MOOD, MOTIVATION, MEMORY AND ATTENTION EFFECTS OF BRIEF STAIR WALKING COMPARED TO A LOW DOSE OF CAFFEINE ON FEMALE HABITUAL CAFFEINE USERS WITH SHORT SLEEP DURATIONS

by

DEREK DUANE RANDOLPH

(Under the Direction of Patrick O'Connor)

ABSTRACT

The aim of this experiment was to compare the influence of 10-minutes of low-to-moderate perceived intensity stair walking to a low dose of caffeine and placebo on mood, cognitive performance and motivation in college female caffeine users with chronic insufficient sleep. A repeated measures crossover experiment was conducted with 18 college women who reported (i) daily caffeine use, (ii) typical physical activity, and (iii) sleeping <45 hours per week. Measures of mood, working memory, sustained attention, simple reaction time, and motivation to complete the cognitive tasks were measured before and twice after all treatments. Results showed that exercise (i) increased vigor at Post-1 compared to both placebo and caffeine, and (ii) attenuated the slowing of simple reaction time that occurred in the placebo condition. A brief bout of low-to-moderate perceived intensity stair walking has energizing effects that exceed a low dose of caffeine for active young women with chronic insufficient sleep.

INDEX WORDS: attention, energy, exercise, fatigue, vigor, reaction time

MOOD, MOTIVATION, MEMORY AND ATTENTION EFFECTS OF BRIEF STAIR WALKING COMPARED TO A LOW DOSE OF CAFFEINE ON FEMALE HABITUAL CAFFEINE USERS WITH SHORT SLEEP DURATIONS

by

DEREK DUANE RANDOLPH

BS, Georgia Gwinnett College, 2014

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2016

MOOD, MOTIVATION, MEMORY AND ATTENTION EFFECTS OF BRIEF STAIR WALKING COMPARED TO A LOW DOSE OF CAFFEINE ON FEMALE HABITUAL CAFFEINE USERS WITH SHORT SLEEP DURATIONS

by

DEREK DUANE RANDOLPH

Major Professor:	Patrick J. O'Connor
Committee:	Phillip D. Tomporowski
	Michael D. Schmidt

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2016

DEDICATION

To my loving wife. I would not be where I am today without you. Thank you for all of your hard-work, sacrifices, support, encouragement, and love that you have provided over the last few years. It has been a long journey but we made it! Now, it is your turn!

ACKNOWLEDGEMENTS

Thank you, Dr. O'Connor for being an amazing mentor, teacher, and all around great guy! I have learned so much from you the past couple of years and I have grown as an individual under your guidance. Thank you, Dr. Tomporowski for agreeing to be on my committee and challenging me to learn and know the purpose and reason for doing things the right way. Thank you, Dr. Schmidt, for also agreeing to be on my committee and for always being in high spirits. I enjoyed being in your class and your sense of humor always made me laugh.

Thank you to the members of the Exercise Psychology Lab: Christie, Jake, Bryan, Katie, Kristen, and Danny. It was great getting to know all of you and you became like a second family to me. Thanks for always answering my questions and providing help when I needed it. I would also like to thank my research assistants Drew and Will. Without your help this would have not been completed in such a short amount of time!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Periods of low energy or fatigue often occur in work or school environments. Fatigue and low energy can impact both productivity and general health. In the United States, surveys reveal that ~14% of men and ~20% of women suffer from persistent fatigue and it is believed that even more cases are never reported. Even with cases not being reported, tiredness and exhaustion still account for over two million visits to the hospital each year (Lewis & Wessely, 1992). In studies comparing the sex-related differences in fatigue, women are more likely to report having fatigue symptoms (Nisenbaum, Reyes, Mawle, & Reeves, 1998). Women also tend to report more severe symptoms of fatigue than men (Kroenke, Mangelsdorff, Meier, & Powell, 1988). In one study, two-thirds of the participants that showed signs of fatigue at a primary care facility were women (Nelson, et al., 1987). Fatigue is often a result of one or many lifestyle factors especially physical inactivity and lack of sleep (Steenbruggen, Hoekstra, & van der Gaag, 2015). Sleep can have a large impact on the feelings of fatigue and energy and cognitive function. When sleep has been restricted to 4-5 hours a night for one week, feelings of fatigue are increased and feelings of energy are decreased (Dinges, et al., 1997). Another study showed that acute sleep deprivation (30 hours) leads to increased fatigue (Scott, McNaughton, & Polman, 2006). These same studies showed that decreased sleep negatively impacted cognitive performance. These observations are consistent with a meta-analysis which showed that even one night of sleep loss negatively effects sustained attention, working memory, and executive functions (Lim & Dinges, 2010). The common suggestion for treatment of fatigue is often to get more rest. When that does not work the treatment of fatigue may depend on the cause. Two methods known to be effective in transiently reducing fatigue and increasing energy are caffeine and exercise. A large number of studies have shown that caffeine, even in low doses of 25 to 50 mg, can lead to an increase in alertness or reduce symptoms of fatigue in low arousal situations (Smit & Rogers, 2000). Some individual studies show dose-response effects but there has not been a comprehensive quantitative review documenting the overall size of the effect of caffeine on mood or cognitive performance or the extent to which the main effect is moderated by dose or type of cognitive test (Hewlett & Smith, 2007).

An alternative method to reduce symptoms of fatigue is through acute exercise. Fatigue has been shown to be reduced after a single bout of moderate intensity exercise in both regular exercisers and non-exercisers (Hoffman & Hoffman, 2008). The results of a meta-analysis showed that an acute bout of exercise increases feelings of energy. The same meta-analysis also showed that fatigue is reduced after exercise but only when changes in energy are increased moderately after a bout of low-to-moderate intensity exercise lasting more than 20 minutes (Loy, O'Connor, & Dishman, 2013). Little is known about the effects of a 10-minute bout of exercise on fatigue and energy feelings. While aerobic exercise consistently increases feelings of energy, the mode has often been walking, running, or biking. A less utilized method is stair walking as the mode of exercise. Walking stairs has cardiovascular benefits and is a common exercise mode (Teh & Aziz, 2002) but its psychological consequences have rarely been studied.

Therefore, the purpose of this experiment was to compare the influence of 10-minutes of low-to-moderate perceived intensity stair walking to the consumption of capsules containing 50 mg caffeine or flour (placebo) on mood, cognitive performance and motivation for the cognitive tasks in physically active, college female caffeine users with chronic insufficient sleep.

Chapter 2 of this thesis provides a review of low energy and fatigue, possible causes and cognitive decrements caused by low energy and fatigue, current treatments for low energy and fatigue. Next, a review of studies involving caffeine and acute exercise with those with low energy and fatigue are discussed.

Chapter 3 of this thesis describes an experiment that was conducted to compare the mood and cognitive effects of a 10-minute bout of stair walking to 50 mg caffeine and a placebo in young, physically active, caffeine using, adult women with chronic insufficient sleep.

References

Dinges, D., Pack, F., Williams, K., Gillen, K. A., Powell, J. W., Ott, G. E., . . . Pack, A. I. (1997). Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. *Sleep, 20*(4), 267-277.

Hewlett, P., & Smith, A. (2007). Effects of repeated doses of caffeine on performance and alertness: new data and secondary analyses. *Human Psychopharmacology: Clinical and Experimental*, *22*(6), 339-350.

Hoffman, M. D., & Hoffman, D. R. (2008). Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Archives of Physical Medicine and Rehabilitation*, *89*(2), 358-363.

Kroenke, K., Mangelsdorff, A. D., Meier, N. J., & Powell, J. B. (1988). Chronic fatigue in primary care: prevelence, patient characteristics and outcome. *Journal of the American Medical Association*, *86*, 929-934.

Lewis, G., & Wessely, S. (1992). The epidemiology of fatigue: more questions than answers. *Journal of epidemiology and community health*, *46*(2), 92.

Lim, J., & Dinges, D. F. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological bulletin, 136*(3), 375.

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*(4), 223-242.

Nelson, E., Kirk, J., McHugo, G., Douglass, R., Ohler, J., Wasson, J., & Zubkoff, M. (1987). Chief complaint fatigue: a longitudinal study from the patient's perspective. *Family Practice Research Journal, 6*(4), 175-188.

Nisenbaum, R., Reyes, M., Mawle, A. C., & Reeves, W. (1998). Factor analysis of unexplained severe fatigue and interrelated symptoms. *American Journal of Epidemiology, 148*(1), 72-77.

Scott, J. P., McNaughton, L. R., & Polman, R. C. (2006). Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior, 87*, 396-408.

Smit, H. J., & Rogers, P. J. (2000). Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. *Psychopharmacology, 152,* 167-173. doi:10.1007/s002130000506

Steenbruggen, T. G., Hoekstra, S. J., & van der Gaag, E. J. (2015). Could a change in diet revitalize children who suffer from unresolved fatigue? *Nutrients, 7*(3), 1965-1977.

Teh, K. C., & Aziz, A. R. (2002). Heart rate, oxygen uptake, and energy cost of ascending and descending the stairs. *Medicine & Science in Sports & Exercise, 34*(4), 695-699.

CHAPTER 2

LITERATURE REVIEW

The purpose of this chapter is to review relevant background information.

Definition of Energy and Fatigue

In this thesis the term energy is defined as subjective feelings of having the capacity to complete mental of physical activities. The term fatigue is defined as subjective feelings of having a reduced capacity to complete mental or physical activities. The vigor and fatigue subscales of the Profile of Mood States are commonly used to provide measures of energy and fatigue and these constructs are thought to be related but separate. The terms "energy" and "fatigue" are often used to describe times of tiredness and exhaustion. Therefore, our purpose here is to clarify how we defined and used these terms for our purposes. Fatigue is often described as extreme tiredness and exhaustion that is not usually alleviated by rest. The term "vigor" is used to describe feelings of energy and is considered a separate construct from fatigue.

Prevalence of Fatigue and Low Energy

Almost all people suffer from some form of fatigue or symptoms of low energy in their lifetime. Fatigue is a growing concern worldwide and impacts both productivity and general health. It has been shown that persistent fatigue of one month or more has a prevalence of about 20% worldwide (Wessely, Hotopf, and Sharpe, 1998). A sample of 4591 twins reported a lifetime prevalence of any fatigue of 36.7% and prolonged fatigue of 22.5% (Furberg, et al., 2005). Tiredness and exhaustion can be severe and has been estimated to account for over two million visits to the hospital each year (Lewis & Wessely, 1992). United States population surveys reveal that the lifetime prevalence of persistent fatigue among adults is ~15% (Cunningham, Ford, Chapman, Liu, & Croft, 2015).

In studies examining sex-related differences, women are two to three times more likely to report having fatigue symptoms than men (Chen, 1986; Nelson, et al., 1987; Nisenbaum, Reyes, Mawle, & Reeves, 1998; Furberg, et al., 2005). Women also tend to report more severe symptoms of fatigue than men (Chen, 1986; Nisenbaum, Reyes, Mawle, & Reeves, 1998; Kroenke, Mangelsdorff, Meier, & Powell, 1988; Furberg, et al., 2005). In one study two-thirds of the participants that showed signs of fatigue at a primary care facility were women (Nelson, et al., 1987).

Possible Causes of Fatigue

Many medical conditions, such as the flu, allergies, asthma, and sleep apnea can lead to the symptoms of low energy or fatigue (Berger, Mitchell, Jacobsen, & Pirl, 2015; Johnson, Deluca, Diamond, & Natelson, 1998). Fatigue is interrelated with perceptions of stress and mental health problems like anxiety and depression (Palmer, 2013; Penner, et al., 2015). The overall cause of fatigue symptoms or low energy is challenging to determine, but is often reported as the most debilitating symptom of many diseases. Medications that treat physical and mental illnesses can cause fatigue (Wang, Wang, Wang, & Chen, 2014; Zlott & Byrne, 2010; Lee, Miller, Townson, & Anton, 2010). Fatigue also can be a result of one or many lifestyle factors especially physical inactivity and lack of sleep. (Steenbruggen, Hoekstra, & van der Gaag, 2015; Akerstedt, 1995).

It is important to recognize that researchers in multiple areas, including nutrition (O'Connor, 2006), human factors (Hockey R. , 2013), sleep (Harvey, 2002), psychopharmacology (Lorist & Tops, 2003), and psychiatry (Stahl, 2002) have generated models of mental fatigue. The complex and multiple causes of mental fatigue and their interactions are incompletely understood and no consensus model has emerged as best. Because the present thesis has an applied focus it does not have as a goal to test the available competing theoretical models of mental fatigue.

