The Effects of Assisted Cycle Therapy on Executive and Motor Functioning in Older Adults

by

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ABSTRACT

This study examines cognitive and motor function in typical older adults following acute exercise. Ten older adults (Mage = 65.1) completed a single session of assisted cycling (AC) (i.e., exercise accomplished through the use of a motor), voluntary cycling (VC) (self-selected cadence), and a no cycling (NC) control group. These sessions were randomized and separated by approximately one week. Both ACT and VC groups rode a stationary bicycle for 30-minutes each session. These sessions were separated by at least two days. Participants completed cognitive testing that assessed information processing and set shifting and motor testing including gross and fine motor performance at the beginning and at the end of each session. Consistent with our hypothesis concerning manual dexterity, the results showed that manual dexterity improved following the ACT session more than the VC or NC sessions. Improvements in set shifting were also found for the ACT session but not for the VC or NC sessions. The results are interpreted with respect to improvements in neurological function in older adults following acute cycling exercise. These improvements are balance, manual dexterity, and set shifting which have a positive effects on activities of daily living; such as, decrease risk of falls, improve movements like eating and handwriting, and increase ability to multitask.

DEDICATION

I dedicate this thesis to my wife Adriana and my three kids Stephen, Samuel, and Skylie. Without their steadfast love and support, this project would not have been possible. Thank you all for the most encouraging support without it I may have caved during this journey. I have been blessed by the almighty God to have received you in this life and am grateful to have you all in my life.

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CHAPTER 1

INTRODUCTION

Introduction to Assisted Cycling Therapy for Older Adults

The United States population is aging and it is projected by the year 2020 that 16% of the population will be over the age of 65. By the year 2040 that will raise to 20%, this number will increase to 20%, and 25% of the population will be over 60 (Older Americans, 2012). Persons who are 85 years or older are expected to be the fastest growing population until the year 2050. Research and education into the aging process are urgently needed to influence the aging process itself, thereby preserving significant physiologic function and improving the health of older persons (Geokas, 1990). Due to the increase in older adults, there is a growing concern about how to prevent and manage chronic illnesses, the ability to delay the onset of disability, and decrease the associated cost of health care. (Lang, 2005).

Aging and Motor Control

Aging is associated with many health outcomes that are detrimental to the individual, family members, and the economy. Cancer, stroke and cardiovascular disease are more prevalent among individuals over the age of 65 (Guralnik, 1996). Likewise, Alzheimer's disease, Parkinson's disease, dementia, cognitive impairment and a decreased ability to perform activities of daily living (ADL) all increase in prevalence with aging. Sedentary behavior and physical inactivity magnify the impairment in physiological and structural systems that occur during the aging process (Chandler, 1996). Being physically active is associated with improved physical function such as rising from a chair, walking, climbing stairs (Rejeski, 2003).

Aging is associated with several changes in gait, including gait automaticity, which increases the likelihood of falling (Bridenbaugh, 2010). Gait disorders along with balance impairments are the most common reasons for falls in older adults. Thirty percent of adults over the age of 65 are likely to have a fall every year (Bridenbaugh, 2010). Falls can lead to minor (e.g., bumps and bruises) or major injuries (e.g., broken bones or traumatic brain injuries), hospitalization, and a decline in quality of life (Nevitt et al., 1989, Rubenstein 2002, Rubenstein 2006, Sudrsky 2001, Tinetti, 2003). Thirty percent of adults over the age of 65 are likely to have a fall every year

(Bridenbaugh, 2010). Fallers and non-fallers who suffer from a fear of falling decrease their activities of daily living (Nikolaus, 2005), thus creating a cycle of fear of falling and a decrease in activities of daily living leading to frailty (Bauer and Sieber, 2008).

Walking appears to be a simple task and yet is actually a complex motor task that takes years, for the human, to master (Woollacott & Shumway-Cook, 2002) and as one ages this skill becomes diminished (Wong et al 2008). Skeletal muscle mass is lost in older adults at about a 1-2% rate after the age fifty (Hughes, Frontera, Roubenoff, Evans, & Fiatarone, Singh, 2002). This small amount of muscle loss is associated with reduced muscle strength which is responsible for frailty and a decline in physical function (Kressig & Proust, 1998).

Aging and Cognitive Decline

Cognitive function declines as a normal consequence of aging. There are instances where the rate of cognitive decline is greater than normal, this is called mild cognitive impairment (MCI). MCI is this cognitive decline that is more severe than what would be expected in a normal aging process but does not meet criteria for dementia (Petersen et al., 1999). MCI can develop into dementia or it can return back to normal cognition (Amieva et al., 2004). It is also accepted that age influences several general factors such as working memory, processing speeds and inhibition which in turn affects cognitive function (Adam, 2013). Cognitive decline places a burden on the person and their significant others because of the unfavorable effects to the quality of life, because of their limitations and disabilities (Mol et al., 2007). In fact, two thirds of nursing home residents have some form of memory impairment (Guralnik, 1996).

Aging and Exercise

Exercise has been associated with increased cognition, especially aerobic exercise. Aerobic training as one ages preferentially benefits executive functions, specifically multi-tasking and inhibition (Kramer, 1999). Exercise influences cognition, executive function through the dopaminergic pathways which positively influences one’s ability to execute and perform executive task (Chang, Liu, Yu & Lee, 2012). Aerobic exercise is thought to improve memory by increasing dopamine, brain-derived neurotropic factor (BDNF) and increasing the cerebral blood volume and thus increasing learning performance (Pereira, 2007). Thus, starting an aerobic exercise program as one ages may benefit their brain, cognition and reduce MCI.

Assisted cycle therapy (ACT) is a recumbent bicycle that assists a participant in cycling faster than they could normally do on their own. Research suggests this mode of exercise may impact cognitive function. Studies done with assisted exercise and those affected by Parkinson's disease, in which the participants with Parkinson's cycled at a 35% faster rate than what they could do voluntarily. Showed that it could improve their motor function and have neuroprotective properties (Fickes, 2012). In a study with adolescents with Down syndrome they performed ACT, voluntary exercise and no exercise; they found improvements in manual dexterity and cognitive function, improvements in global improvements in motor function as shown by the Purdue pegboard, thus indicating that ACT may alter brain structures (Ringenbach, 2013). Assisted cycle therapy has never been studied in a population of normal functioning older adults.

The purpose of this study is to investigate the use of an assisted cycle Therapy (ACT) versus Voluntary Cycling (VC) and No Cycling/Exercise (NC) on gait speed, balance and cognitive function on older adults. This study has not been conducted in a population of older adults and will be the first of its kind to use an assisted cycle which may be safer and easier to use than other methods of training.

Hypotheses

Specific Aim 1: To determine the effects of ACT and VC on balance and motor function in older adults. The balance outcomes are the change in Timed up and go (TUG) and Fullerton Advanced Balance Scale. Secondary outcomes include changes in manual dexterity by the Perdue pegboard and dual task.

<u>Hypothesis 1</u> The ACT group will exhibit greater improvements in balance, compared to those in the VC and NC sessions.

<u>Hypothesis 2</u> The ACT group will exhibit greater improvements in manual dexterity compared to those in VC and NC sessions.

<u>Hypothesis 3</u> The ACT group will exhibit greater improvements in Dual task performance compared to those in the VC and NC sessions.

Specific Aim 2: To determine the effects of ACT and VC on cognitive function in older adults. The primary outcome measures will be change in cognitive function; specifically, information processing, and the Stroop test.

Hypothesis 4 The ACT group will exhibit greater improvements in measures of cognitive function compared to those in the VC and NC sessions.

CHAPTER 2

BACKGROUND LITERATURE

Demographics of Aging

The elderly population is increasing worldwide and current projections of population growth it will, the human population will continue to grow until at least 2050. The United States is experiencing considerable growth in the older population. By the year 2050 the population for those over 65 is projected to be 83 million. That is almost twice the population of 43 million in 2012 (Ortman, Velkoff and Hogan, 2014). That will be one in five people over the age 65.

Population aging is a phenomenon that occurs when the median age of a country rises due to increasing life expectancy, declining birth rates or both. This is most advanced in developed countries (United Nations, 2013). The median age through 1950-1970 was 30 years, today it is 36 years and in the year 2050 it is expected to increase to 44 years (United Nations, 2013). In the U.S. the total fertility rate in 2014 was 1.8 children per woman (Harper, 2014). This is below the replacement fertility rate. This growth may place a strain on various public expenditures, such as health care. Which in many countries this is the largest expenditure. Some social security systems have already began to feel the pressure of an aging population (Canada, 2008). Our continuing aging population stimulates questions about the ability of a community to meet the demands of a population.

The World's Health Organization has encouraged active aging to help prepare for these challenges. A compression of morbidity, which is a decrease in disability, is necessary for our ever increasing aging population (WHO, 2015). Over the past few decades health care cost have risen 1-2% faster than the GDP. Age has been an important determinant for health care cost. One approach to minimize cost would be to maintain health among the elderly for an extended time as possible, thus reducing long term social care cost (Harper, 2014).

