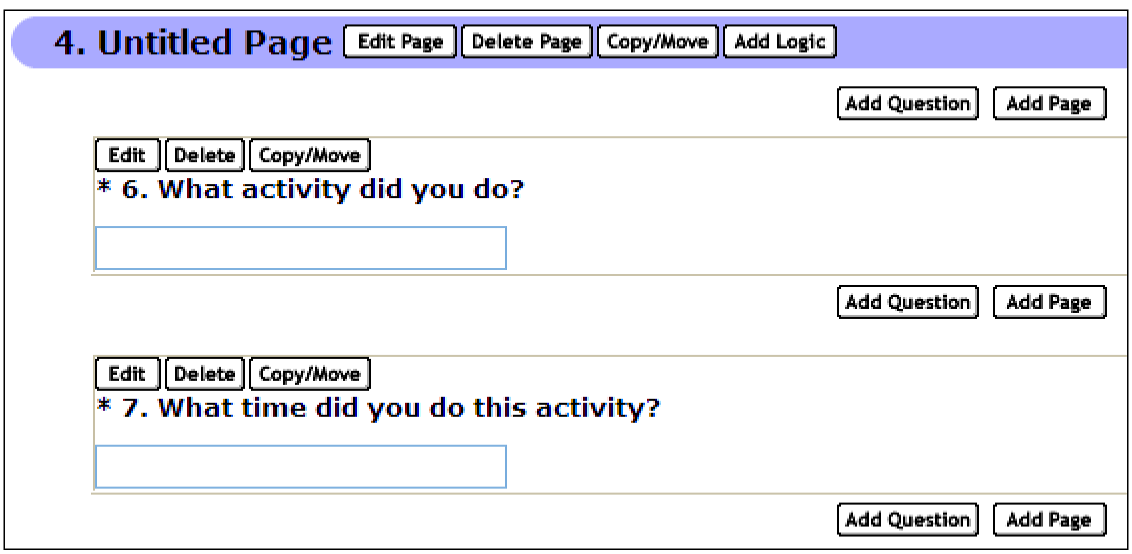
Edit Delete Copy/Move
* 1. Name:

Add Question Add Page

Edit Delete Copy/Move
* 2. What time is it right now (as you begin the questionnaire)?

Add Question Add Page


Edit
Delete
Copy/Move
Add Logic
* 3. How do you feel today, in general?
Very Bad
Bad
Slightly Bad
Neutral
Slightly Good
Good
Very Good
Add Question
Add Page
Edit
Delete
Copy/Move
Edit Logic
* 4. Did you participate in the walking program today?
Yes
No
Add Question
Add Page


4. Untitled Page
Edit Page
Delete Page
Copy/Move
Add Logic
Add Question
Add Page
Edit
Delete
Copy/Move
* 6. What activity did you do?
Add Question
Add Page
Edit
Delete
Copy/Move
* 7. What time did you do this activity?
Add Question
Add Page