Fatigue, Sleep Loss and Reduced Cognitive Function and Motivation

Many studies have observed effects that fatigue can have on cognition. In one study, the learning and cognitive performance of college age adults were shown to be negatively impacted by fatigue (Palmer, 2013). This observation is consistent with research on chronic fatigue patients, that showed that mental fatigue led to a significant impairment of both spatial memory and sustained attention (Capuron, et al., 2006). Fukuda et al. (2010) observed that fatigue is associated with poor school performance. Other research shows that attention, information processing (Van der Linden & Eling, 2006) and short-term memory (Johnson, Deluca, Diamond, & Natelson, 1998) are negatively impacted by symptoms of fatigue.

Sleep can have a large impact on the feelings of fatigue and cognitive function. Acute sleep deprivation (30 hours) leads to increased fatigue and decrements in cognitive performance (Scott, McNaughton, & Polman, 2006). These observations are consistent with a meta-analysis which showed that even one night of sleep loss negatively affects sustained attention, working memory, and executive function (Lim & Dinges, 2010). When sleep has been restricted to 4-5 hours a night for one week, feelings of fatigue are increased and cognitive performance is reduced (Dinges, et al., 1997). Reviews of the influence of sleep deprivation on cognitive performance indicate that sleep deprivation has its greatest effects on attention and working memory but this might be the result of reductions in motivation which also occur in response to sleep loss (Alhola & Polo-Kantola, 2007).

Current Treatments for Fatigue and Low Energy

Medications can be used to treat fatigue symptoms. Amantadine, methylphenidate and modafinil have been found to reduce fatigue (Johansson, Wentzel, Andrell, Mannheimer, & Ronnback, 2015; Shaygannejad, Janghorbani, Ashtari, & Zakeri, 2012; Lou, et al., 2009). Cognitive behavior therapy (CBT) is an intervention that attempts to help individuals deal with the effects of behavior-induced fatigue. Individuals must be able to identify behaviors that lead to fatigue, such as excessive alcohol use or not enough sleep, and then change their fatigue-inducing behaviors over time (Lange, Cook, & Natelson, 2005).

Physical activity is a behavior that has been shown to be an effective treatment for the symptoms of fatigue. Aerobic exercise has been found to be safe and improve physical function, fitness, and quality of life for people with medical illnesses that are characterized by fatigue (Stagl, Antoni, Lechner, Carver, & Lewis, 2014). Healthy sedentary adults consistently show improvements in fatigue after adopting a regular exercise program (Martin, Church, Thompson, Earnest, & Blair, 2009) or even following a single bout of exercise (Loy, O'Connor, & Dishman, 2013).

Caffeine, Fatigue, and Low Energy

A large number of studies have shown that caffeine, even at doses as low as 25-50 mg (a 12 oz cola has ~45 mg), can lead to an increase in alertness or reduction in symptoms of fatigue in low arousal situations (Smith, 2002; Childs & de Wit, 2006; Smit & Rogers, 2000; Haskell, Kennedy, Wesnes, & Scholey, 2005). Caffeine is effective in increasing the alertness and cognitive performance among fatigued people (Rogers, 2007). Some studies show dose-response effects but there has not been a comprehensive quantitative review documenting the overall size of the effect of caffeine on mood or cognitive performance or the extent to which the main effect is moderated by dose or type of cognitive test (Hewlett & Smith, 2007).

Caffeine enters the blood stream, crosses the blood-brain barrier, and quickly acts on brain neurons. Mood and cognitive effects of caffeine can occur within 15 minutes of caffeine consumption and such effects are well documented 30 to 60-minutes post-consumption. The mechanism by which caffeine alters alertness, feelings of energy, and cognitive performance is its ability to block adenosine receptors (mostly type A1 and A2) in mood- and cognitive-related neural brain circuits (Fredholm, Ijzerman, Jacobson, Linden, & Muller, 2011).

Effects of Acute Exercise on Low Energy and Fatigue

An alternative method to reduce symptoms of fatigue is through acute exercise. Fatigue has been shown to be reduced after a single bout of moderate intensity exercise in both regular exercisers and non-exercisers (Hoffman & Hoffman, 2008). One study showed that after 10, 20, or 30 minutes of exercise on a bicycle ergometer vigor increased and fatigue was reduced (Hansen, Stevens, & Coast, 2001). Resistance exercise also has been shown to be effective for increasing vigor and reducing fatigue (Herring & O'Connor, 2009). The results of a meta-analysis showed that acute bouts of exercise increase feelings of energy by a standardized effect size of 0.47. The same meta-analysis also showed that fatigue is not usually reduced after exercise but it is when feelings of energy are increased to a moderately large degree after a bout of low-to-moderate intensity exercise lasting more than 20 minutes (Loy, O'Connor, & Dishman, 2013). Little is known about the effects of 10 minute bouts of exercise on energy or fatigue, but exercise bouts of 30-seconds to 10-minutes are increasingly suggested as useful for improving various health outcomes (Holmstrup, Fairchild, Keslacy, Weinstock, & Kanaley, 2014; Wollseiffen, et al., 2015).

While aerobic exercise consistently increases feelings of energy, the mode has often been walking, running, or biking. A less utilized method is stair walking as the mode of exercise. Walking stairs produces robust physiological responses and is a common activity of daily life for many (Teh & Aziz, 2002). Stair walking has been shown to be effective in reducing cardiovascular health risks in previously sedentary young women (Boreham, et al., 2005). To the author's knowledge, no studies of fatigued individuals have documented the psychological consequences of a single, short bout of stair walking on outcomes such as attention, working memory, motivation to perform cognitive work or feelings of energy. One study has used an incremental step test to observe the changes in mood during different stages of pregnancy. The results showed that while pregnant women's mood tended to worsen (decreased vigor and increased fatigue and confusion) after stair walking, the non-pregnant control group's mood improved (Williams, Reilly, Campbell, & Sutherst, 1988).

Summary

Many illnesses and life choices can elicit symptoms of fatigue and low energy. Fatigue can lead to decreased cognition, school and work productivity, and quality of life. Two methods known to be effective in transiently reducing fatigue and increasing energy are caffeine and exercise. Both of these methods have been shown to have limited risks and side effects in young healthy people. These interventions also have benefits beyond reducing fatigue including improved cognitive function. The influence of a single bout of exercise appears to have never been compared to a single dose of caffeine in the same experiment. There is a need to know if a short practical bout of exercise can boost mental energy and how it compares to other practical ways to increase energy such as through the consumption of caffeine. Thus, the purpose of this experiment was to compare the influence of 10-minutes of low-to-moderate perceived intensity stair walking to the consumption of capsules containing 50 mg caffeine or flour (placebo) on mood, cognitive performance and motivation for the cognitive tasks in physically active, college female caffeine users with chronic insufficient sleep.

References

Akerstedt, T. (1995). Work hours and sleepiness. *Neurophysiologie Clinique/Clinical Neurophysiology, 25*(6), 367-375.

Alhola, P., & Polo-Kantola, P. (2007). Sleep deprevatioin: Impact on cognitive performance. *Neuropsychiatric Disease and Treatment, 3*(5), 553-567.

Berger, A. M., Mitchell, S. A., Jacobsen , P. B., & Pirl, W. F. (2015). Screening, evaluation, and managment of cancer-related fatigue: Ready for implementation to practice? *CA: a cancer journal for clinicians, 65*(3), 190-211.

Boreham, C., Kennedy, R. A., Murphy, M. H., Tully, M., Wallace, W., & Young, I. (2005). Training effects of short bouts of stair climbing on cardiorespiratory fitness, blood lipids, and homocysteine in sedentary young women. *British Journal of Sports Medicine, 9*, 590-593.

Capuron, L., Welberg, L., Heim, C., Wagner, D., Solomon, L., Papanicolaou, D., . . . Reeves, W. C. (2006). Cognitive dysfunction relates to subjectie report of mental fatigue in patients with chronic fatigue syndrome. *Neuropsychopharmacology, 31*(8), 1777-1784.

Chen, M. (1986). The epidemiology of self-perceived fatigue among adults. *Preventive Medicine, 15*, 74-81.

Childs, E., & de Wit, H. (2006). Subjective, behavioral, and physiological effects of acute caffeine in light, nondependent caffeine users. *Psychophamacology, 185*, 514-523. doi:10.1007/s00213-006-0341-3

Cunningham, T. J., Ford, E. S., Chapman, D. P., Liu, Y., & Croft, J. B. (2015). Independent and joint associations of race/ethnicity and educational attainment with sleep-related symptoms in a population-based U.S. sample. *Preventive Medicine, 77*, 99-105.

Dinges, D., Pack, F., Williams, K., Gillen, K. A., Powell, J. W., Ott, G. E., . . . Pack, A. I. (1997). Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. *Sleep, 20*(4), 267-277.

Fredholm, B. B., Ijzerman, A. P., Jacobson, K. A., Linden, J., & Muller, C. E. (2011). International Union of Basic and Clinical Pharmacology. LXXXI. Nomenclature and classification of adenosine receptors-an update. *Pharmacological Reviews, 63*(1), 1-34.

Fukuda, S., Yamano, E., Joudoi, T., Mizuno, K., Tanaka, M., Kawatani, J., . . . Watanabe, Y. (2010). Effort-reward imbalance for learning is associated with fatigue in school children. *Behavioral Medicine, 36*(2), 53-62.

Furberg, H., Olarte, M., Afari, N., Goldberg, J., Buchwald, D., & Sullivan, P. (2005). The prevalence of self-reported chronic fatigue in a U.S. twin registry. *Journal of Psychomatic Research, 59*, 283-290.

Hansen, C. J., Stevens, L. C., & Coast, J. R. (2001). Exercise duration and mood state: How much is enough to feel better? *Health Psychology, 20*(4), 267-275.

Harvey, A. (2002). A cognitive model of insominia. *Behaviour Research and Therapy, 40*, 869-893.

Haskell, C. F., Kennedy, D. O., Wesnes, K. A., & Scholey, A. B. (2005). Cognitive and mood improvements of caffeine in habitual consumers and habitual non-consumers of caffeine. *Psychopharmacology, 179*, 813-825. doi:10.1007/s00213-004-2104-3

Herring, M. P., & O'Connor, P. J. (2009). The effect of acute resistance exercise on feelings of energy and fatigue. *Journal of Sports Sciences, 27*(7), 701-709.

Hewlett, P., & Smith, A. (2007). Effects of repeated doses of caffeine on performance and alertness: new data and secondary analyses. *Human Psychopharmacology: Clinical and Experimental, 22*(6), 339-350.

Hockey, R. (2013). *The psychology of fatigue: work, effort and control.* Cambridge University Press.

Hoffman, M. D., & Hoffman, D. R. (2008). Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Archives of Physical Medicine and Rehabilitation, 89*(2), 358-363.

Holmstrup, M., Fairchild, T., Keslacy, S., Weinstock , R., & Kanaley, J. (2014). Multiple short bouts of exercise over 12-h period reduce glucose excursions more than an energy-matched single bout of exercise. *Metabolism, 63*, 510-419.

Johansson, B., Wentzel, A., Andrell, P., Mannheimer, C., & Ronnback, L. (2015). Methylphenidate reduces mental fatigue and improves processing speed in persons suffered a traumatic brain injury. *Brain Injury, 29*(6), 1-8.

Johnson, S. K., Deluca, J., Diamond, B. J., & Natelson, B. H. (1998). Memory dysfunction in fatiguing illness: Examining interference and distractioin in short-term memory. *Cognitive Neuropsychiatry, 3*(4), 269-285.

Kroenke, K., Mangelsdorff, A. D., Meier, N. J., & Powell, J. B. (1988). Chronic fatigue in primary care: prevelence, patient characteristics and outcome. *Journal of the American Medical Association, 86*, 929-934.

Lange, G., Cook, D. B., & Natelson, B. H. (2005). Rehabilitation and treatment of fatigue. In J. DeLuca, *Fatigue as a window to the brain* (pp. 301-316). Cambridge, MA: MIT Press.

Lee, A., Miller, W., Townson, A., & Anton, H. (2010). Medication use is associated with fatigue in a sample of community-living individuals who have a spinal cord injury: a chart review. *Spinal Cord, 48*(5), 429-433.

Lewis, G., & Wessely, S. (1992). The epidemiology of fatigue: more questions than answers. *Journal of epidemiology and community health, 46*(2), 92.