The problem with aging is that there is an increase in prevalence of health related issues, such as frailty, cognitive decline, slow, weak, depressed, Alzheimer's, cardiovascular disease and multiple other physiological and functional issues (Erickson, 2012, Chekir, 2012). The incident of frailty in the elderly population is estimated between 7-20% and increases with age. One component to limit frailty is early intervention (Chekir, 2012). Research into the aging process are urgently needed to influence the aging process itself, thereby preserving significant physiologic function and improving the health of older persons (Geokas, 1990). Due to the increase in older adults, there is a growing concern about how to prevent and manage chronic illnesses, the ability to delay the onset of disability, and decrease the associated cost of health care and increase quality of life. (Lang, 2005).

Falls

Fall related injuries for those above 65 years old is a serious health concern (Stevens, Corso, Finkelstein, and Miller, 2006), and approximately one third of these adults will fall every year, between 30 and 50% of these falls result in minor injuries and about 10% will results in major injuries, like a fracture or brain injury. Those that break their hip, due to a fall, are about 1% and the morbidity after a hip fracture is about 25 % within one year, of the survivors only half regain their baseline abilities to do daily activities (Bradley, 2011). Falls have also been identified as one of the leading causes of unintentional injuries and death for those in this age group. These adults that do fall and do not sustain any injuries often develop a fear of falling and will often restrict their activities to avoid another fall. This type of behavior then increases their risk of falling (Limona, 2009). Falls pose problems on a personal, familial, economical and societal level (Frith and Davison, 2013) approximately 8 million people are treated for unintentional falls, where 19,000 die and half a million are hospitalized. The direct medical cost of people over the age of 65 exceeded $19 billion in 2000 (Mertz, Lee, Sui, Powell, Blair, 2010). Medical cost such as hospitalization have been estimated to be between $17,500 and $22,500 and up to 69,000 for hip related fractures. If falling rates continue medical expenditures, for a fall, are expected to double by 2020. Thus, fall prevention should become an essential part to control the rate of healthcare expenditures (Bohl, Fishman, Ciol, Williams, LoGerfo, and Phelan, 2010.

Effects of exercise on balance

Tai Chi has been shown to reduce the risk of falls and fear of falling, by about half in adults who participated in a 15 week Tai Chi intervention (Wolf et. al., 1996), also in a 6 month intervention by Li showed that Tai Chi practiced by older adults decreased the frequency of falls or risk of falls by 55%. The mechanism for Tai Chi's success may be because of the emphases of control over the displacement of the body, the postural control and range of motion of the joints and the muscles it uses, leg strength, to control the whole body (Li, 2005). This study had some limitations such as the need for an expert in Tai Chi to teach the classes and that this study found that you must do Tai Chi for a minimum of three months in order for the intervention to show the effect.

Resistance training programs have been shown to increase strength in older adults yet have shown only a minimum improvement to decrease falls (Liu and Latham, 2009). Power training on the other hand has shown better promise with a study done with 112 older adults using a power training intervention, using a low, medium and high load, 20%, 50% and 80% respectively (Orr, 2006). There results were that using a low load of power training was more effective for balance over twelve weeks than using a high or medium load. Power is force over time and suggest that movement patterns may need to be fast in order to illicit changes in balance. Using a higher percentage of one rep max may not allow a participant to move as fast as the body needs to see the changes in control of the body. These showed changes in at least a 12 week intervention.

High Velocity Movements Increase balance

Within the last fifteen years power has been found to contribute more to improvements in physical function than muscle strength. Power training is generally associated with power lifting or Olympic lifting, where a heavy amount of weight is lifted; with older adults power lifting is performed as fast as possible generally with lower resistance than traditional resistance training. The goal being to improve the ability to produce rapid force (Sayers, 2007). Suzuki, Bean and Fielding tested peak power and how it is related to physical functioning (gait velocity) in older women with functional limitations, and found that power and physical functioning are essential components of mobility in older adults (2007). Cuoco et al. also found similar results when they tested older men and women on power output and habitual gait velocity. They found that when velocities were high (power at 40% of one rep max) that participants performed better in their functional task, like gait velocity, than their control doing slow velocity movements (power 70% of one rep max). This suggest that measures that do not require maximal strength could be more sensitive to the velocity of movement than the need for strength (2004). Subsequently, muscle power (velocity) is becoming the focus of many resistance training studies in older adults (Fukumoto, 2014). Where Fielding et al. and Miszko et al. studies have compared high-velocity resistance training with regular resistance training (slow movement) in older adults and found that high-velocity training resulted in a greater improvement in physical function (2002, 2003). A novel study by Orr et al in 2006, assessed power training and balance in older community dwelling adults and found that after 10 weeks of training, of low load and high speed had the greatest improvements in balance. They hypothesized that the training at low loads and high speeds may have optimized other adaptations necessary for the task of balancing, such as improving sensory information. This suggest that training velocity, not intensity, may be the critical variable in improving balance and decreasing falls.

Gait is a complicated motor task which requires attention, planning and memory. Older adults require more attention to maintain stable gait, therefore it is important to investigate motor activities such as gait in the presence of additional attention demanding cognitive task (Theill, Martin, Schumacher, Bridenbaugh and Kressig, 2011). In a pivotal study “stops walking while talking” showed that not being able to hold a conversation while walking is a marker of older adults who are more likely to have a fall (Lundin-Olsson, Nyberg, Gustafson, 1997). Since then dual task paradigms are used to test if older adults gait may become impaired due to difficulty of shifting focus from a cognitive task to a balance task (Hawkes, Siu, Silsupadol, Woollacott, 2011). A dual task is where an individual performs an attention demanding task while walking to assess any modifications from the reference single task condition. More specifically this dual task paradigm has been used to assess interactions of cognition, gait, dynamic balance and risk of falls (Montero-Odasso, Verghese, Beauchet, Hausdorff, 2012).

Aging and Cognition

Cognition is control processes are the regulatory means of motor execution or responses of monitoring, selecting, and manipulating movement and information.

Advancing age is associated with a decline across an assortment of cognitive functions, these declines are expected, considered normal and are inevitable (Vink, 2015, Erickson, 2012). The brain traditionally has been labeled as non-elastic with no or little room for growth (Vink, 2015). Recent research challenges the definition of normal aging signifying that it is more plastic than previously thought. This suggest that the normal of amount of cognitive decline in aging deemed acceptable should be reduced (Erickson, 2012). Although, there is growing recognition that the aged brain preserves some capacity for plasticity, there is notable evidence for brain atrophy with advancing age. In a longitudinal study it has reported that between 1- 2% annual hippocampal atrophy in adults over 55 years without dementia (Jack et. al., 1998). Other regions of the brain can also atrophy in late adulthood, including the prefrontal cortex, caudate nucleus, and cerebellum, at estimated rates between 0.5% and 2% per year (Fjell et. al., 2009). Thus, the reasoning that advancing age is associated with smaller brain volumes and a decline in cognitive functions.

Cognition clearly plays a major role in motor control and age related decreases in motor performance suggest relationships between cognitive aging, motor function and learning. Attention has a significant role in cognition, which allocates mental resources to a specific task and is essential for motor learning (Arnten, 2005). Some attention capacity deteriorates during the aging process and response time is slower in older adults than young adults. Attention is dependent upon on for other cognitive processes; such as working memory and executive functions (Christ, 2008).

Effects of exercise on cognition

Sedentary behavior is often associated with cognitive decline in older adults, predominantly concerning populations with a genetic propensity for cognitive impairments. Research indicates that there is a positive relationship for those who follow a regular physical activity regimen and improved cognitive function (Etnier, 2006). Others have found that physical activity had a positive impact on motor performance, attention and thought problems and information processing

(Verret, 2010). Chaddock et al. looked at aerobic fitness as a mediator for cognitive performance in adolescents and found that cognitive performance and attentional processes are superior in fit versus non-fit adolescents. Suggesting that fit individuals are better able to control their cognitive processes. This improvement through fitness is also observed in the later cycles of life and does not decline across the lifespan. Fitness is predictive of achievement in the adult life and can delay MCI associated with disease like dementia (2011). Physical activity is generally viewed as a way to maintain physical health and is recommended at some level for most people. The CDC currently recommends at least 30 minutes a day, of moderate to vigorous activity, for adults to maintain health and minimize health risk.

Although physical activity is regarded as a health benefit for health, some suggest that it may also benefit cognitive functioning. Dishman (2006) looked at impacts of exercise on emotional and cognitive processes and found that exercise is associated with processes that require higher level executive control, such as task coordination, planning and scheduling. Also they found changes in the brain's plasticity and are thought to be responsible for improvements in learning and memory.

Executive Function

In recent years there has been considerable interest within neuropsychology and in certain areas of cognitive psychology in the concept of executive functioning, broadly defined as control processes responsible for planning, assembling, coordinating, sequencing, and monitoring other cognitive operations. The executive functioning concept is loosely based on an analogy to a business executive who is not necessarily a specialist in any particular domain but instead is responsible for supervising and managing many different domains. Because disruption of central control processes might result in the impairment of relevant behavior even if the component processes are intact, executive functioning clearly has the potential to affect performance in a wide variety of cognitive variables (Salthouse, 2003).

Although many consider executive dysfunction a collective set of maladaptive behaviors, some research has suggested there may be additional neurobiological pathway associated with executive function. Marx, et al. (2009) have suggested that there are two separate neurobiological pathways, a cognitive pathway and a motivational pathway. The cognitive pathway is the pathway most associated with deficits in executive functioning and may be associated with cognitive and behavioral dysregulation (Marx, et al., 2009).