Edit | Delete | Copy/Move

*** 8. How long were you engaged in the activity? (in minutes)**

Add Question | Add Page

Edit | Delete | Copy/Move | Edit Logic

*** 9. How would you rate your intensity during this activity?**

- Easy/Light
- Moderate
- Moderate/High
- High

Add Question | Add Page

5. Untitled Page

Edit Page | Delete Page | Copy/Move | Add Logic

Add Question | Add Page

Edit | Delete | Copy/Move

*** 10. What time did you walk?**

Add Question | Add Page

Edit | Delete | Copy/Move

*** 11. How long did you walk? (in minutes)**

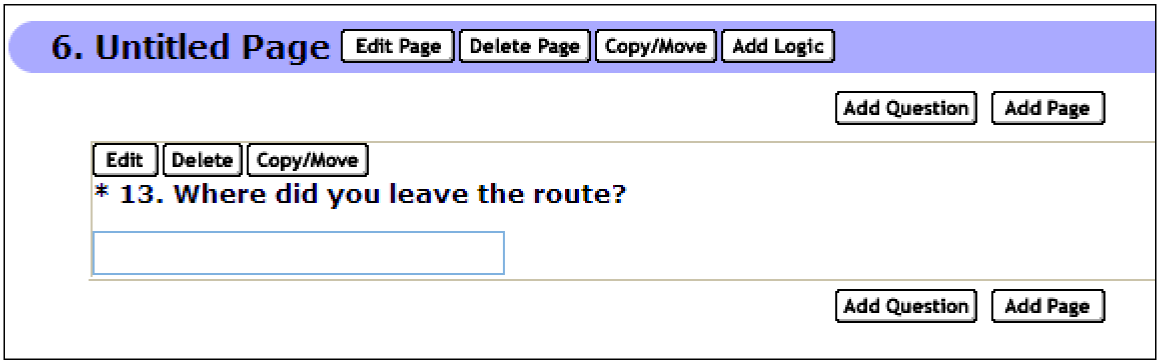
Add Question | Add Page

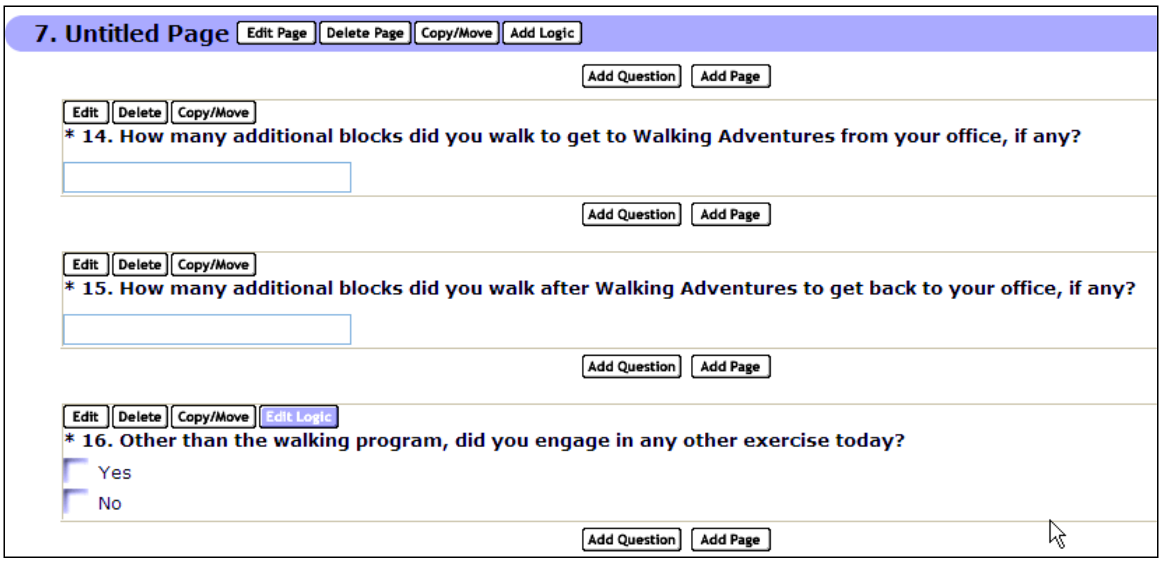
Edit | Delete | Copy/Move | Edit Logic

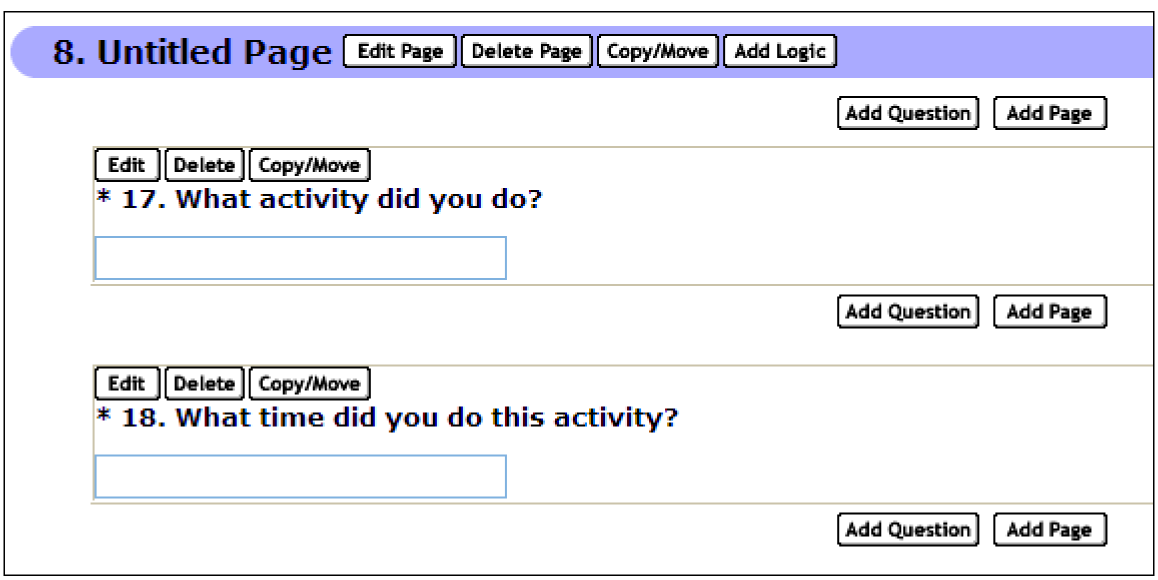
*** 12. Did you complete the entire walking route?**

- Yes
- No

Add Question | Add Page


6. Untitled Page
Edit Page
Delete Page
Copy/Move
Add Logic
Add Question
Add Page
Edit
Delete
Copy/Move
* 13. Where did you leave the route?
Add Question
Add Page


7. Untitled Page
Edit Page
Delete Page
Copy/Move
Add Logic
Add Question
Add Page
Edit
Delete
Copy/Move
* 14. How many additional blocks did you walk to get to Walking Adventures from your office, if any?
Add Question
Add Page
Edit
Delete
Copy/Move
* 15. How many additional blocks did you walk after Walking Adventures to get back to your office, if any?
Add Question
Add Page
Edit
Delete
Copy/Move
Edit Logic
* 16. Other than the walking program, did you engage in any other exercise today?
Yes
No
Add Question
Add Page


8. Untitled Page
Edit Page
Delete Page
Copy/Move
Add Logic
Add Question
Add Page
Edit
Delete
Copy/Move
* 17. What activity did you do?
Add Question
Add Page
Edit
Delete
Copy/Move
* 18. What time did you do this activity?
Add Question
Add Page

Edit | Delete | Copy/Move

*** 19. How long were you engaged in this activity? (in minutes)**

Add Question | Add Page

Edit | Delete | Copy/Move | Add Logic

*** 20. How would you rate your intensity during this activity?**

- Easy/Light
- Moderate
- Moderate/High
- High

Add Question | Add Page

9. Untitled Page

Edit Page | Delete Page | Copy/Move | Add Logic

Add Question | Add Page

Edit | Delete | Copy/Move | Add Logic

*** 21. What did you do today on your lunch break? Please check all that apply.**

- Walk in walking program
- Eat by self
- Eat with others
- Run errands
- Work through lunch
- Other (please specify)

Add Question | Add Page

10. Thank You!

Edit Page | Delete Page | Copy/Move | Add Logic

Thank you for completing this survey! Have a great afternoon.

Add Question | Add Page