Lim, J., & Dinges, D. F. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological bulletin, 136*(3), 375.

Lorist, M. M., & Tops, M. (2003). Caffeine, fatigue, and cognition. *Brain and Cognition, 53,* 82-94.

Lou, J.-S., Dimitrova, D. M., Park, B. S., Johnson, S. C., Eaton, R., Arnold, G., & Nutt, J. G. (2009). Using modafinil to treat fatigue in parkinson disease: a double-blind, placebo-controlled pilot study. *Clinical Neuropharmacology, 32*(6), 305-310.

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*(4), 223-242.

Martin, C. K., Church, T. S., Thompson, A. M., Earnest, C. P., & Blair, S. N. (2009). Exercise dose and quality of life. *Archives of Internal Medicine, 169*(3), 269-278.

Nelson, E., Kirk, J., McHugo, G., Douglass, R., Ohler, J., Wasson, J., & Zubkoff, M. (1987). Chief complaint fatigue: a longitudinal study from the patient's perspective. *Family Practice Research Journal, 6*(4), 175-188.

Nisenbaum, R., Reyes, M., Mawle, A. C., & Reeves, W. (1998). Factor analysis of unexplained severe fatigue and interrelated symptoms. *American Journal of Epidemiology, 148*(1), 72-77.

O'Connor, P. J. (2006). Mental energy: Developing a model for examining nutrition-related claims. *Nutrition Reviews, 64*(7), S2-S6.

Palmer, L. (2013). The relationship between stress, fatigue, and cognitive functioning. *College Student Journal*, *47*(2), 312-325.

Penner, I., Sivertsdotter, E. C., Celius, E. G., Fuchs, S., Schreiber, K., Berko, S., & Svenningsson, A. (2015). Improvement in fatigue during natalizumab treatment is linked to improvement in depression and day-time sleepiness. *Frontiers in Neurology*, *6*. doi:10.3389/fneur.2015.00018

Rogers, P. (2007). Caffeine, mood and mental performance in everyday life. *Nutrition Bulletin, 32*(s 1), 84-89.

Scott, J. P., McNaughton, L. R., & Polman, R. C. (2006). Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior, 87*, 396-408.

Shaygannejad, V., Janghorbani, M., Ashtari, F., & Zakeri, H. (2012). Comparison of the effect of aspirin and amantadine for the treatment of fatigue in multiple sclerosis: a randomized, blinded, crossover study. *Neurological Research, 34*(9), 854-858.

Smit, H. J., & Rogers, P. J. (2000). Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. *Psychopharmacology*, *152*, 167-173. doi:10.1007/s002130000506

Smith, A. (2002). Effects of caffeine on human behavior. *Food and Chemical Toxicology, 40*, 1243-1255.

Stagl, J. M., Antoni, M. H., Lechner, S. C., Carver, C. S., & Lewis, J. E. (2014). Postsurgical physical activity and fatigue-related daily interference in women with breast cancer. *Psychology and Health, 29*(2), 177-198.

Stahl, S. (2002). The psychopharmacology of energy and fatigue. *The Journal of Clinical Psychiatry, 63*(1), 7-8.

Steenbruggen, T. G., Hoekstra, S. J., & van der Gaag, E. J. (2015). Could a change in diet revitalize children who suffer from unresolved fatigue? *Nutrients, 7*(3), 1965-1977.

Teh, K. C., & Aziz, A. R. (2002). Heart rate, oxygen uptake, and energy cost of ascending and descending the stairs. *Medicine & Science in Sports & Exercise, 34*(4), 695-699.

Van der Linden, D., & Eling, P. (2006). Mental fatigue disturbs local processing more than global processing. *Psychological research, 70*(5), 395-402.

Wang, S.-S., Wang, J.-J., Wang, P.-X., & Chen, R. (2014). Determinants of fatigue after first-ever ischemic stroke during acute phase. *PLos ONE, 9*(10). doi:10.1371/journal.pone.0110037

Wessely, S., Hotopf, M., & Sharpe, M. (1998). *Chronic fatigue and its syndromes.* Oxford.

Williams, A., Reilly, T., Campbell, I., & Sutherst, J. (1988). Investigation of changes in responses to exercise and in mood during pregnancy. *Ergonomics, 31*(11), 1539-1549.

Wollseiffen, P., Ghadiri, A., Scholz, A., Struder, H. K., Herpers, R., Peters, T., & Schneider, S. (2015). Short bouts of intensive exercise during the workday have a positive effect on neuro-cognitive performance. *Stress and Health* .

Zlott, D. A., & Byrne, M. (2010). Mechanisms by which pharmacologic agents may contribute to fatigue. *PM&R, 2*(5), 451-455.

CHAPTER 3

STAIR WALKING IS MORE ENERGIZING THAN LOW DOSE CAFFEINE IN SLEEP DEPRIVED WOMEN [1]

[1] Randolph D.R. & O'Connor P. J. To be submitted to *Medicine and Science in Sports and Exercise*.

ABSTRACT

Purpose: The aim of this experiment was to compare the influence of 10-minutes of low-to-moderate perceived intensity stair walking to the consumption of capsules containing 50 mg caffeine or flour (placebo) on mood, cognitive performance and motivation for the cognitive tasks in physically active, college female caffeine users with chronic insufficient sleep.

Methods: A repeated measures crossover experiment was conducted with 18 college women (18-23 years) who reported (i) daily caffeine consumption that was not extreme (40-400 mg), (ii) typical leisure time physical activity that was not extreme (at least 2 weekly mild 15-minute or longer bouts and no more than 5 strenuous 15-minute or longer bouts), and (iii) sleeping less than 45 hours per week. Measures of mood (POMS-BF), working memory (N-Back), sustained attention (CPT), simple reaction time (SRT), and motivation to complete the cognitive tasks were measured before and twice after a 10-minute exercise condition (20 minutes seated rest followed by 10 minutes of low-to-moderate perceived intensity stair walking) and compared to both a caffeine condition (50 mg caffeine capsule followed by 30 minutes of seated rest) and a similar flour (placebo) capsule condition. Condition (exercise vs. placebo; exercise vs. caffeine; caffeine vs. placebo) X Time (Baseline, Post-1, Post-2, and Post-3) ANOVAs tested hypothesized exercise and caffeine improvement in all outcomes. **Results:** Condition x Time interactions showed that stair walking (i) increased POMS-BF vigor at Post-1 compared to both placebo and caffeine, and (ii) attenuated the slowing of simple reaction time that occurred in the placebo condition. **Conclusion:** A brief bout of low-to-moderate perceived intensity stair walking has transient energizing effects that exceed a low dose of caffeine for active young women with chronic insufficient sleep.

Key Words: attention, energy, exercise, fatigue, vigor, reaction time

INTRODUCTION

Fatigue can be defined in multiple ways, here the emphasis is on fatigue as subjective feelings of having a reduced capacity to complete mental or physical activities while energy is a separate but related construct defined as subjective feelings of having the capacity to complete mental of physical activities.

Feelings of low energy or fatigue are common and costly. One national cross-sectional survey of 28,902 U.S. workers found a 2-week prevalence of fatigue of 38%. Not only was fatigue significantly more prevalent in women than men but when compared to those without fatigue, fatigued workers were more than twice as likely to report health-related lost productive time and it was estimated that the lost productive time among workers with fatigue cost U.S. employers more than 100 billion annually (Ricci, Chee, Lorandeau, & Berger, 2007).

Feelings of low energy and fatigue can be caused by multiple factors including mental work, illness (e.g., depression, flu, heart failure), inadequate nutrition (e.g., dieting) (Steenbruggen, Hoekstra, & van der Gaag, 2015), drug use (e.g., alcohol) (Maruff, Falleti, Collie, Darby, & McStephen, 2005), physical inactivity (O'Connor & Puetz, 2005) and sleep loss (Kessing, Denollet, Widdershoven, & Kupper, 2015). Chronic partial sleep loss not only increases feelings of low energy and fatigue but has substantial effects on cognitive performance including decreased speed in working memory tasks and increased lapses of attention on tasks of sustained attention (Goel, Rao, Durmer, & Dinges, 2005).

One common temporary countermeasure for feelings of low energy and fatigue is to use caffeine. An average of about 180 mg caffeine is used daily by ~90% of adults in North America. There is a large body of research documenting the acute effects of caffeine and reviewers have concluded that caffeine is a psychostimulant that appears to have its largest effects on wakefulness, feelings of energy and fatigue, and cognitive performance including improvements in sustained attention and processing speed (Lorist & Tops, 2003). Some studies show that neurocognitive effects of caffeine are responsive to the dose but there has not been a comprehensive quantitative review documenting the overall size of the effect of caffeine on mood or cognitive performance or the extent to which the main effect is moderated by dose or type of cognitive test (Hewlett & Smith, 2007). Caffeine in doses between 100 and 200 mg increases motivation to perform cognitive tasks (Maridakis, Herring, & O'Connor, 2009; Maridakis, O'Connor, & Tomporowski, 2009). One small study suggests that the lowest discriminable dose of caffeine is 10 to 56 mg (Griffiths, et al., 1990), while another study has shown that a dose of caffeine as low as 12.5 mg can significantly affect feelings of energy and fatigue and some aspects of cognitive performance (Smit & Rogers, 2000). To put this in context, 12-oz cola drinks have 35 to 50 mg caffeine.

Acute exercise also is a psychostimulant that can have transient effects on cognition, motivation to perform cognitive work and feelings of energy and fatigue. Quantitative reviews of 40 to 79 studies, in general, have concluded that acute exercise has small transient beneficial effects on post-exercise cognitive performance which include improvement in reaction time and attention (Chang, Labban, Gapin, & Ethnier, 2012; Lambourne & Tomporowski, 2010). With regard to mood responses, one meta-analysis of 16 experiments showed that acute exercise consistently increases feelings of energy by an average standardized effect size of 0.47. The same meta-analysis showed that fatigue is not usually reduced after exercise but that fatigue is reduced when feelings of energy are increased to a moderately large degree after a bout of low-to-moderate intensity exercise lasting more than 20 minutes (Loy, O'Connor, & Dishman, 2013). Little is known about the influence of acute exercise on motivation to work on cognitive tasks.

One study found that 20 minutes of cycle exercise increased motivation to perform cognitive work in a sample of male college students with elevated symptoms of ADHD (Fritz & O'Connor, 2016).

Researchers rarely have examined the psychological consequences of short exercise bouts (≤ 10 minutes), therefore, whether brief bouts of exercise can produce psychostimulant effects is uncertain. A brief bout of exercise is practical, and potentially healthy, for workers who are permitted a 10- to 20-minute work break (Taylor, 2005). Walking stairs has cardiovascular benefits and is a common exercise mode that would be convenient for many workers, especially during periods of bad weather (Teh & Aziz, 2002). The psychological effects of acute stair walking exercise have not been investigated.

The purpose of this experiment was to compare the influence of 10-minutes of low-to-moderate perceived intensity self-paced stair walking to the consumption of capsules containing 50 mg caffeine or flour (placebo) on mood, cognitive performance and motivation for the cognitive tasks in physically active, college female caffeine users with chronic insufficient sleep. It was hypothesized that compared to the placebo condition, feelings of energy, performance on tests of attention and reaction time and self-reported motivation to perform cognitive work will improve equally after stair walking and caffeine consumption.

METHODS

Sample

Participants were recruited using listservs, flyers, and verbal announcements in academic classes. In order to qualify participants had to be female, 18-23 years old, who reported (i) consuming an average of 40 to 400 mg caffeine per day on 4 or more days per week (i.e., they neither abstained from caffeine nor consumed an extremely large amount [> 2SD above typical daily consumption in the United States]), (ii) mild or greater intensity exercise at least two or more times weekly for more than 15 minutes each time and no more than 5 strenuous, 15 minute or longer exercise bouts in a typical week (i.e., they are neither completely sedentary nor highly physically active in a typical week), and (iii) sleeping less than 45 hours per week. This total sleep duration represents about 2 hours less per night than a national sample of 4,546 United States females aged 19 to 22 years (Maslowsky & Ozer, 2014). Excluded were those who (i) have major health or medical condition or other contraindications to exercise, (ii) reported taking sleep medication during the prior month and (iii) reported higher than normal feelings of energy (>11 on POMS-BF vigor scale). All of the cognitive measures have been shown to have a high reliability between short time points within a single day. The sample of 18 was based on a statistical power analysis using SPSS (D'Amico, Neilands, & Zambarano, 2001). The power analysis assumed an alpha error of 0.05 and a correlation of r=.90 between repeated measures across time (Loy & O'Connor, 2016). The sample of 18 provided a statistical power of .81 for a hypothesized Condition X Time interaction effect size of 0.43.