Executive functioning is a broad term that encompasses the top-down, higher-order decisional process that helps individuals control their behaviors. According to Hummer, Kronenberger, Wang, Dunn, Moisier, Kalnin, and Mathews (2011), "executive function refers to a collective set of processes that encompasses planning, cognitive flexibility, working memory, organization, inhibition and problem solving". Diminished executive functioning plays a major role in movement. Executive functioning is a combination of processes in the brain that are the primary regulators of behavior, planning and other cognitive processes (Sagvolden, et al., 2005).

It is thought that older adults often have executive dysfunction which leads to a host of negative behaviors and disinhibition. Some researchers have evaluated the importance of executive functioning in our daily lives. Willcutt, Doyle, Nigg, Farone & Pennington, have identified executive functioning as the most important component for successful navigation of the ever-changing environment (2005). The importance of proper functioning is essential to be able to continuously evaluate the barrage of stimuli and choose an appropriate action or response from a seemingly endless list of possibilities.

Exercise and Executive Function

Changes in brain structures, physiology and neurotransmitters occur during aging. Some of these are a reduction in cerebral volume, frontal lobe .23%, temporal lobe .55% and smaller reductions in the parietal, occipital lobes, hippocampus and cerebellum annually. These areas are linked to memory and inhibitory control. Reductions in gray matter in the frontal lobe may deteriorate attention and executive function. Also white matter deficits are related to cognitive decline in executive control, processing speeds, task switching. Loss of gray and white matter in the frontal parietal areas may explain higher disruption in cognitive functions during aging.

Dopamine is a neurotransmitter that shows changes in the brain as it ages and is related to various cognitive functions (Arnten, 2005, Pereira, 2007)

Aging is generally accompanied by a decrease in motor control. Older adults are slower and less smooth in motor execution than young adults when asked to perform rapid aiming arm movements. These findings suggest that they are unable to individualize motor units for quick and efficient movement (Yan et al., 2000). Another study found greater deficits in postural control on a moving platform than younger adults, especially when a dual task was performed. Aging results in declining motor performance (Yan, 2000). Furthermore, aging results in morphological and neurochemical changes in the basal ganglia that may contribute to the decline in motor and cognitive functions. In order to fully understand dysregulated executive functioning, impaired cognitive functioning and maladaptive behaviors, it is necessary to understand the role of the neurobiological forces at work.

The dopaminergic activity was reduced in older adults when compared to young adults, when asked to perform task requiring frontal functions of cognition such as inhibitory control (Volkow, 1998). Dopamine is a biological compound known as a neurotransmitter which is synthesized in the brain and plays a role in coordinated movement and hormone secretion.

Dopamine helps to regulate mood and emotional stability and is a key component in the brain's motor functioning and reward system (Okada, 2005). Volkow et al., (2009) has shown through brain imaging studies with stimulus-response reward, that aging individuals have a disrupted dopamine transmission pattern which may be the underlying cause of inattention, impulsivity, cognitive decline and deficits in reward and motivation. Also, a study by Troiano et al (2010) determined that there was an age related decline in dopamine as one ages into their fifties. This drop in dopamine reception is related with motor decline. The dopaminergic system consists of five dopamine receptors, essential for central nervous system functioning (Wu, Xian, Sun, Zou, Zhu, 2012). Similarly, according to Klostermann et al. (2011) the dopaminergic system has various dopamine receptors, essential to central nervous systems functioning. Some of these receptors regulate dopamine production and others are responsible for the release of the neurotransmitter in different areas of the brain (Wu et al., 2012).

Backman et al. (2010) reviewed the D2 and D4 receptor genes in order to gain a better understanding of brain functioning in older adult populations. The D2 receptor gene has been found to be the regulator of the catecholamine system in the brain. Catecholamines are groups of neurochemicals involved in neural regulation which are connected in neural dysregulation. Dopamine is considered to be one of the primary catecholamines and attention to this system is important for gaining a better understanding of the neural workings of the aging brain. They also found that the D4 receptor is the primary dopamine receptor in the brain, which may associate dysregulation of motor control (Backman et al., 2010).

Another neurobiological component of dysregulated function in older individuals is the abnormal functioning dopamine reward pathway. It is commonly known that dopamine plays a role in reward and motivation and some researchers suggest there is disrupted neurotransmission in the aging brain (Volkow, et al., 2009). Reward and motivation deficits are have been observed in older populations and may be the result of abnormal neural responses to reward and punishment. This dysregulation may help understand the impulsive behaviors and the inability to delay gratification. Understanding the role of these structures in the brain is important when considering how to treat the cognitive impairment (Beck et al, 2009).

Exercise has been effective in increasing the synthesis of several neurotransmitters, most importantly dopamine. A dopamine receptor indicated in attention deficit hyperactivity disorder ADHD, the D2 is related to reward mechanisms after physical activity and helps movement control. ADHD is similar to cognitive decline in that it is characterized by smaller brain volumes, low executive function and dysfunctional motor control and reward mechanisms (Simonen, et al., 2003, Beck et al., 2009). Dopamine is a major neurotransmitter specified for reward and pleasure in which exercise has been shown to influence this dopaminergic pathway, in individuals with ADHD, positively affecting their ability to execute cognitive and motor task (Chang, Liu, Yu & Lee, 2012). In ADHD, class II narcotics are administered to increase dopamine in the prefrontal cortex (Briggs, 2011). Other drugs are administered for Parkinson’s and Alzheimer’s diseases and mild cognitive impairment adults that can also have serious side effects such as weight loss, dizziness and premature death (Van Leuven, 2010). Therefore, exercise may be one potential alternative treatment that could improve executive and motor functioning by increasing dopamine production as well as other proteins specific to neurogenesis in older adults.

Treadmill exercise has been found to increase dopamine levels and dopaminergic transmission regions in the brain that affect cognition and motor control (Petzinger et al., 2007). Another, protein responsible for neurogenesis, and neuroprotection is brain derived neurotropic factor BDNF. Exercise has been shown to increase BDNF of up to 32% (Schmolesky, Webb & Hansen, 2013, Erickson, 2012).

In studies with animals, elevated levels of exercise, have led to the increased production of dopamine, thus increasing the plasticity of the neurotransmitter systems (Foley & Fleschner, 2008). Also mice that were exercised were observed to have significant positive changes in dopamine production and receptor sites when compared to a sedentary group of mice (Foley & Fleschner, 2008). Zhao et al., 2013 identified structures in the brain that were impacted by exercise due to some changes in neurochemical availability and suggests that exercise interventions may reduce the chance for negative outcomes that are associated with stimulant medication use. Lentz et al., also states that after an acute bout of exercise there is an immediate change in the availability of neurochemicals (2012).

Assisted Cycle Therapy

Assisted Cycle Therapy is an innovative exercise that suggests that increased rate of exercise can improve motor/balance *and* cognitive function. Originally Assisted Cycle Therapy was conducted in animals and termed Forced exercise (FE). In FE rodents would exercise on a motorized treadmill at a rate greater than their voluntary exercise rate (Tajiri et al., 2009, Zigmond et al., 2009). Failure to maintain speed would result in a noxious stimulus (i.e., electric current). In rodents FE has been shown to increase Nerve Growth Factor (NGF) (Counts & Mufson, 2005). Low levels of NGF are associated with cardiovascular disease (Manni et al., 2005). Research in animals also showed that high intensity exercise promotes behavioral recovery by modulating genes and proteins important to basal ganglia function which are crucial to voluntary motor control and cognitive functions (Li et al., 2004).

The first research of this kind, FE, was conducted in 2009 by Ridgel et al. at the Cleveland clinic. There they used a tandem bicycle in which a trainer maintained a pedaling rate of 80-90 rpms, which was about 30% faster than the Parkinson's disease (PD) patients' voluntary pedaling rate. This is referred to as assisted cycling (AC). Another group pedaled at their own rate. Both groups exercised for 40 minutes three times a week for eight weeks. The results of this research found that AC improved motor function as seen in a 35% improvement in the Unified Parkinson's Disease Rating Scale, and no improvements in following the VE. Also, there was an improvement in bimanual dexterity task following AC but not VE in these PD patients. This is indicative of global motor function and suggest that improvements are happening at a cortical level. Later, a study in 2011 by Alberts et al. studied the effects of acute AC on brain activation and looked at nine patients with PD. These subjects were scanned under three conditions 1) off meds, 2) on meds, 3) after AC and no meds. The scans included a MRI protocol, and the scans showed that subcortical and cortical regions of the brain were activated in both the AC and no meds and on meds and these findings indicate that AC and medication use similar pathways to produce symptomatic relief in PD.

People with Down syndrome (DS) have deficits in cognitive functioning, and compared to their peers they show diminished levels of working memory, inhibition, planning and set shifting. These deficits limit their ability to perform activities of daily living. Current exercise interventions for those with DS have not achieved desired results in functional task. DS individuals often choose sedentary activities and congenital heart defects contribute to low levels of physical activity. When individuals with DS stick to an exercise program, they typically see improvements in fitness. However, because individuals with DS have limited movement due to physiological factors their ability to induce changes in CNS may be compromised when engaging in voluntary cycling; because of this abnormally lower level of intensity DS individuals have not seen significant therapeutic benefits of exercise (i.e., cognitive function) (Ringenbach, Albert, Chen, and Alberts, 2014). Older adults may have a lower level of intensity during exercise and may not receive as great of therapeutic benefit from exercise.

In a study on acute bouts of assisted cycling in adolescents with Down syndrome where they took nine participants and randomly completed 3 interventions of VC, AC, and NC. In the 30 minute VC session the average cadence was 54.6 rpm, whereas in the AC session the average cadence was 81.5 rpm. The results were that in the unimanual and bimanual conditions of the Purdue Pegboard increased. Also the reaction time increased in the AC session but not the VC session. This study showed that only in the AC session that resulted in pre/post improvements in motor and cognitive function. Another finding in this study was that they found that the perception of exercise (i.e., easy to exercise, and made their body feel better) improved during one AC session and not with the VC or NC. This has positive implications for those with reduced motivation to exercise, in that those with low motivation or low exercise tolerance to exercise would be more willing to exercise after a bout of AC (Ringenbach, Albert, Chen, and Alberts, 2014).

A similar experiment with Autism Spectrum Disorder (ASD) was recently performed. ASD is associated with a lack of motor coordination, and a stationary bike is believed to eliminate some of the clumsiness, balance and motor control deficits that those with ASD may have. They randomly completed 3 acute interventions randomly of VC, AC and NC. The exercise time was reduced to 20 minutes to accommodate the behavioral differences. Inhibitory behavior and cognitive planning were both found to increase after AC but not VC and NC. This relates to activities of daily living for those who have ASD. Although, in this study they found that AC did not improve manual dexterity by the Purdue Pegboard where they did find an increase in manual dexterity in the VC sessions. It is also important to note that in both the AC and VC sessions the participants are exercising at the same intensity. Showing that AC may have benefits because of the high velocity movement and not just the intensity. The primary focus of this research is to investigate whether similar improvements normal older adults in regards to cognition and motor performance; following an AC and VC compared to a NC.

CHAPTER 3

METHODOLOGY

Participants and Study Design

Ten adults, six female and four male volunteers between the ages of 50 and 78 were recruited through word of mouth, fliers and community centers (Appendix A) Inclusion criteria for participation included: (1) Men and women aged 50 – 85; (2) No limitations on riding a stationary bike; (3) meets the Physical Activity Readiness Questionnaire Plus (PAR-Q+) criteria (Appendix B), or received clearance for moderate intensity exercise from a physician, in order to protect the participant from potential risk factors associated with exercise.

All protocols were approved by Internal Review Board at Arizona State University. All volunteers signed informed consent. Participation was voluntary and participants could withdraw from the study at any time without reproach.

The independent variables were assisted cycling, voluntary cycling and no cycling. The dependent variables were balance, manual dexterity, and force production, for the motor task. The Stroop test and reaction time for the cognitive tasks. The Stanford Leisure-Time Activity Categorical Item (L-CAT) and the Montreal Cognitive Assessment (MOCA) were used as covariates.

Experimental Groups

We used a with-in subjects, randomized cross-over design. All participants completed three separate randomly ordered interventions. (1) Assisted Cycling Therapy (ACT, AC), (2) Voluntary Cycling (VC), (3) No Cycling/Control (NC). Each intervention was separated by at least two days to minimize any residual learning effects. Breaks were given as needed during the cycling interventions, as well as five minutes before the onset of, and after exercise; between pre-test and post-test. Both ACT and VC exercise intervention lasted 30 minutes plus another 10 for a warm up and cool down. For the ACT intervention the bicycles mechanical motor will be engaged, which assisted the volunteer in pedaling at a faster rate (cadence) than self-selected. In the VC intervention the mechanical motor was turned off and the volunteers cycled at their own cadence. There was no cycling or exercised of any sort during the control session. Participants were asked to passively watch a video.

AC: Training pedaling rate was set by a mechanical motor to a cadence at least 35% greater than the volunteer's preferred pedaling rate, determined from baseline. A 35% increase is consistent with previous research using this methodology (Alberts et al., 2011). Subjects were instructed to maintain their HR within their THR zone through active pedaling of the cycle. Subjects adjusted their contribution to the pedaling action in order to maintain their HR rate within THR.

VC: Training pedaling rate was determined by self-selection and volunteers were instructed to maintain their HR within their THR

NC: There was no exercise or cycling during the control intervention. The volunteers watched a video.

All Volunteers were asked to maintain their current level of activity for the study period.

Exercise Protocol:

The participants were instructed to exercise within their THR during the 30 minute main exercise set. The main exercise set began with a 5 minute warm-up and a 5 minute cool-down phase. Because some participants were deconditioned upon enrollment, participants were allowed to take a 2 minute 'on the cycle' rest breaks every 10 minutes during their 30 minute cycling session if needed. To monitor participant's exercise intensity participants were asked to visually point to rate their perceived exertion (RPE) on a scale from 1 (easy) to 10 (difficult) every five minutes. Our pilot data indicates that RPE increased as HR increased. If any participant exhibited signs of cardiac distress (e.g., pressure, tightness, aching, or burning in their upper back, neck, shoulders, and arms, or even in their jaw, or shortness of breath, fatigue, stomach pain, cold sweats, dizziness, indigestion, or nausea, etc.) as determined by the researcher, or participant, the session was stopped immediately and 911 was called. All study personnel with any participant contact had completed a Basic Cardiac Life Support training course.

During all testing sessions, resting was individualized to reduce attentional and motivational limitations. Qualitative (e.g., be sure the participant maintains heart rate within THR during the main exercise set) and motivational (e.g., Great job!) verbal feedback was provided after each trial.

Exercise Intensity:

Heart rate values were used to calculate the intensity of the exercise administered to the volunteers. Target heart rate was calculated using the following formula: THR = 220 – (age) x 0.7. A RPE from 1 – 10 was used to verify intensity. The volunteers wore a heart rate monitor in order to measure HR during exercise, by using a Polar HR monitor (mode S610i; Polar Electro, Finland). This model can transmit data via short range radio in order to collect data during the entire experimental stage.

Cycle:

The proposed study used the Technogym motorized cycle developed in an R21 by Dr. Alberts and is currently in use in NICHD R03 with adolescents with Down syndrome and in a larger NIH R01 Cycle for Parkinson's clinical trial. It samples (at 100 Hz) and stores HR, power produced by the subject, power contribution of the motor, and cadence and ensures participant safety (e.g., emergency stop tether, excessive load detector within motor, etc.). Volunteers were asked to wear tennis shoes and athletic clothing for all test days. Volunteers were seated on the bicycle and asked to hold onto the handles at their side, for safety. A SRM PowerControl-V computer is wired to the bike which reads cadence.

Intervention:

Every intervention (session) lasted at least two and one half hours and the first visit took at least three hours. During the initial visit the participant signed the consent forms; filled out the PAR-Q+, and L-Cat questionnaires this took approximately 30 minutes to complete. This was then followed by the administration of the assessment test which took approximately 40-50 minutes to complete. The AC, VC or NC session followed the pre-tests, the exercise and control interventions took about 45 minutes to complete. Then the post-tests were administered. These were the same test that were assessed and administered at pre-intervention, these final test took 40-50 minutes to complete. Each participant, participated in one session of each intervention

(AC, VC & NC), followed by a minimum of two days break.

Assessments

Fullerton Advanced Balance Scale (FAB):

Test both static and dynamic balance. This test consist of ten items that assess subtle balance deficits. These items are: stand feet together, eyes closed, reach forward, turn in a full circle, step up and over, tandem walk, stand on one leg, stand on foam eyes closed, two-footed jump, walk with head turn, and reactive posture control. These items test sensory systems, such as somatosensation, vestibular, vision, neuromuscular systems and synergisms, and musculoskeletal systems. It is an assessment tool that can identify developing balance problems within a higher functionally independent older population. The FAB has a high test retest reliability (p=0.96) and has good construct validity (Rose, Lucchese, and Wiersma, 2006). (Appendix H)

Timed up and go (TUG):

The TUG-test is an effective method of assessing mobility and quantifying locomotor performance (Podsiadlo and Richardson, 1991). This is a test that may predict future falls. The norm is under 10 seconds for normal individuals who are independent. The test consist of a chair, 10 feet around a cone on the floor. The participant starts sitting, and is told to have arms in lap, stand up, to walk comfortably and safely around cone. The time starts from "go" to back against chair after returning. The mean of 3 trials after 1 practice trial. (Steffen, Hacker, Mollinger, 2002) (Appendix G)

Purdue Pegboard:

Subjects are required to place as many pins as possible in 30 second periods using the right hand, left hand, and then both hands simultaneously. Then subjects use both hands to construct assemblies, which consist of a peg, washer, collar, and another washer, for 1 rninute. The objective is to place as many pins or assemble the pins, washers and collars in the holes before time ends. This test measures gross and fine motor control and evaluates manual dexterity. Purdue Pegboard evaluates intralimb and interlimb movements and is used to detect neuropsychological deficits. It has a test retest correlation of 0.65 (Redden et al., 1988) (Appendix K)

Dual Task:

Divided attention between cognitive and motor task assessed. This test is done by walking 60 feet around cones for one minute, while counting backwards from 100 by 2. Test-retest reliability is ICC>0.85 (Montero-Odasso, et. al., 2009). (Appendix F)

Grip Strength

Grip strength a measurement of manual force production. This is measured using a dynamometer and can measure of frailty in older adults. It is performed by bending the elbow to 90 degrees and squeezing as hard as possible for five seconds. This has an r = 0.85 and reflects strength and motor control processes (Hamilton, McDonald and Chenier, 1992). (Appendix J)

Stroop Task:

This test measures executive functions involving cognitive inhibition or set-shifting, which is the ability to shift cognition when a replying to an autonomic response in the environment. Cognition happens when one is exposed to a stimulus and must choose an appropriate response. This interference requires a special degree of focus, attention and set-shifting (Lansbergen and Kenemans, 2007). This test probes the frontal lobe associated with selective attention. Selective attention is the ability to process one feature while disregarding another. Selective attention is important in daily life, for it is required to inhibit interfering stimuli and focus on the relevant task in the environment (Kaplan, Sengor, Gurvit and Guzelis, 2007). In older adults this may be the difference from looking up and tripping over a sidewalk, or step over sidewalk, stop and then look up when name is called.