Screening Questionnaires

A questionnaire was used to obtain demographic, sleep and health-related background information and to screen out participants that did not meet the inclusion criteria. 90 individuals completed the screening questionnaire, and 20 women met the study inclusion criteria. The Physical Activity Readiness Questionnaire (PAR-Q) is a 9-item questionnaire that was used to determine if an individual had contraindications to maximal exercise. The Godin Leisure-Time Exercise Questionnaire was used to estimate leisure-time physical activity. Respondents were asked to indicate “how many times on average” they completed more than 15 minutes of strenuous, moderate, or mild exercise during a typical 7-day period. Total weekly leisure activity was calculated in arbitrary units by summing the products of the separate components using the following formula: Total weekly leisure activity score = (9 X Strenuous) + (5 X Moderate) + (3 X Light) (Godin & Shephard, 1985). The Prior Week Caffeine Consumption Questionnaire is a 38 item questionnaire that asks about the types of caffeine, frequency, and dose that participants consume on a typical week (Loy, O'Connor, Lindheimer, & Covert, 2015). The Profile of Mood States – Brief Form is a 30 item questionnaire that was used to assess how the participants felt during the past week (McNair, Lorr, Heuchert, & Droppleman, 2003). Potential participants who scored above published norm on the vigor subscale were excluded.

Cognitive Tests

The Continuous Performance Task (CPT) was used to measure sustained attention. During the CPT the participants were presented with 12 different letters in Times New Roman (font size 60) (A, C, E, H, K, N, P, Q, S, U, X, Z), individually for 200 ms with an interstimulus interval of 800 ms. Participants were asked to respond to a target letter "X" but only when preceded by the cue letter "A." During an 8-minute testing period, there was a total of 92 correct responses and 480 total stimuli (Rosvold, Mirsky, Sarason, Bransome Jr., & Beck, 1956).

The N-Back is a type of continuous performance task that also assesses working memory (Kane, Conway, Miura, & Colflesh, 2007). The objective of the N-Back task is to match a presented stimulus (i.e. "A") with a previously displayed stimulus n-positions before. Two conditions were used in this version of the test. The 2-back condition required the participant to detect any letter that is the same as the letter presented two trials earlier (i.e. A, C, A). The 3-back required the participant to match the letter that was presented three trials before the current stimulus (i.e. A, E, C, A). Each condition consisted of 25 trials.

Simple reaction time was obtained to assess psychomotor speed. Participants were presented with a warning stimulus (fixation cross) followed by the signal stimulus (red circle). Participants were instructed to respond as fast as they could by pressing a button on the respond pad with their preferred hand. There were 3 practice trials followed by 5 test trials for the simple reaction time. The interval separating the warning stimulus and the signal stimulus ranged from 500 ms to 1000 ms.

Motivation to Perform Cognitive Tasks

Participants were asked to indicate their level of motivation to complete mental work on a visual analog scale (VAS). Responses ranged from "0" indicating "No Motivation" to 100 indicating "Highest Motivation Imaginable."

Heart Rate

A Polar heart rate monitor (V800) was used to assess the participant's resting and exercise heart rate (HR). Resting HR was obtained during standardized seated conditions on testing Day 1. HR was assessed during stair walking and averaged across 10-minutes to characterize HR during the activity. Maximal heart rate was estimated from 208 - 0.7 x age (Tanaka, Monahan, & Seals, 2001). The percentage heart rate reserve (HRR) during stair walking was estimated using the following formula: % HRR = (activity HR-HRrest)/(HRmax-HRrest) x 100 (Strath, et al., 2000). This was used to provide one estimate of the intensity of the exercise performed.

Perceptual Ratings

Ratings of perceived exertion (RPE) were obtained using Borg's 6-20 scale. The responses range from 6 (no exertion) to 20 (maximal exertion). Participants were provided with standardized instructions (Motl, O'Connor, Tubandt, Puetz, & Ely, 2006). Overall RPE was assessed immediately after each time the participant walked to the top of the stairwell. RPE values were averaged within each individual and used to provide a second measure of exercise intensity.

Ratings of perceived leg muscle pain intensity were obtained immediately after each RPE rating using standardized instructions and a category scale with ratio-like properties and responses that range from 0 (no pain at all) to 10 (extremely intense pain) (Cook, O'Connor, Eubanks, Smith, & Lee, 1997). These data provided an additional measure of the perceptual response to stair walking.

Mood

Subjective feelings of energy and fatigue were assessed using the Profile of Mood States-Brief Form (POMS-BF). This is a well-validated 30-item questionnaire used to assess the intensity of six different moods which include tension, depression, anger, confusion, vigor, and fatigue. Each mood was assessed from 5-items and possible responses ranged from 0 (indicating not at all) to 4 (indicating extremely) (McNair, Lorr, Heuchert, & Droppleman, 2003). Participants were instructed to report how they feel “right now, at this moment”.

Procedures

The experiment was a within participants, crossover design with one 10-minute exercise condition (20 minutes seated rest followed by 10 minutes of stair walking) compared with both a non-exercise caffeine condition (50 mg oral caffeine capsule consumption with 237 ml water followed by 30 minutes of seated rest) and an identical non-exercise flour capsule placebo condition. Order of treatment was blocked randomized in blocks of three (exercise, caffeine, placebo) so that 3 participants were assigned to each of the 6 possible orders. All testing was approved by the University of Georgia Institutional Review Board.

Female students were recruited via student listservs, in-class presentations, and flyers. Potential participants were directed to complete an online screening questionnaire administered via Qualtrics. The screening questionnaire included an informed consent for screening, a demographic, sleep and health-related questionnaire, PAR-Q, Godin Leisure-Time Exercise Questionnaire, Prior Week Caffeine Consumption Questionnaire, and the POMS-BF. Those completing the screening questionnaire were informed of their eligibility, and if eligible, were invited for baseline testing.

Habituation Day (Day 1) Upon arrival to the laboratory for the initial visit, the participants read the informed consent. If a participant chose to participate she then signed the informed consent. Next, height and weight were measured and participants were fitted with a Polar heart rate monitor to measure resting heart rate during the cognitive testing. Next, the participants performed practice trials of the cognitive tasks after being provided with instructions. If a participant was more than two standard deviations below our laboratory-derived historical accuracy averages on the CPT and N-back tasks (Maridakis, O'Connor, & Tomporowski, 2009; Lindheimer, O'Connor, McCully, & Dishman, 2016) they were asked to complete more practice trials to insure the instructions were understood. Three participants completed additional practice trials.

After completion of the practice trials the participant was provided with instructions for rating RPE and leg muscle pain intensity. Then the participant walked 90 meters to a stairwell and up and down 4 flights of stairs and practiced providing ratings of perceived exertion and leg muscle pain intensity.

Table 3.1 presents a time line of each phase of testing on Days 1 through 4.

Experimental Days (Days 2, 3, and 4) After participants arrived to the laboratory, they confirmed no caffeine within 6 hours of testing, no exercise the day of the visit, and a normal night's sleep (within one hour of typical sleep duration). A heart rate monitor was then self-affixed to the lower chest in a private room. Next, participants were asked to complete the brief form of the Profile of Mood States (POMS-BF) and indicate their level of motivation to complete the upcoming mental work on a visual analog scale (VAS). Participants then completed the first trial of cognitive tasks (i.e., baseline). Next, participants completed the POMS-BF, after which they were allocated to one of the three 30 minute conditions (placebo, caffeine, or stair walking).

The caffeine (50 mg, caffeine anhydrous, USP; purchased from Sciencelab.com and compounded by Add Drug, Athens, GA) and placebo (all-purpose flour) conditions involved swallowing a capsule (gray/yellow gelatin, size 2; Medlabsupply.com) with 237 ml water followed by 30 minutes of seated rest. The stair walking procedure began with 20 minutes of seated rest. The participant then walked 90 meters (~1-minute) for a warm-up by proceeding from the laboratory to a stairwell with four flights of 16 stairs (a total of 64 stairs, each with a height of 16 cm). The participant was then instructed to walk up the stairs at a safe, low-to-moderate intensity (i.e., perceived as less than 15 on the 6-20 Borg scale). The investigator walked up the first 4-flights of stairs with the participant and remained at the top to obtain ratings of perceived effort and leg pain intensity each time the participant ascended to the top. The investigator was visually able to monitor the participant as she continued to walk at a self-selected pace down and up the stairs until the 10 minutes was completed. After the bout of stair walking, the participant cooled down by walking ~90 meters back to the laboratory for post-treatment testing. The participant performed the post-treatment testing procedures twice (Post-

Treatment 1 and Post-Treatment 2) by completing the POMS-BF, motivation to complete mental work VAS, and then the cognitive tests. The POMS-BF was completed a final time (Post-Treatment 3) in order to examine mood consequences of the cognitive testing. All mood and cognitive testing was conducted while the participant sat alone in a distraction-free, sound dampened environmental chamber.

Statistical Analysis

Preliminary Analysis. IBM SPSS Statistics (Version 22.0) was used for all data analyses. For the cognitive data, each data file was scored using Cedrus Data Viewer 2.0 (Cedrus Corp., 2007) and then imported into SPSS. Mood and motivation scales were scored using excel and then entered into SPSS.

Primary Analysis. For the mood measures, comparisons were made between the Exercise and Placebo Conditions, the Caffeine and Placebo Conditions, and the Exercise and Caffeine Conditions using a series of 2 Condition X 4 Time (Baseline, Post-1, Post-2, Post-3) repeated measures ANOVAs. The focus was on hypothesized Condition X Time interactions. For the cognitive performance and motivation measures, 2 Condition X 3 Time (Baseline, Post-1, Post-2) repeated measures ANOVAs were used. Adjustments for sphericity, when needed as determined by a significant Mauchley's test, were made using Greenhouse-Geisser epsilon. One-way ANOVAs within each condition followed by dependent-t tests were used to understand the interaction effects. Covariates were added to significant models to assess whether the results were influenced by one of the six testing orders, the time of day of testing (10 tested in the morning versus 8 in the afternoon), or birth control use (3 used birth control). Effect sizes are reported as Cohen's d and partial eta-squared (η^2). Data in the text are presented as mean and SD.

RESULTS

Participants were characterized by a (mean ± SD) age, height, weight and BMI of 20.6 ± 1.4 years, 161.4 ± 5.3 cm, 60.6 ± 8.6 kg and 23.1 ± 3.0 kg·m^2, respectively.

Heart Rate and Perceptions During Stair Walking

During the 10-minutes of stair walking the participants walked a total of 988.44 ± 114.53 stairs at an average heart rate reserve of 62.39 ± 12.74. The descriptive heart rate data are presented in Table 3.2. A two-way ANOVA comparing the exercise to the placebo condition showed a significant condition by time interaction $F(1.389, 23.615) = 300.439$, $P < .001$, η^2=.956). There was no difference between the conditions in baseline heart rates but exercise (post-treatment 1) and recovery (post-treatment 2) heart rates were higher than baseline values for the exercise condition only. A two-way ANOVA comparing the caffeine to the placebo condition showed significant main effects for condition ($F(1,17)=5.209$, $P = .036$, η^2=.235) and time ($F(1,17)=5.209$, $P = .036$, η^2=.235) only. Heart rate was lower in the caffeine condition at each time period, and in both conditions heart rates were higher at baseline compared to the two subsequent time periods.

Mean perceived exertion ratings during stair walking were less than 15 for each participant and ranged from 8.1 to 14.7. The overall average rating for the group during the 10-minute walk was 11.4 (1.9) which indicated that participants chose to walk at an intensity that on average was perceived as "light".

Mean leg muscle pain intensity ratings during stair walking were less than 4 (somewhat strong pain intensity) for each participant. Four participants reported no pain at all and two individuals reported moderate intensity leg muscle pain. The overall average pain intensity rating for the group during the 10-minute walk was 1.2 (1.1) which indicated that during the walk the average leg muscle pain intensity was perceived overall as "weak pain".

Exercise Versus Placebo

Mood. The descriptive mood data are presented in Tables 3.3-3.5. No significant interactions were found for the mood states of tension, depression, anger, fatigue or confusion. For vigor, a two-way ANOVA comparing the exercise and placebo condition showed a significant condition by time interaction ($F(3,51) = 5.526$, $P = .002$, $\eta^2=.245$), which remained significant after controlling for test order, time of day and use of birth control. Within the placebo condition there was no significant change over time. Within the exercise condition there was a Time effect for vigor ($F(3,51) = 8.30$, $P < .001$, $\eta^2=.328$). Dependent t-tests showed that vigor was increased at Post-1 compared to all other time points in both the exercise and placebo condition (all $P < .001$). The magnitude of the Cohen's d effect size for the difference between the Post-1 minus baseline change scores for the exercise and placebo conditions was d = 0.99. The group vigor data are illustrated in Figure 3.1 and the Post-1 minus baseline change in vigor for each individual participant is shown in Figure 3.2. After exercise, only one participant had a reduction in vigor at Post-1.

Simple Reaction Time. A two-way ANOVA comparing the exercise and placebo condition showed a significant condition by time interaction ($F(1.414, 24.02) = 6.230$, $P = .012$, $\eta^2=.268$). Within the exercise condition there was no significant change over time. Within the placebo condition there was a main time effect for simple reaction time ($F(1.49, 25.335) = 4.485$, $P < .031$, $\eta^2=.209$). Dependent t-tests showed that baseline simple reaction time was faster than the Post-1 ($P = .002$) and Post-2 ($P = .037$) time periods. Simple reaction time was significantly faster in the stair walking condition compared to the placebo condition at Post-1 (P =.001) and Post-2 (P =.02). The simple reaction data are shown in Figure 3.3.

Continuous Performance Task. The descriptive CPT data are presented in Table 3.6 There was no significant condition by time interactions for the number of correct responses, false alarms, misses, or choice reaction time for the CPT.

N-Back. The descriptive N-back data are presented in Table 3.7. No significant interactions were found for any of the outcomes of the 2-back or 3-back tasks.

Motivation. A two-way ANOVA comparing the exercise and placebo condition showed a significant condition by time interaction ($F(1.429,24.296) = 5.457$, $P = .018$, $\eta^2=.243$). Mean motivation scores did increase immediately after stair walking; however, within both the placebo ($P = .051$) and stair walking conditions ($P = .056$) there was no significant change over time and there was no significant difference between the two conditions at Post-1. The magnitude of difference between the two conditions at Post 1 was 6.6 VAS units and equal to a Cohen's d effect size of 0.31. The descriptive motivation data are shown in Tables 3.3 to 3.5.

Exercise Versus Caffeine

No significant interactions were found for any of the mood, motivation, simple reaction time, CPT or N-back data except for vigor. For vigor, a two-way ANOVA comparing the exercise and caffeine showed a significant condition by time interaction ($F(3,51) = 4.932$, $P = .004$, $\eta^2=.225$). Mean vigor scores were highest at the Post-3 time period which was ~72 minutes after caffeine consumption; nevertheless, within the caffeine condition there was no significant change in vigor scores over time. As also was mentioned in the exercise versus placebo section of the results (see above), within the exercise condition there was a main effect for vigor ($F(3,51) = 8.30$, $P < .001$, $\eta^2=.328$). Dependent t-tests showed that vigor was higher at

Post-1 in the exercise compared to the caffeine condition (t = 2.734, df=17, P = .014). The Post-1 time period was immediately following stair walking and ~30 minutes after caffeine was consumed.

Caffeine Versus Placebo

No significant interactions were found for any of the mood, motivation, simple reaction time, CPT or N-back data except for CPT false alarms. For CPT false alarms, a two-way ANOVA comparing the caffeine and placebo showed a significant condition by time interaction ($F(2,34) = 4.110$, $P = .025$, $\eta^2=.195$). Within group one-way ANOVAs showed no significant change over time in either the placebo or caffeine condition. In the caffeine condition, the mean number of false alarms decreased from Baseline to Post-2 by 1.33. In the placebo condition, the mean number of false alarms increased from Baseline to Post-2 by 1.17. Dependent t-tests showed that baseline false alarms for the caffeine condition (8.2± 5.5) differed significantly (t=2.185, df=17, P = .025) from the baseline placebo condition (6.1± 3.9), and that false alarms did not differ at other time points for these two conditions.

DISCUSSION

The primary finding of this experiment is that among a small sample of physically active, college female caffeine users with chronic insufficient sleep, 10 minutes of low-to-moderate perceived intensity stair walking immediately and transiently produced a large magnitude increase in feelings of energy that exceeded the effect produced by 50 mg of caffeine. Dozens of experiments have shown that 20 or more minutes of other types of exercise usually results in increased feelings of energy (Loy, O'Connor, & Dishman, 2013). New knowledge from this study includes that increased feelings of energy were observed after only 10 minutes of low-to-moderate intensity stair walking and that the effect was larger than a low dose of caffeine. One individual reported a reduction of vigor immediately after exercise and this may have been the result of high pre-test vigor scores as this individual had the highest pre-exercise vigor score of the sample.

There appear to be no prior studies documenting any acute psychological consequences of stair walking despite the fact that stair walking is a common type of activity. Stair walking is a practical exercise mode, especially for many office workers during periods of bad weather. Work breaks, often 10 to 20 minutes in duration, were started in the early part of the 20^{th} century, in part, to combat industrial fatigue and increase worker efficiency (Kent, 1917). Here we show that 10 minutes of low-to-moderate perceived intensity stair walking does not improve working memory, sustained attention or other mood states, except for feelings of energy immediately post-exercise. It may seem surprising that feelings of fatigue also were not improved but the weight of the available research shows that acute bouts of exercise longer than 20 minutes do not consistently result in improvements in perceptions of fatigue (Loy, O'Connor, & Dishman, 2013). Thus, the present results are consistent with prior observations that feelings of energy are more sensitive to changing after a single bout of exercise than are feelings of fatigue.

The improvement in mood states other than feelings of energy have frequently been reported after a single bout of exercise, especially reductions in anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015) and depression symptoms (Bartholomew, Morrison, & Ciccolo, 2005). Those improvements often have been largest among samples with elevated symptoms of anxiety or depression. The failure to find significant improvements in these other mood states, as well as in cognitive performance or motivation to perform the cognitive tasks, may have been in part the result of initial values, the nature of the exercise stimulus or the accompanying social or environmental features. Acute sleep deprivation produces dramatic increases in feelings of fatigue (Pilcher & Huffcutt, 1996) but much less data are available about the mood consequences of chronic partial sleep loss. By recruiting individuals with chronic sleep deprivation it was expected that they would report higher than average feelings of fatigue at baseline but that was untrue as mean baseline values were consistent with published reference values (McNair, Lorr, Heuchert, & Droppleman, 2003). So, in the absence of elevated baseline fatigue symptoms, there was little room for fatigue scores to be reduced further. Thus, there may have been a “floor effect” for the mood states of tension, depression, anger, fatigue and confusion that reduced the chance for these mood states to improve after stair walking.

The stair walking was low-to-moderate in perceived intensity and only 10 minutes in duration. Longer or more intense exercise may be necessary to produce improvements in working memory and sustained attention or reductions in symptoms of anxiety and depression or increases in feelings of energy that are more long-lasting than immediately post-exercise. Work breaks and exercise bouts are often performed with other people or involve being outdoors both of which can elevate mood states (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004). Acute exercise performed outdoors may produce larger mood improvements than indoor exercise (Focht, 2009). Interventions aimed at increasing stair walking, such as through signage, music and interactive stairwell decorations, have been successful but the psychological consequences of these interventions is unknown (Swenson & Siegel, 2013; Kerr, Yore, Ham, & Dietz, 2004) . The sterile nature of the stairwell within which the stair walking was performed may have prevented improvements in anxiety or other mood states that often have been reported after exercise.

In the placebo condition, simple reaction time significantly slowed by ~30 msec at Post-1 and Post-2 compared to baseline while after stair walking simple reaction time was nonsignificantly faster by ~17 msec. Thus, exercise appears to have attenuated the slowing of simple reaction time that occurred in the placebo condition. The mean reaction time in the placebo condition was generally consistent with mean baseline values from other samples tested in in the same lab using the same task (Fritz & O'Connor, 2016). This result is generally consistent with prior studies that showed exercise can, but does not always, improve simple reaction time (Davranche, Burle, Audiffren, & Hasbroucq, 2006; Draper, McMorris, & Parker, 2010; McMorris & Keen, 1994). Key differences between the present investigation and prior studies is that in many prior studies (i) the simple reaction time task was often performed during exercise and therefore was related to the allocation of attention during a dual task (e.g., cycling exercise + the reaction time task) (Draper, McMorris, & Parker, 2010; McMorris & Keen, 1994) and (ii) longer durations of exercise and higher intensities were examined or the data were related to variations in movement speed which were not considered here (Fritz & O'Connor, 2016; Brisswalter, Durand, Delignieres, & Legros, 1995).

Mean scores regarding motivation to perform the cognitive tasks increased immediately after stair walking by a small amount (4.7 VAS units, d = .31) and were reduced after the other conditions. Thus, the findings for motivation were in the expected direction but the interaction was insignificant. Although not statistically significant, the motivation findings potentially warrant attention. Even small increases in motivation to perform work could translate to large improvements in worker productivity. There is very little literature examining the influence of acute exercise on motivation to perform cognitive tasks. One prior experiment showed a significant increase in motivation to perform cognitive tasks of 9.4 VAS units immediately after 20-minutes of cycling at 65% VO_2 peak in young men at increased risk for ADHD (Fritz & O'Connor, 2016). Differences in exercise mode (stair walking vs. cycling), duration (10 vs. 20

minutes), psychological / physiological status (ADHD vs. sleep deprived) and the control conditions (placebo vs. seated rest) between the exercise groups in the two investigations may explain the different findings with regard to the motivation to complete the cognitive tasks.

In general, the caffeine condition produced very small changes in mood (increased vigor, reduced fatigue) and cognitive performance (faster simple, CPT and n-back reaction times, greater n-back accuracy) that were in the expected direction but were statistically insignificant except for the significant CPT false alarm interaction. This interaction was in the expected direction, with fewer false alarms after caffeine and more after placebo. However, the placebo and caffeine conditions differed at baseline, making this observation difficult to interpret in part because regression to the mean could not be ruled out. The lack of significant results from the caffeine condition was not expected given the widespread use of cola drinks containing caffeine in amounts similar to what was used here and previous studies which have shown that caffeine can significantly speed up reaction time with as little as 12.5 mg (Smit & Rogers, 2000). In studies involving doses of caffeine that exceed 100 mg, mean improvements in cognitive performance and energy and fatigue mood states are commonly observed (Maridakis, Herring, & O'Connor, 2009; Childs & de Wit, 2006). The failure to find larger caffeine responses may have been because of biases in the present small sample that we did not measure. For example, the effects of caffeine on anxiety and sleep are influenced by genetic variation in adenosine and dopamine receptors that were not measured here (Retey, et al., 2007; Childs, et al., 2008). We attempted to minimize this type of bias by recruiting individuals who were caffeine consumers and not recruiting those who abstained from the use of caffeine.

The present investigation has several limitations including that no testing was done to confirm that participants had refrained from using caffeine for at least 6-hours prior to participating. If participants had consumed caffeine prior to the caffeine condition, this may have contributed to the lack of a caffeine response. Also, another limitation was the lack of control over the exercise environment. Some of the participants encountered other individuals while walking in the hallway to the stairwell or while stair walking in the stairwell and this could have an impacted the results from the exercise condition. We attempted to minimize potential social interaction effects by instructing the participants to not engage with any individuals and continue walking.

Based on the overall evidence provided from this experiment, and bearing limitations in mind, it is concluded that a 10-minute bout of low-to-moderate perceived intensity stair walking has immediate, transitory energizing effects that exceed those resulting from a low dose of caffeine for active young women with chronic insufficient sleep.

References

Bartholomew, J. B., Morrison, D., & Ciccolo, J. T. (2005). Effects of acute exercise on mood and well-being in patients with major depressive disorder. *Medicine and Science in Sports and Exercise*, *37*(12), 2032.

Brisswalter, J., Durand, M., Delignieres, D., & Legros, P. (1995). Optimal and non-optimal demand in a dual task of pedalling and simple reaction time: effects on energy expenditure and cognitive performance. *Journal of Human Movement Studies*, *29*(1), 15-34.

Chang, Y., Labban, J., Gapin, J., & Ethnier, J. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87-101.