The Stroop test consist of color words that are written in different colors (the word red is spelled out but it is written in Green). The task is to touch the color of the word on the iPad instead of touching the color that one reads. This test last 30 seconds and is performed on an iPad, the mean of three trials is gathered. (Appendix E)

Choice Reaction Time: This is a standard test in which there are different responses depending on different stimulus. This test was limited to two stimuli (red and yellow lights) and two responses the right and left hands. Choice reaction time will be assessed 20 times. A trial will not count if the participant touches both buttons at the same time. Choice reaction time measures more complex decision making and has a r = 0.90 (Inui, Yananishi, and Tada, 1995) (Appendix I)

Montreal Cognitive Assessment (MOCA)

The MOCA (available at www.mocatest. org) is a one-page 30-point test administered in 10 minutes. It is a test which evaluates Mild Cognitive impairment (MCI) in patients who complain and usually perform in the normal range on the Mini-Mental State Examination (MMSE). The test consist of trail making, cube drawing, clock drawing, delayed recall, phonemic fluency, naming, and orientation, digit span, sustained attention. The MOCA has a high test-retest validity yielding an r = 0.87 with the MMSE. It also has a 90% sensitivity in identifying a MCI and 100% with identifying Alzheimer's disease. Mild cognitive impairment cut-off scores were placed at 25 and below (Nasreddine et. al., 2005). (Appendix L)

Stanford Leisure-Time Activity Categorical Item (L-Cat):

The L-Cat is an assessment which comprises of six activity categories, varying from inactive to very active. It is self-administered in which each category consists of 1–2 sentences describing common activity patterns differing in frequency, intensity, duration and types of activities, thus encompassing content validity. After reading respondents then pick the category best describing their activity during the past month. This has a high reliability ($p<0.001$)

Statistical Analysis

A linear mixed model analysis was used with three main effects: session as a between-subjects factor, time or period as a within-subjects factor, and treatment as a within-subjects factor. Assignment to one of the three possible treatment sequences will be coded as: 1, 2, or 3. Time/period were coded as 1 (1^{st} visit), 2 (2^{nd} visit), and 3 (3^{rd} visit) and treatment was coded as 1

(ACT), 2 (VC), and 3 (NC). Outcome measures (dependent variables) were entered as the difference between pre- and post-scores. Recall that each outcome measure was administered before (pre) and immediately after (post) each treatment session. Least-square means, which adjusts for randomly missing values, were computed for each group at each time point. Two-tailed type I error probability was set at $\alpha = 0.05$. Least Significant Difference (LSD) post-hoc analysis were used to test differences among the three treatments. The analysis were completed with a customized univariate general linear model in SPSS v.22. Session was entered as a random effect, time and treatment were entered as fixed effects and sequence x subjects were entered as an interaction. The session x subjects' interaction was entered specifically to use as the error term (denominator) to calculate the F statistic for the session effect. The p-value for the session effect was computed using an online p-value calculator (www.graphpad.com/quickcalcs/PValue1.cfm). If the session term was significant indicating a carryover effect, then the treatment effect at time 1 were analyzed as a between-subjects factor using a one-way ANOVA which means that the times 2 and were disregarded. MOCA, L-CAT scores as well as age were entered into the model as covariates.

Normality testing was completed by Shapiro-Wilks test and all were normally distributed except for the Stroop data. Therefore, we log transformed the Stroop data. Once transformed the data was normally distributed.

CHAPTER 4

RESULTS

Quantitative Data

Ten older adults were screened for this study, of which all ten met the PAR-Q+ physical activity criteria. All ten of the participants completed the study. Participant characteristics are presented in Table 1. Baseline (pre-intervention) executive and motor function assessments are presented in Table 2. Normality testing was completed by Shapiro-Wilks test and all were normally distributed except for the Stroop data. Therefore, log transformation of the Stroop data was necessary. Once transformed the data was normally distributed. There were no sequence effects or carry over effects as tested by the sequence main effect by time. There were also no interactions between age, activity level (L-Cat), gender or cognition (MOCA)

Table 1: Participant demographic information;		N=10	(%)
Sex			
Male		4	(40)
Female		6	(60)
Race/Ethnicity			
White/Caucasian		8	(80)
Hispanic		2	(20)
Stanford Leisure-Time Activity Categorical Item			
1	Inactive	1	(10)
2	Very Light Activity	2	(20)
3	Light Activity	4	(40)
4	Moderate Activity	2	(20)
5	Active	1	(10)
6	Very Active	0	(0)
Montreal Cognitive Assessment			
		27.75/30 Average	Standard deviation +/- 1.9

11 participants were screened, and 10 participated. All 11 pasted the PAR-Q+, the 11th participant lost interest before participating in the study and never signed the consent forms. All participants were healthy older adults with no complaints to pain, except for a few who mentioned arthritis before participating in exercise but not after (not recorded). Arthritis was not a criteria for exclusion to the study.

Table 2. Pre-post intervention executive and motor function assessments scores (mean)

	ACT (pre)	ACT (post)	VC (pre)	VC (post)	NC (pre)	NC (post)
Cadence (rpm)[1]	81.75		54.45			
Power (Watts)[1]	25.73		32.04			
HR (bpm)[1]	82.1		84.96			
Balance (score)	32.9	36.4	35.1	37.1	34.7	33.8
TUG (sec)	6.25	6.31	6.19	6.29	6.24	6.41
Purdue Pegboard (total = Right + Left + Both)	12.08	13.11	12.59	12.83	12.69	12.55
Purdue Right Pegboard (pegs)	13	14.3	13.39	13.93	13.67	13.67
Purdue Left Pegboard (pegs)	12.96	13.93	13.5	13.49	13.6	13.07
Purdue Both Pegboard (pegs)	10.3	11.03	10.89	11.06	10.83	10.47
Purdue Assembly Pegboard (pegs)	25.79	29.37	25.8	28.23	28.67	28.67
Force production Dominant (pounds/sq. inch)	61.33	56.06	62.2	58.93	64.06	61.13
Force production Non-dominant (pounds/sq. inch)	62.74	58.13	61.26	56.9	66.19	62.9
Dual Task (ft./sec)	4.41	4.31	4.33	4.4	4.47	4.55
Walking Speed (ft./sec)	5.25	5.24	5.18	5.24	5.17	5.07
Stroop	26.58	29.03	27.4	28.97	28.67	28.9
Reaction Time (sec)	0.406	0.378	0.411	0.397	0.405	0.402

[1]Means and SD for cadence, power, and HR are listed under ACT (pre) and VC (pre) but they represent the means of the entire cycling sessions

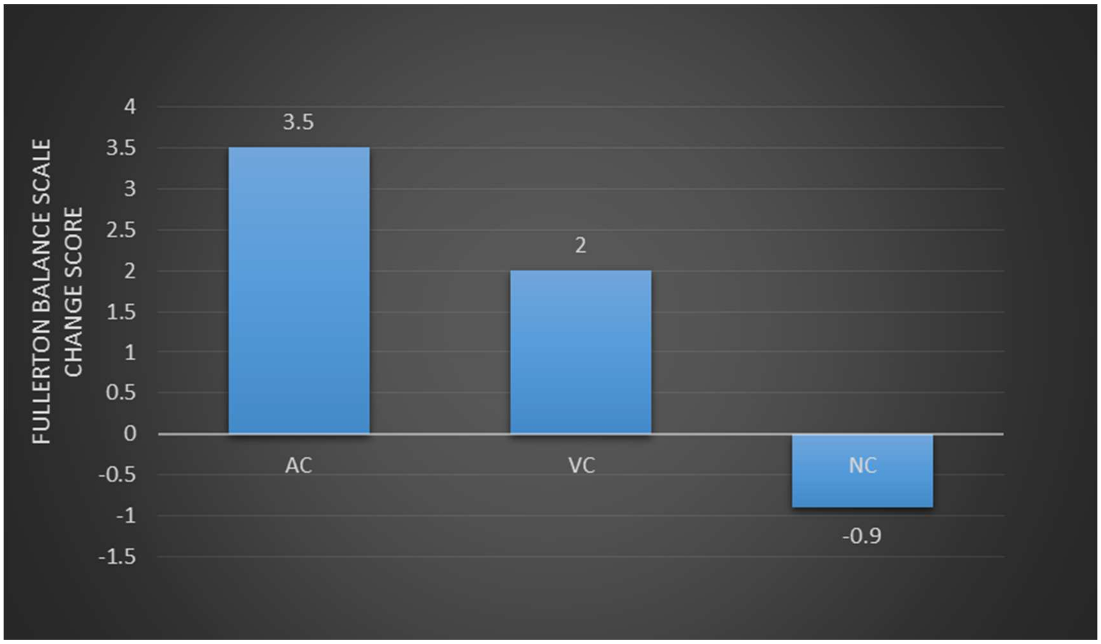
Table 3. One-way ANOVA results of treatment main effects and Cohen's d effect size of mean change by treatment

Variable	F (2,29)	p	Cohen's d ACT	Cohen's d VC	Cohen's d NC
Balance	4.57	0.027*	0.73	0.54	-0.15
TUG	0.034	0.714	0.05	0.08	0.15
Purdue Peg Board Total	7.96	0.004*	0.61	0.13	-0.1
Purdue Peg Board Right	2.70	0.096	0.64	0.25	0.001
Purdue Peg Board Left	7.09	0.006*	0.57	-0.001	-0.43
Purdue Peg Board Both	3.6	0.051	0.45	0.09	-0.25
Purdue Peg Board Assembly	2.72	0.096	0.45	0.31	-0.0002
Dual Task	0.682	0.520	-0.13	0.1	0.13
Grip Strength Right	6.516	0.010*	-0.27	-0.15	-0.17
Grip Strength Left	2.171	0.101	-0.25	-0.21	-0.22
STROOP	1.180	0.331	0.33	0.25	0.04
Reaction Time	.649	0.536	-0.63	-.022	-0.05

*p < 0.05; **p < 0.01

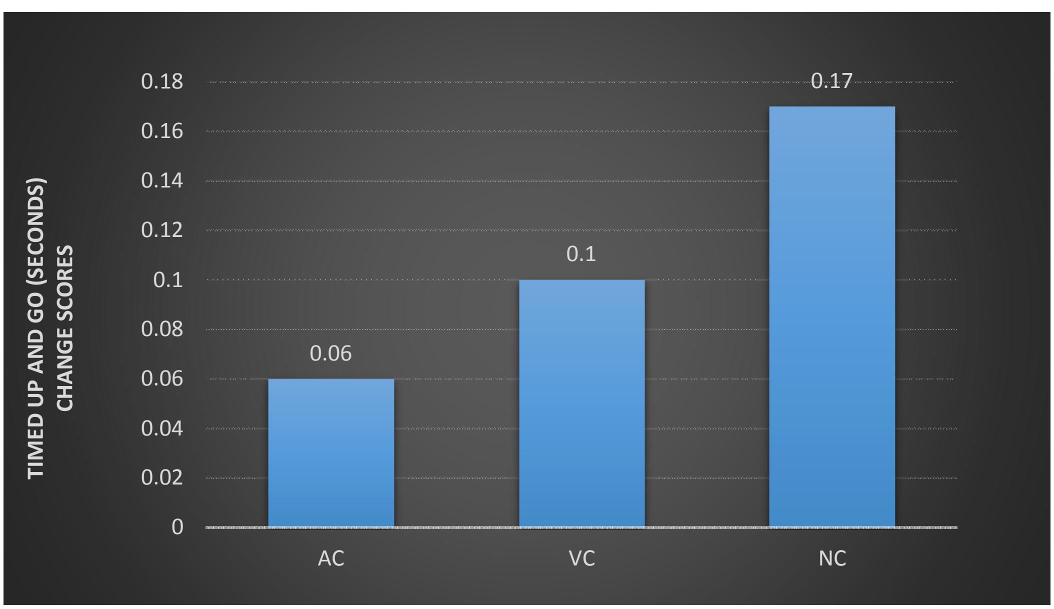
Motor Function

Figure 1. Effects of exercise on balance



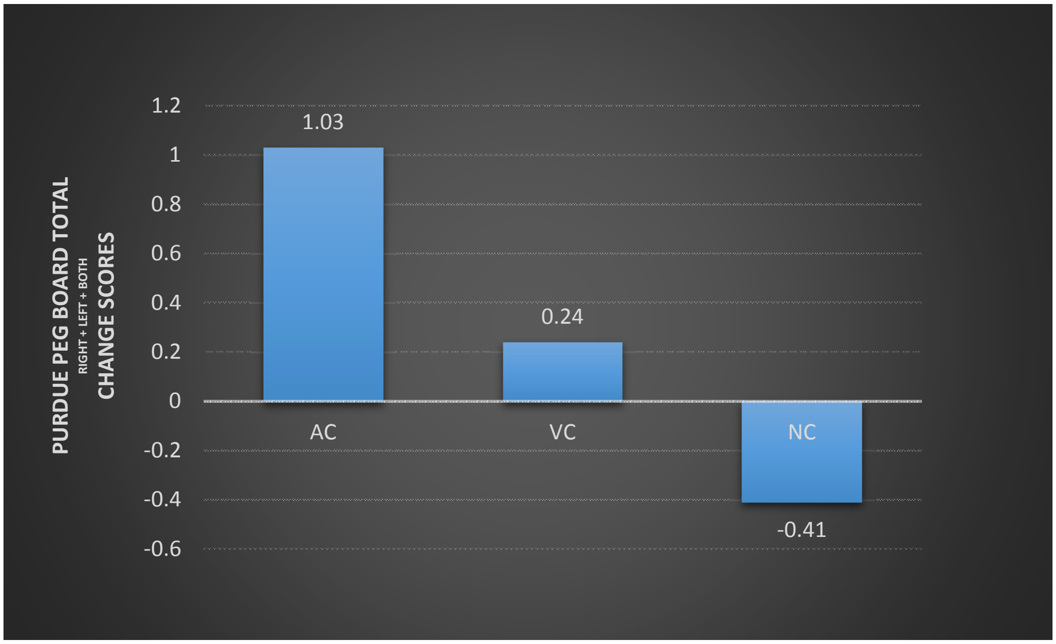
The results showed a main effect for change scores on the Fullerton Balance scale for session, F(2, 29) = 4.57, p = .027. Post hoc analysis for revealed that ACT was significantly different than NC (control) p= 0.005 and a significant difference was present between VC and NC p= 0.049 but not significantly different from AC and VC p= 0.288.

Figure 2. Effects of exercise on dynamic balance



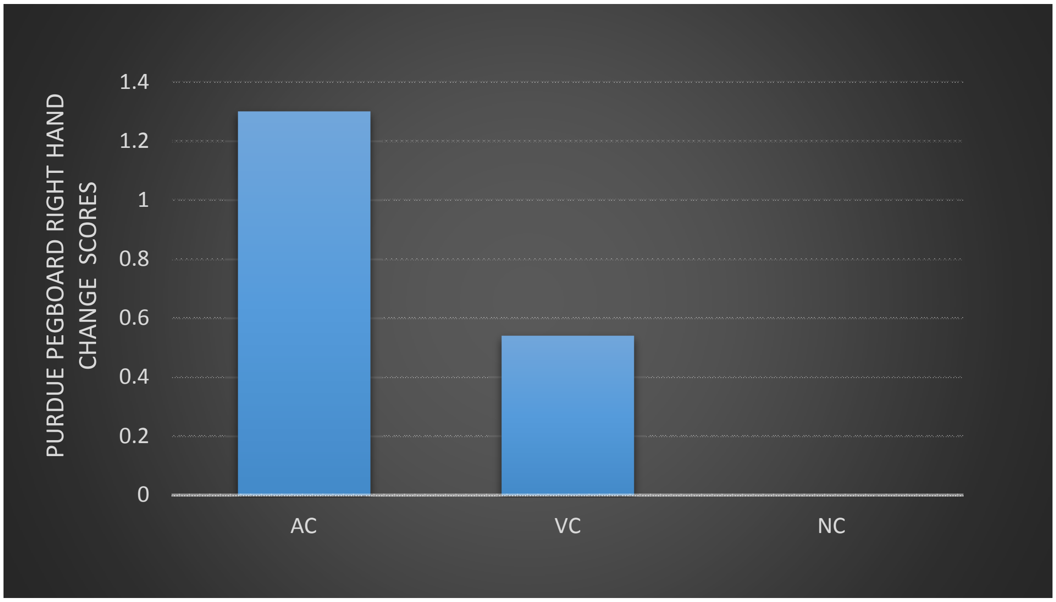
For the TUG there was no significant difference between ACT and VC p= 0.795, ACT and NC p=0.451 or VC and NC p= 0.618.