Childs, E., & de Wit, H. (2006). Subjective, behavioral, and physiological effects of acute caffeine in light, nondependent caffeine users. *Psychophamacology, 185*, 514-523. doi:10.1007/s00213-006-0341-3

Childs, E., Hohoff, C., Deckert, J., Xu, K., Badner, J., & de Wit, H. (2008). Association between ADORA2A and DRD2 polymorphisms and caffeine-induced anxiety. *Neuropsychopharmacology*, *33*(12), 2791-2800.

Cook, D. B., O'Connor, P. J., Eubanks, S. A., Smith, J. C., & Lee, M. (1997). Naturally ocurring muscle pain during exercise: assessment and experimental evidence. *Medicine and Science in Sports and Exercise, 29*(8), 999-1012.

D'Amico, E. J., Neilands, T. B., & Zambarano, R. (2001). Power analysis for multivariate and repeated measures design: A flexible approach using the SPSS MANOVA procedure. *Behavior Research Methods, Instruments, & Computers, 33*(4), 479-484.

Davranche, K., Burle, B., Audiffren, M., & Hasbroucq, T. (2006). Physical exercise facilitates motor processes in simple reaction time perfomance: an electromyographic analysis. *Neuroscience Letters, 396*(1), 54-56.

Draper, S., McMorris, T., & Parker, J. K. (2010). Effects of acute exercise of differing intensities on simple and choice reaction and movement times. *Psychology of Sport and Exercise, 1*(6), 536-541.

Ensari, I., Greenlee, T. A., Motl, R. W., & Petruzzello, S. J. (2015). Meta-analysis of acute exercise effects on state anxiety: an update of randomized controlled trials over the past 25 years. *Depression and Anxiety, 62*(8), 624-634.

Focht, B. C. (2009). Brief walks in outdoor and laboratory environments: effects on affective responses, enjoyment, and intentions to walk for exercise. *Research Quarterly for Exercise and Sport, 80*(3), 611-620.

Fritz, K. M., & O'Connor, P. J. (2016). Acute exercise improves mood and motivation in young men with ADHD symptoms. *Medicine and Science in Sport and Exercise, 48*(6), 1153-1160.

Godin, G., & Shephard, R. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences, 10*, 141-6.

Goel, N., Rao, H., Durmer, J. S., & Dinges, D. F. (2005). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology, 29*(4), 320-339.

Griffiths, R. R., Evans, S. M., Heishman, S. J., Preston, K. L., Sannerud, C. A., Wolf, B., & Woodson, P. P. (1990). Low-dose caffeine discrimination in humans. *Journal of Pharmacology and Experimental Therapeutics, 252*(3), 970-978.

Hewlett, P., & Smith, A. (2007). Effects of repeated doses of caffeine on performance and alertness: new data and secondary analyses. *Human Psychopharmacology: Clinical and Experimental, 22*(6), 339-350.

Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. (2004). A survey method for characterizing daily life experience: the day reconstruction method. *Science, 306*(5702), 1776-1780.

Kane, M. J., Conway, A. R., Miura, T. K., & Colflesh, G. J. (2007). Working memory, attention control, and the n-back task: A question of construct validity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(3), 615-622.

Kent, A. S. (1917). Industrial fatigue and Efficiency. *Journal of the Textile Institute, 8*(3), 185-197.

Kerr, N. A., Yore, M. M., Ham, S. A., & Dietz, W. H. (2004). Increasing stair use in a worksite through environmental changes. *American Journal of Health Promotion, 18*(4), 312-315.

Kessing, D., Denollet, J., Widdershoven, J., & Kupper, N. (2015). Fatigue and self-care in patients with chronic heart failure. *European Journal of Cardiovascular Nursing*. doi:10.1177/1474515115575834

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research, 1341*, 12-24.

Lindheimer, J. B., O'Connor, P. J., McCully, K. K., & Dishman, R. K. (2016). The effect of low intensity cycling on mood and working memory in response to a randomized, placebo-controlled design. *Psychosomatic Medicine*.

Lorist, M. M., & Tops, M. (2003). Caffeine, fatigue, and cognition. *Brain and Cognition, 53,* 82-94.

Loy, B. D., & O'Connor, P. J. (2016). The effect of histamine on changes in mental energy and fatigue after a single bout of exercise. *Physiology & Behavior, 153*, 7-18.

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*(4), 223-242.

Loy, B. D., O'Connor, P. J., Lindheimer, J. B., & Covert, S. F. (2015). Caffeine is ergogenic for adenosine A2A receptor gene (ADORA2A) T allele homozygotes: a pilot study. *Journal of Caffeine Research, 5*(2), 73-81.

Maridakis, V., Herring, M. P., & O'Connor, P. J. (2009). Sensitivity to change in cognitive performance and mood measures of energy and fatigue in response to differing doses of caffeine or breakfast. *International Journal of Neuroscience, 119*, 975-994. doi:10.1080/002074502333995

Maridakis, V., O'Connor, P. J., & Tomporowski, P. D. (2009). Sensitivity to change in cognitive performance and mood measures of energy and fatigue in response to morning caffeine alone or in combination with carbohydrate. *International Journal of Neuroscience, 119*(8), 1239-1258.

Maruff, P., Falleti, M. G., Collie, A., Darby, D., & McStephen, M. (2005). Fatigue-related impairment in the speed, accuracy and variability of psychomotor performance: comparison with blood alcohol levels. *Journal of Sleep Research, 14*(1), 21-27.

Maslowsky, J., & Ozer, E. J. (2014). Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. *Journal of Adolescent Health, 54*(6), 691-697.

McMorris, T., & Keen, P. (1994). Effect of exercise on simple reaction times of recreational athletes. *Perceptual and Motor Skills, 78*, 123-130.

McNair, D., Lorr, J., Heuchert, J. W., & Droppleman, L. (2003). *Profile of Mood States-Brief Form.* North Tonawanda, NY: Multi-Health Systems Inc.

Motl, R. W., O'Connor, P. J., Tubandt, L., Puetz, T., & Ely, M. R. (2006). Effect of caffeine on leg muscle pain during cycling exercise. *Medicine and Science in Sport and Exercise, 38*(3), 598.

O'Connor, P. J., & Puetz, T. W. (2005). Chronic physical activity and feelings of energy and fatigue. *Medicine and Science in Sport and Exercise, 37*(2), 299-305.

Pilcher, J. J., & Huffcutt, A. J. (1996). Effects of sleep deprivation on performance: a meta-analysis. *Sleep: Journal of Sleep Research and Sleep Medicine, 19*(4), 318-326.

Retey, J. V., Adam, M., Khatami, R., Luhmann, U., Jung, H. H., Berger , W., & Landolt, H. P. (2007). A genetic variation in the adenosine A2A receptor gene (ADORA2A) contibutes to individual sensitivity to caffeine effects of sleep. *Clinical Pharmacology and Therapeutics, 81*(5), 692-698.

Ricci, J. A., Chee, E., Lorandeau, A. L., & Berger, J. (2007). Fatigue in the US workforce: prevalence and implications for lost productive work time. *Journal of Occupational and Environmental Medicine, 49*(1), 1-10.

Rosvold, H., Mirsky, A., Sarason, I., Bransome Jr., E., & Beck, L. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology, 20*(5), 343.

Smit, H. J., & Rogers, P. J. (2000). Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. *Psychopharmacology, 152*, 167-173. doi:10.1007/s002130000506

Steenbruggen, T. G., Hoekstra, S. J., & van der Gaag, E. J. (2015). Could a change in diet revitalize children who suffer from unresolved fatigue? *Nutrients*, *7*(3), 1965-1977.

Strath, S. J., Swartz, A. M., Bassett, Jr. , D. R., O'Brien, W. L., King, G. A., & Ainsworth, B. E. (2000). Evaluation of heart rate as a method for assessing moderate intensity physical activity. *Medicine and Science in Sports and Exercise, 32*(9 Suppl), S465-470.

Swenson, T., & Siegel, M. (2013). Increasing stair use in an office worksite through an interactive environmental intervention. *Health Promotion*, *27*(5), 323-329.

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153-156.

Taylor, W. C. (2005). Transforming work breaks to promote health. *American Journal of Preventive Medicine*, *29*(5), 461-465.

Teh, K. C., & Aziz, A. R. (2002). Heart rate, oxygen uptake, and energy cost of ascending and descending the stairs. *Medicine & Science in Sports & Exercise*, *34*(4), 695-699.

Figure Captions

Figure 3.1: Feelings of energy (POMS-BF vigor scores) in the placebo (line 1), stair walking (line 2) and caffeine (line 3) conditions at baseline and three times after the treatments (Post-1 [30-mins post-start of treatments], Post-2 [51-mins post-start of treatments], and Post-3 [72-mins post-start of treatments]).

Figure 3.2: Changes in vigor for each participant in the stair walking (top), caffeine (middle) and placebo (bottom) conditions. Change scores were calculated as Post-1 values minus Baseline values. Baseline occurred immediately before the treatments and Post-1 was 30-minutes after the start of the treatment period. Positive values indicate increased vigor score after the condition.

Figure 3.3: Simple reaction time in the placebo (line 1), caffeine (line 2) and stair walking (line 3) conditions at baseline and twice after the treatments (Post-1 [34-mins post-start of treatment], and Post-2 [55-mins post-start of treatment].

Table 3.1

Time (hours:min)	Task	Test Phase
Day 1		
0:00-0:02	Greet Participant	Practice
0:02-0:10	Participant Completes Informed Consent	Practice
0:10-0:15	Participant Puts on Heart Rate Monitor	Practice
0:15-0:18	Explain and Practice Simple Reaction Time Test	Practice
0:18-0:28	Explain and Practice N-Back Test	Practice
0:28-0:38	Explain and Practice Continuous Performance Test	Practice
0:38-0:43	Obtain Resting Heart Rate, Check Performance, Repeat Practice If Needed	Practice Practice
0:43-0:46	Participant Will Walk up 4 Flights of Stairs (64 stairs total), walk down the stairs and Practice Providing Overall and Local RPE	Practice Practice Practice
0:46-0:48	Participant Will Remove Heart Rate Monitor	Practice
0:48-0:49	Next Visit will be scheduled	
Days 2,3,&4		
0:00-0:02	Greet Participant	Pre-baseline
0:02-0:10	Confirm Compliance to Requested Pre-Test Procedures	Pre-baseline
0:02-0:10	Participant Puts on Heart Rate Monitor	Pre-baseline
0:10-0:13	POMS	Pre-baseline
0:13-0:14	Motivation to Complete Mental Work (VAS)	Pre-baseline
0:14-0:15	Simple Reaction Time Task	Baseline
0:15-0:23	N-Back Task	Baseline
0:23-0:31	Continuous Performance Task	Baseline
0:31-0:34	POMS	Baseline
0:34-1:04	Experimental Condition (**placebo:** 30 min quiet seated rest, **caffeine:** 50 mg immediately followed by 30 min quiet seated rest, or **exercise:** 20 min of quiet seated rest followed by 12 minutes of walking [1 minute warm up, 10 min of stair walking, 1-minute cool down)	Treatment
1:04-1:07	POMS	Post-Treatment 1
1:07-1:08	Motivation to Complete Mental Work (VAS)	Post-Treatment 1
1:08-1:09	Simple Reaction Time Task	Post-Treatment 1
1:09-1:17	N-Back Task	Post-Treatment 1
1:17-1:25	Continuous Performance Task	Post-Treatment 1
1:25-1:28	POMS	Post-Treatment 2
1:28-1:29	Motivation to Complete Mental Work (VAS)	Post-Treatment 2
1:29-1:30	Simple Reaction Time task	Post-Treatment 2
1:30-1:38	N-Back Task	Post-Treatment 2
1:38-1:46	Continuous Performance Task	Post-Treatment 2
1:46-1:49	POMS	Post-Treatment 3
1:49-1:51	Removal of Heart Rate Monitor	

Table 3.2
Means and Standard Deviations for Heart Rate

Measure		Placebo	Caffeine	Exercise
Time				
	Baseline	82.28 (9.54)	80.06 (10.04)	82.11 (9.46)
	Post-Treatment 1	74.72 (10.10)	71.94 (8.11)	150.75 (15.05)
	Post-Treatment 2	77.28 (8.23)	73.69 (9.08)	92.39 (10.43)

Table 3.3
Means and Standard Deviations for Mood and Motivation score in the Placebo Condition