Figure 3. Effects of exercise on Manual Dexterity



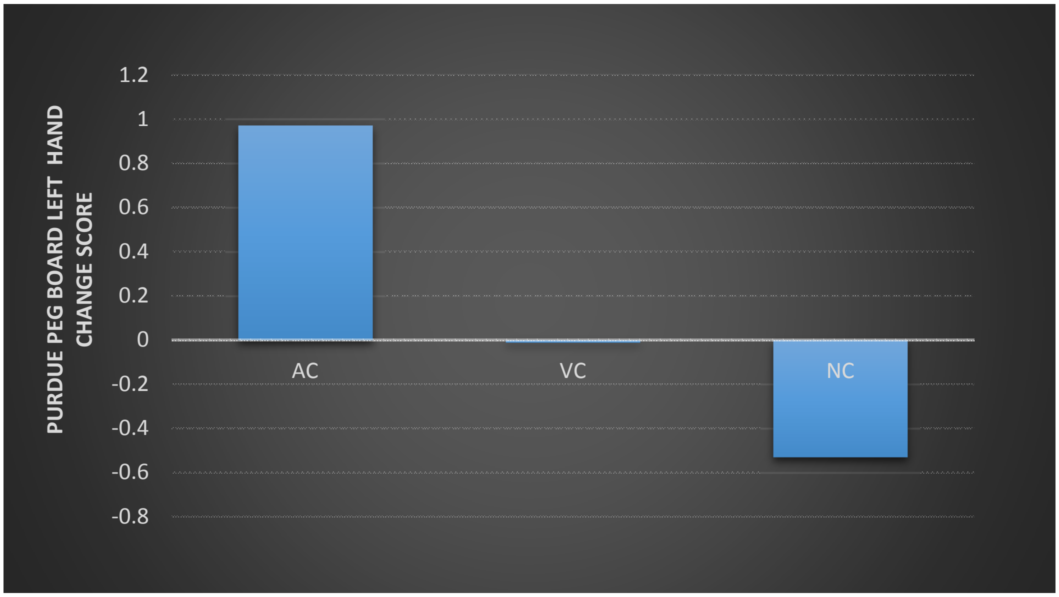
For Purdue pegboard total score there was a significant main effect of session, $F(2,29) = 7.96$, $p = .004$. Post hoc analysis revealed that there was a difference between ACT and VC p= 0.007, and ACT and NC p<0.000. There was no significant difference between VC and NC p= 0.160.

Figure 4. Effects of exercise on manual dexterity



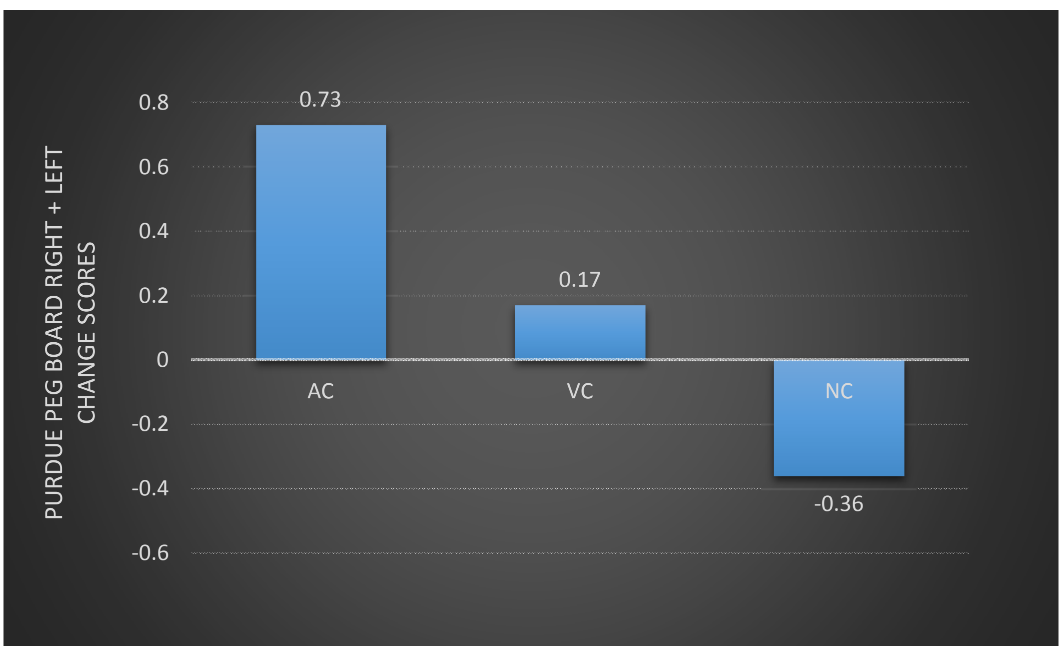
For the Purdue pegboard right hand performance there was not a significant difference between ACT and VC p= 0.119 or ACT and NC p=0.013 or VC and NC p=0.269.

Figure 5. Effects of exercise on manual dexterity



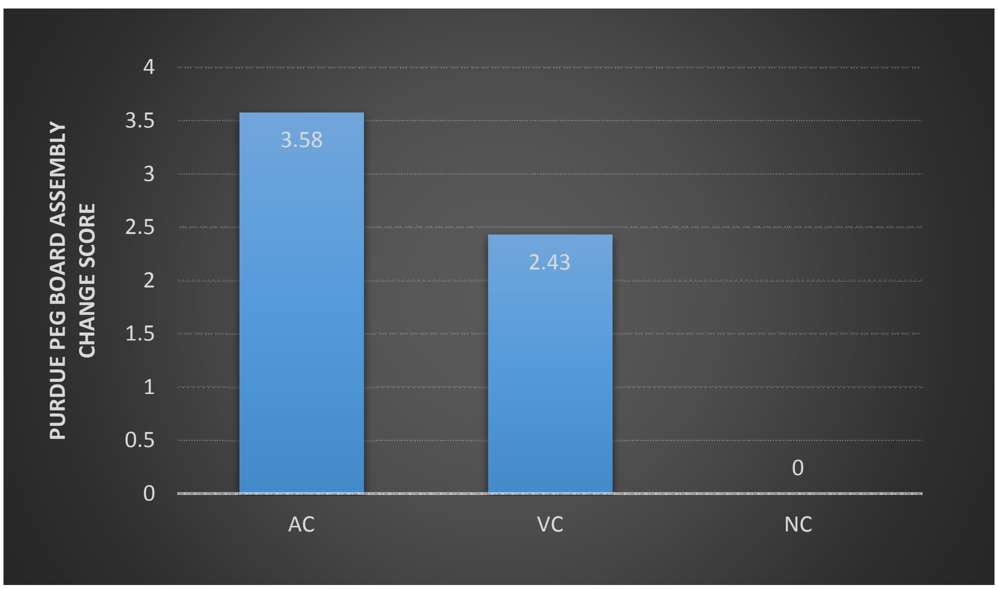
For the Purdue pegboard left hand performance there was a main effect for session F(2,29) = 7.09, p = .006. Post hoc analysis revealed that there was a significant difference between ACT and VC p=0.026, and ACT and NC p=0.002. There was no difference between VC and NC p=0.197.

Figure 6. Effects of exercise on bimanual dexterity



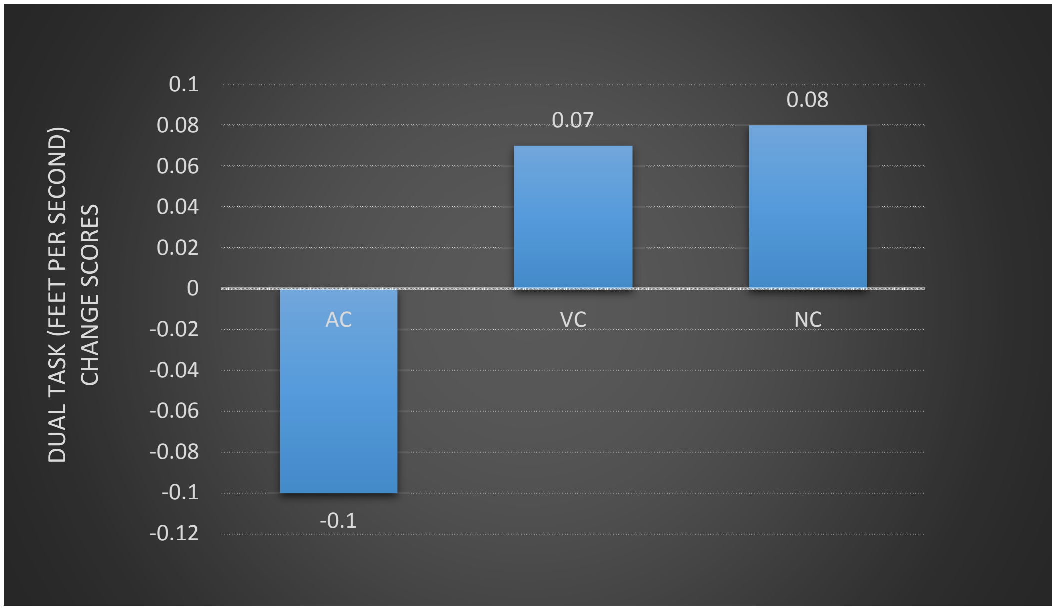
For the Purdue pegboard total there was no significant difference between ACT and VC p= 0.113, however there was a significant difference between ACT and NC p=0.005. There was no significant difference between VC and NC p=0.113.