Measure	Baseline-1	Baseline-2	Post-1	Post-2	Post-3
Tension	1.33 (2.20)	0.9 (1.68)	0.8 (1.98)	1.2 (2.53)	1.06 (2.34)
Depression	1.22 (3.06)	1.1 (2.69)	1.2 (3.29)	1.5 (4.30)	0.94 (2.88)
Anger	1.17 (2.20)	0.8 (1.47)	1.00 (2.14)	1.4 (2.91)	1.67 (2.97)
Vigor	3.94 (2.84)	2.3 (2.19)	2.00 (2.35)	2.1 (2.27)	2.17 (2.26)
Fatigue	3.56 (3.33)	4.3 (3.12)	3.50 (2.31)	4.2 (3.70)	4.39 (3.82)
Confusion	1.39 (2.15)	1.3 (2.11)	1.1 (2.11)	1.6 (2.48)	1.44 (1.98)
Motivation	56.8 (26.48)		54 (24.5)		50.9 (25.87)

Table 3.4
Means and Standard Deviations for Mood and Motivation score in the Caffeine Condition

Measure	Baseline-1	Baseline-2	Post-1	Post-2	Post-3
Tension	1.83 (2.43)	1.72 (1.93)	0.94 (1.43)	1.50 (1.50)	1.44 (1.46)
Depression	1.06 (1.73)	1.00 (1.53)	0.78 (1.59)	0.89 (1.84)	0.72 (1.23)
Anger	0.61 (1.46)	0.83 (1.47)	0.50 (1.04)	0.56 (0.98)	0.67 (1.37)
Vigor	4.06 (2.46)	2.61 (2.85)	3.28 (2.74)	3.00 (2.50)	3.78 (2.94)
Fatigue	3.44 (3.07)	4.56 (3.52)	3.28 (3.37)	3.28 (3.44)	3.33 (3.66)
Confusion	1.56 (1.42)	1.33 (1.57)	1.11 (0.96)	1.22 (1.48)	1.61 (1.65)
Motivation	60.16 (25.75)		57.2 (23.66)		55.44 (24.07)

Table 3.5
Means and Standard Deviations for Mood and Motivation score in the Exercise Condition

Measure	Baseline-1	Baseline-2	Post-1	Post-2	Post-3
Tension	1.83 (2.62)	1.28 (1.84)	2.22 (3.54)	1.56 (2.43)	1.44 (2.64)
Depression	1.00 (2.00)	0.83 (1.69)	0.89 (1.81)	0.56 (1.34)	0.78 (1.59)
Anger	0.89 (2.00)	1.11 (2.00)	0.94 (2.29)	0.83 (1.82)	1.22 (2.84)
Vigor	3.78 (3.10)	2.94 (2.31)	4.89 (2.56)	2.67 (1.94)	3.06 (2.92)
Fatigue	4.00 (3.16)	2.94 (2.31)	3.89 (3.07)	3.78 (2.53)	4.11 (3.20)
Confusion	1.44 (1.79)	1.44 (1.58)	1.56 (2.15)	1.50 (1.82)	1.56 (1.69)
Motivation	55.44 (19.58)		60.10 (17.41)		52.44 (21.41)

Table 3.6
Means and Standard Deviations for SRT and CPT Performance

Measure	Placebo			Caffeine			Exercise		
	Baseline	Post-1	Post-2	Baseline	Post-1	Post-2	Baseline	Post-1	Post-2
SRT (ms)	264.91 (36.06)	291.63 (36.06)	294.09 (41.42)	284.83 (49.19)	283.84 (42.11)	280.5 (37.10)	279.47 (51.97)	267.16 (36.03)	261.48 (48.07)
CPT									
Accuracy (%)	93.58 (6.00)	93.92 (5.93)	93.75 (6.23)	92.13 (8.20)	93.63 (5.82)	92.71 (8.95)	95.26 (5.47)	94.56 (4.16)	94.45 (6.16)
False Alarms	6.06 (3.92)	6.83 (3.63)	7.22 (3.57)	8.17 (5.51)	7.78 (5.46)	6.83 (5.02)	6.56 (5.32)	7.67 (5.27)	7.39 (5.34)
Misses	6.17 (5.76)	5.83 (5.69)	6 (5.98)	7.56 (7.87)	6.11 (5.58)	7 (8.59)	4.56 (5.25)	5.22 (3.99)	5.33 (5.91)
Reaction Time	359.52 (35.55)	356.21 (25.94)	355.07 (34.42)	358.17 (49.65)	345.68 (66.64)	350.82 (55.29)	348.55 (58.82)	339.27 (55.51)	343.55 (58.52)

Table 3.7
Means and Standard Deviations for 2-Back and 3-Back Task Performance

Measure	Placebo			Caffeine			Exercise		
	Baseline	Post-1	Post-2	Baseline	Post-1	Post-2	Baseline	Post-1	Post-2
2-Back									
Total Accuracy (%)	86 (18.37)	91.33 (6.80)	91.11 (4.64)	91.76 (4.48)	92.39 (3.70)	93.8 (2.90)	91.33 (3.11)	92.74 (3.72)	93.7 (3.19)
Total False Alarms	5.06 (2.48)	4.83 (3.55)	5.22 (2.98)	4.65 (2.45)	3.82 (1.78)	3.53 (1.77)	4.89 (2.00)	4.33 (2.03)	3.72 (1.64)
Total Misses	2.53 (3.41)	1.72 (2.11)	1.44 (1.42)	1.53 (1.77)	1.88 (2.42)	1.12 (1.54)	1.61 (1.09)	1.11 (1.64)	1.06 (1.98)
Reaction Time (ms)	648.66 (120.28)	612.9 (97.04)	596.82 (95.36)	635.27 (101.08)	623.15 (70.97)	582.20 (86.81)	629.38 (74.99)	589.99 (75.63)	570.83 (76.89)
3-Back									
Total Accuracy (%)	86.15 (16.11)	91.11 (6.14)	90.00 (6.21)	88.63 (7.12)	89.73 (8.30)	91.53 (6.88)	90.3 (7.01)	90.89 (4.89)	90.96 (5.12)
Total False Alarms	4.83 (3.00)	4.28 (2.97)	5.00 (3.20)	4.89 (3.89)	4.94 (4.04)	4.67 (4.07)	4.67 (3.16)	4.83 (2.87)	4.94 (2.82)
Total Misses	2.76 (2.70)	2.39 (2.77)	2.50 (2.83)	3.35 (3.12)	2.47 (3.83)	1.47 (2.32)	2.61 (3.48)	2.00 (2.40)	1.83 (2.20)
Reaction Time (ms)	696.2 (105.97)	674.6 (126.41)	637.51 (105.50)	745.74 (146.7)	671.33 (106.12)	609.2 (92.30)	706.1 (77.66)	621.3 (121.94)	597.3 (93.32)

Figure 3.1

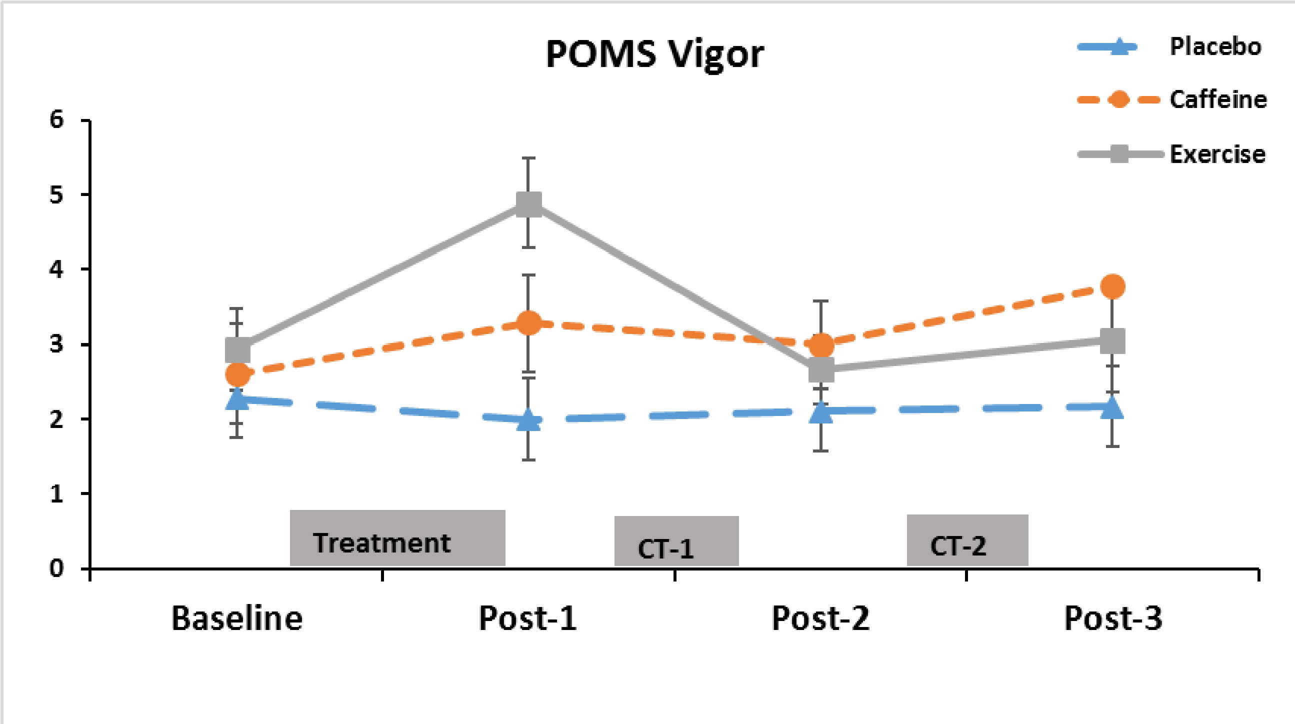
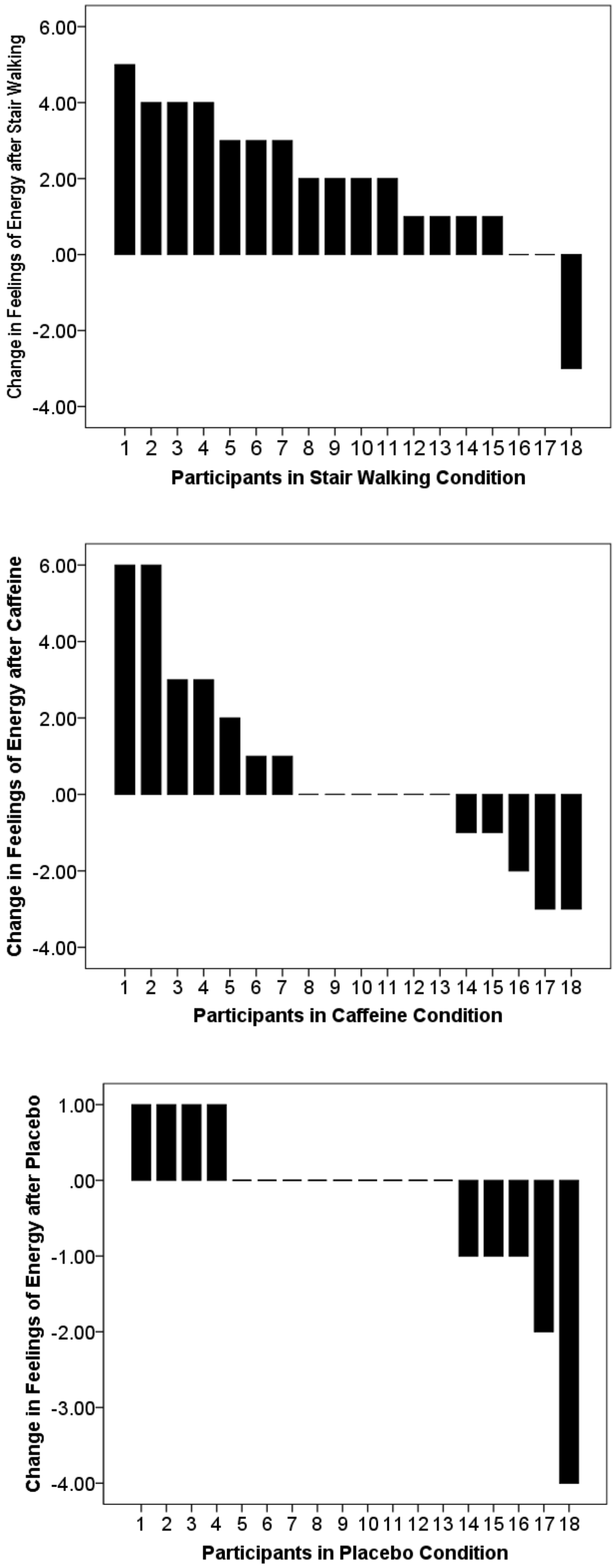
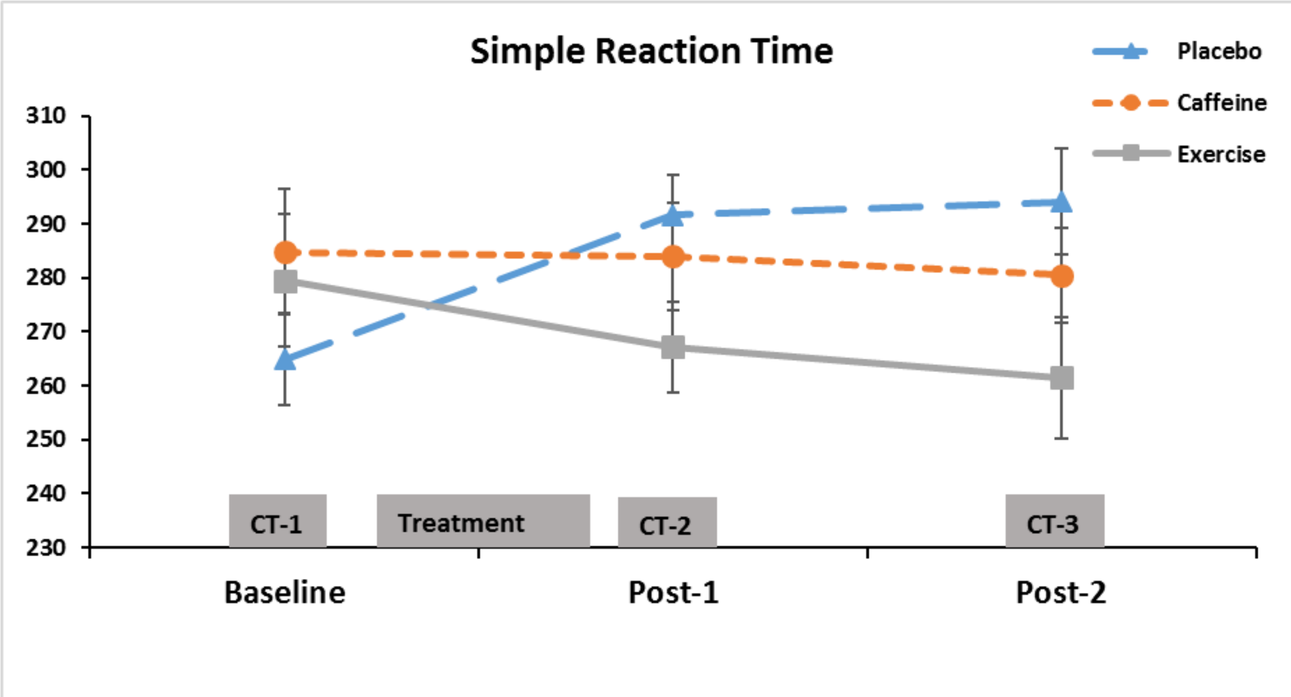

POMS Vigor
Placebo
Caffeine
Exercise
6
5
4
3
2
1
0
Treatment
CT-1
CT-2
Baseline
Post-1
Post-2
Post-3

Figure 3.2



6.00
4.00
2.00
.00
-2.00
-4.00
Change in Feelings of Energy after Stair Walking
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Participants in Stair Walking Condition
6.00
4.00
2.00
.00
-2.00
-4.00
Change in Feelings of Energy after Caffeine
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Participants in Caffeine Condition
1.00
.00
-1.00
-2.00
-3.00
-4.00
Change in Feelings of Energy after Placebo
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Participants in Placebo Condition

Figure 3.3



Simple Reaction Time
Placebo
Caffeine
Exercise
310
300
290
280
270
260
250
240
230
CT-1
Treatment
CT-2
CT-3
Baseline
Post-1
Post-2

APPENDICES

A. Demographic, Sleep, and Health-Related Screening

Sex: ______________________ Age:_________________

Do you regularly take any prescription or over-the-counter medications? 1) Yes 2) No
If yes, what do you take?

Are you allergic to cocoa or chocolate or caffeine? 1) Yes 2) No

Indicated the number of hours (to the quarter hour, eg. 7.25) that you sleep on a typical night:_________

Has a doctor ever told you that you should avoid taking things containing caffeine?
1) Yes
2) No

Is there any reason that you know of why taking caffeine would be unsafe for you?
1) Yes
2) No
If yes, describe why

Have you ever had a serious side effects from taking caffeine?
1) Yes
2) No
If yes, briefly what happened?

Do you have any major medical or health condition that would prevent you from safely walking up and down stairs for 10 minutes at a self-controlled low-to-moderate intensity? 1) Yes 2) No

If so, indicate the condition.

On average during the past month, how energetic or fatigued have you usually felt?

1) Very, very energetic
2) Very energetic
3) Energetic
4) Neither energetic or fatigued
5) Fatigued
6) Very fatigued
7) Very, very fatigued

B. Prior Week Caffeine Consumption Questionnaire

The following survey will ask you questions about your caffeine intake during a typical week. This information will help us to determine if you are eligible to participate in this study.

1) Do you take caffeine during a typical week? This could include drinking coffee, tea, soft drinks, and energy drinks, and/or eating products like coffee ice cream or candy.
No (1)
Yes (2)

Instructions: Considering a typical week, please tell us about the caffeine products you consume. If you indicate that you drink a specific caffeine product you will then be asked to provide some additional details about what type of product you consume, the number of times per week you usually consume each product, and your usual serving size.

2) During a typical week do you drink coffee?
No (1)
Yes (2)

How many times a week do you consume this type of beverage?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of beverage?
(1) (2) (3) (4) (5+)

What is your typical serving size of this beverage?
(1) 8oz (2) 16oz (3) More than 16oz

3) During a typical week do you drink expresso?
No (1)
Yes (2)

How many times a week do you consume this type of beverage?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of beverage?
(1) (2) (3) (4) (5+)

What is your typical serving size of this beverage?
(1) 1oz (2) 2oz

4) During a typical week do you drink tea?
No (1)
Yes (2)

How many times a week do you consume this type of beverage?
(1)(2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of beverage?
(1) (2) (3) (4) (5+)

What is your typical serving size of this beverage?
(1) 8oz (2) 16oz (3) more than 16oz

5) During a typical week do you drink soft drinks (soda)?
No (1)
Yes (2)

How many times a week do you consume this type of beverage?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of beverage?
(1) (2) (3) (4) (5+)

What is your typical serving size of this beverage?
(1) 8oz (2) 12oz (3) 20oz (4) more than 20oz

6) During a typical week do you drink energy drinks?
No (1)
Yes (2)

How many times a week do you consume this type of beverage?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of beverage?
(1) (2) (3) (4) (5+)

What is your typical serving size of this beverage?
(1) 2oz (5 hour energy) (2) 8oz (3) 12oz (4) 16oz (5) more than 16oz

7) During a typical week do you eat Frozen Desserts (i.e. Ice Cream, Frozen Yogurt, and Ice Cream Bars)?
No (1)
Yes (2)

How many times a week do you consume this type of item?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of item?
(1) (2) (3) (4) (5+)

What is your typical serving size of this item?
(1) less than 8oz (2) 8oz (3) more than 8oz

8) During a typical week do you eat chocolate, candies or drink hot chocolate?
No (1)
Yes (2)

How many times a week do you consume this type of item?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of item?
(1) (2) (3) (4) (5+)

What is your typical serving size of this item?
(1) 1 (2) 2 (3) 3 (4) 4+

9) During a typical week do you take Over the Counter Drugs for staying awake, pain relief or weight management (i.e. NoDoz, Excedrin, Midol, Dexatrim)?
No (1)
Yes (2)

How many times a week do you consume this type of item?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of item?
(1) (2) (3) (4) (5+)

What is your typical serving size of this item?
(1) 1 tablet (2) 2 tablets (3) more than 2 tablets

10) During a typical week do you take any other items that contain caffeine that have not been previously listed?
No (1)
Yes (2)

If yes, list the items that contain caffeine below

How many times a week do you consume this type of item?
(1) (2) (3) (4) (5) (6) (7)

How many times a day do you consume this type of item?
(1) (2) (3) (4) (5+)

What is your typical dose of this item?
(1) 1 (2) 2 (3) 3+

C. Godin Leisure Time Exercise Questionnaire

Considering a **7-Day period** (a week), how many times on average do you do the following kinds of exercise for **more than 15 minutes** during your **free time**?

a) **Strenuous Exercise**
(Heart Beats Rapidly)

(i.e. running, jogging, hockey, football, soccer, squash, basketball, cross country, skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)

Times per Week: ________

b) **Moderate Exercise**
(Not Exhausting)

(i.e. fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing (downhill skiing), popular and folk dancing)

Times per Week: ________

c) **Mild Exercise**
(Minimal Effort)

(i.e. yoga, archery, fishing from a shore, bowling, horseshoes, golf, snow-mobiling, easy walking)

Times per Week: ________

Consider a 7-Day period (a 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: _____

D. Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active. These questions will help determine if it is safe for to begin an exercise program.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check True or False.

True / False 1) I have a heart condition and my healthcare professional recommends only medically supervised physical activity.

True / False 2) During or right after I exercise, I often have pains or pressure in my neck, left shoulder, or arm.

True / False 3) I have developed chest pain within the last month.

True / False 4) I tend to lose consciousness or fall over due to dizziness.

True / False 5) I feel extremely breathless after mild exertion.

True / False 6) My healthcare provider recommended that I take medicine for high blood pressure or a heart condition.

True / False 7) I have bone or joint problems that limit my ability to do moderate-intensity physical activity.

True / False 8) I have a medical condition or other physical reason physical reason not mentioned here that might need special attention in an exercise program.

True / False 9) I am pregnant and my healthcare professional hasn’t given me the OK to be physically active.

E. Profile of Mood States- Brief Form (POMS)

POMS Brief Form					
Participant ID:		**Age:**		**Gender:**	
Birth Date:		**Today's Date:**			
Below is a list of words that describe feelings that people have. Please read each word carefully. Then circle the number that best describes how you feel RIGHT NOW.					
	Not at all	**A Little**	**Moderately**	**Quite a bit**	**Extremely**
1. Tense	**0**	**1**	**2**	**3**	**4**
2. Angry	**0**	**1**	**2**	**3**	**4**
3. Worn Out	**0**	**1**	**2**	**3**	**4**
4. Lively	**0**	**1**	**2**	**3**	**4**
5. Confused	**0**	**1**	**2**	**3**	**4**
6. Shaky	**0**	**1**	**2**	**3**	**4**
7. Sad	**0**	**1**	**2**	**3**	**4**
8. Active	**0**	**1**	**2**	**3**	**4**
9. Grouchy	**0**	**1**	**2**	**3**	**4**
10. Energetic	**0**	**1**	**2**	**3**	**4**
11. Unworthy	**0**	**1**	**2**	**3**	**4**
12. Uneasy	**0**	**1**	**2**	**3**	**4**
13. Fatigued	**0**	**1**	**2**	**3**	**4**
14. Annoyed	**0**	**1**	**2**	**3**	**4**
15. Discouraged	**0**	**1**	**2**	**3**	**4**
16. Nervous	**0**	**1**	**2**	**3**	**4**
17. Lonely	**0**	**1**	**2**	**3**	**4**
18. Muddled	**0**	**1**	**2**	**3**	**4**
19. Exhausted	**0**	**1**	**2**	**3**	**4**
20. Anxious	**0**	**1**	**2**	**3**	**4**
21. Gloomy	**0**	**1**	**2**	**3**	**4**
22. Sluggish	**0**	**1**	**2**	**3**	**4**
23. Weary	**0**	**1**	**2**	**3**	**4**
24. Bewildered	**0**	**1**	**2**	**3**	**4**
25. Furious	**0**	**1**	**2**	**3**	**4**
26. Efficient	**0**	**1**	**2**	**3**	**4**
27. Full of pep	**0**	**1**	**2**	**3**	**4**
28. Bad-tempered	**0**	**1**	**2**	**3**	**4**
29. Forgetful	**0**	**1**	**2**	**3**	**4**
30. Vigorous	**0**	**1**	**2**	**3**	**4**