Figure 7. Effects of exercise on fingertip dexterity



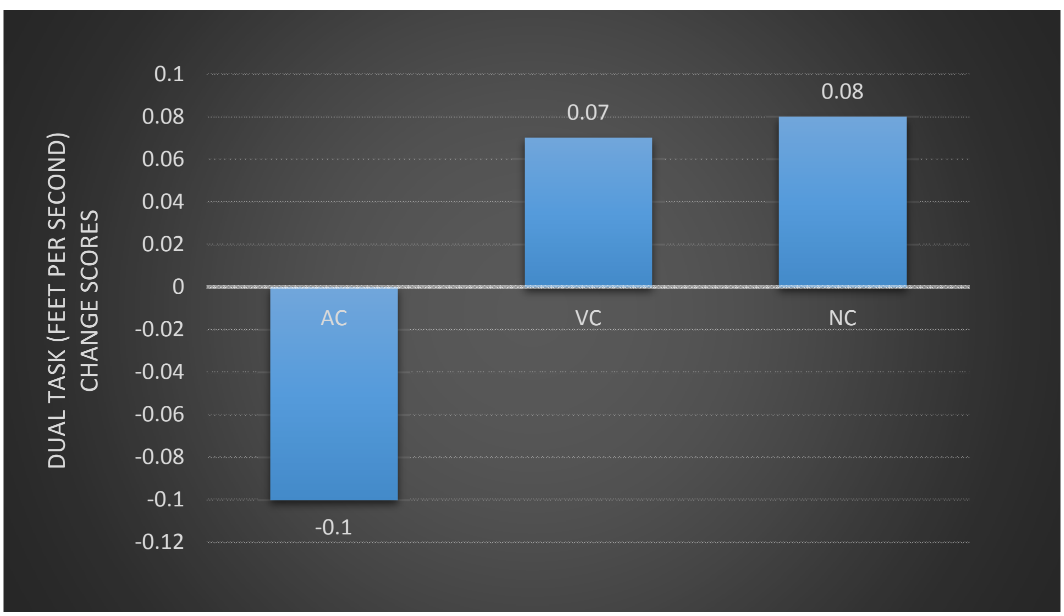
For Purdue pegboard assembly there was no significant difference between ACT and VC p= 0.404. There was a significant difference between ACT and NC p=0.016. There was no significant difference between VC and NC p= 0.085. This represents improvements in fingertip dexterity.

Figure 8. Effects of exercise on dynamic balance



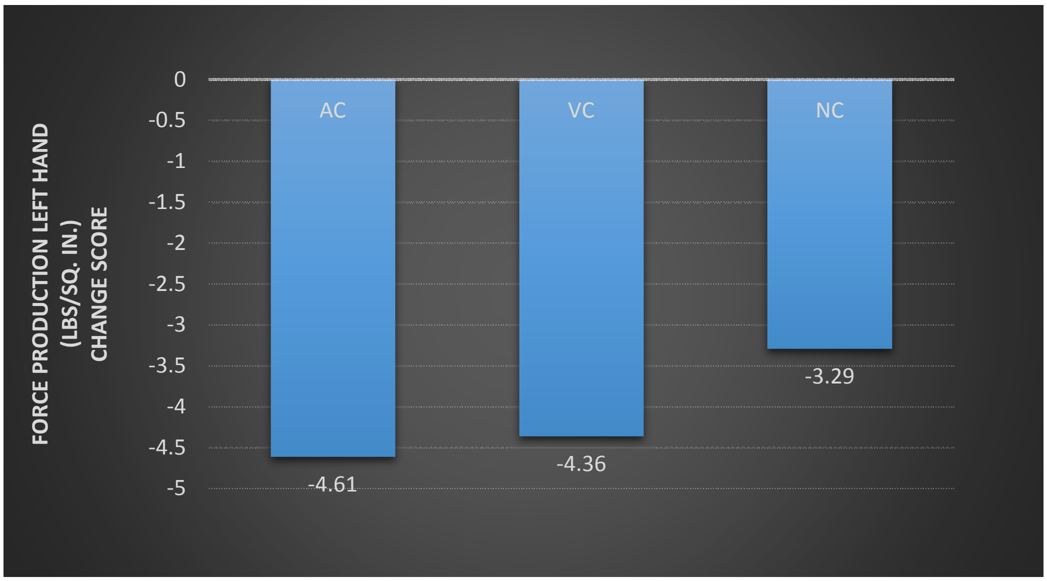
For the Dual Task there was no significant difference between ACT and VC p= 0.275, ACT and NC p=0.262 or VC and NC p= 0.974.

Figure 9. Effects of exercise on grip strength



For force production in the dominant hand there was a main effect of session, $F(2,29) = 6.52$, $p = .010$. Post hoc analysis revealed that there was no significant difference between ACT and VC $p= 0.172$, however there was a significant difference between ACT and NC $p=0.025$ and between VC and NC $p= 0.001$.

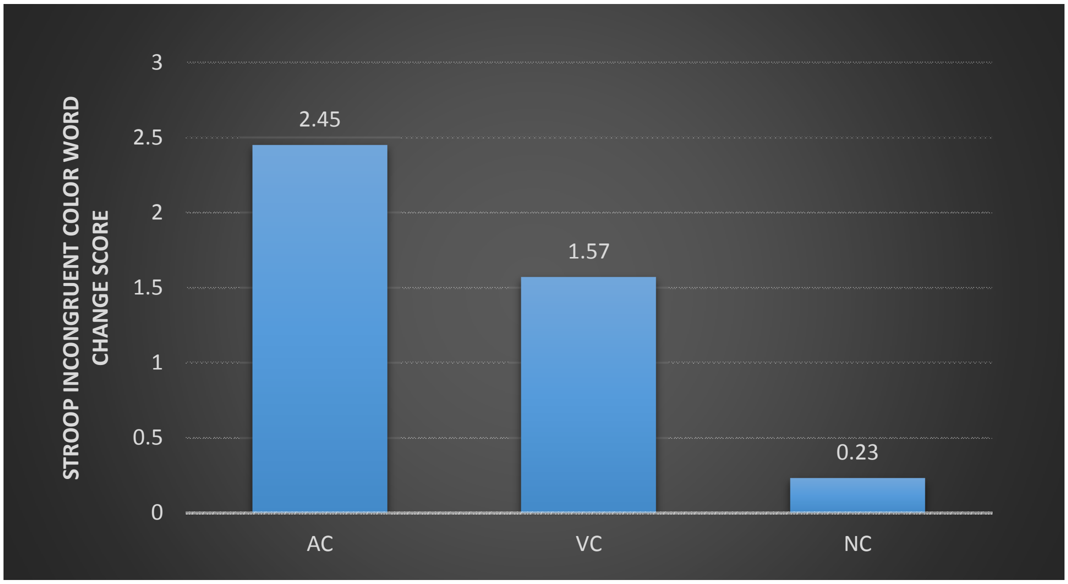
Figure 10. Effects of exercise on grip strength



For force production in the non-dominant hand there was no significant difference between ACT and VC $p= 0.953$, ACT and NC $p=0.013$ or VC and NC $p= 0.011$.

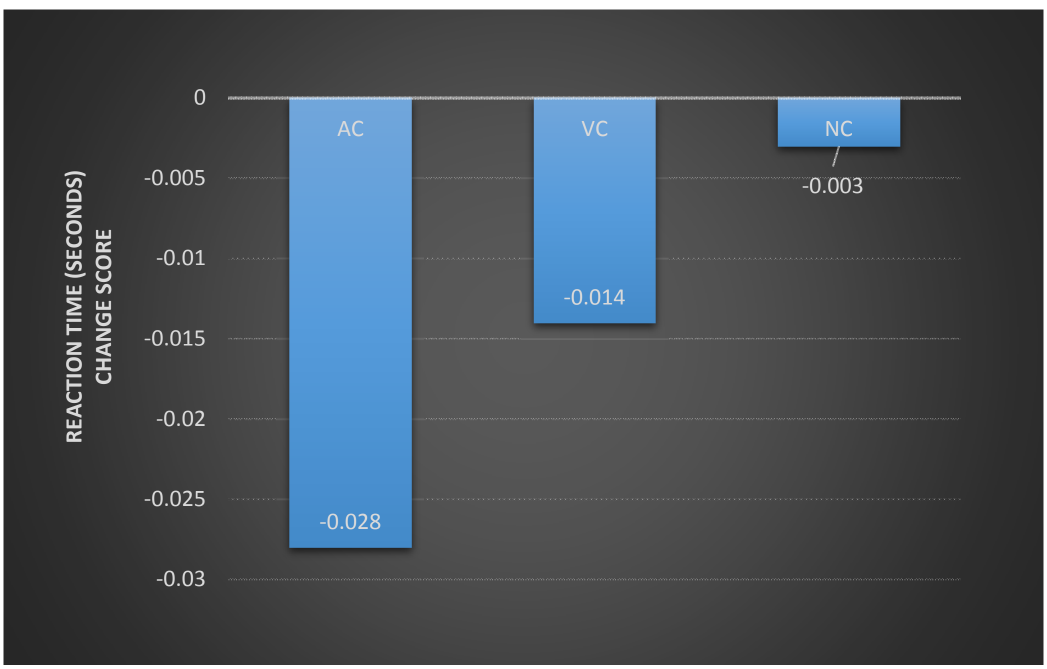
Cognitive Function

Figure 11 Effects of exercise on cognition



For the Stroop test which is a measure of set-shifting there was no significant difference between ACT and VC p= 0.223 and there was a significant difference between ACT and NC p=0.011. There was not a significant difference between VC and NC p= 0.124.

Figure 12. Effects of exercise on cognition



For reaction time, although reaction time improved after each session and more so after exercise, there were no statistically significant differences between ACT and VC p=0.449, ACT and NC p= 0.185. There was also not a significant difference between VC and NC p= 0.551.

CHAPTER 5

DISCUSSION

This is among the first studies to examine an acute session of ACT, VC or NC in typical older adults on motor and cognitive function. This is important because in older adulthood many motor and cognitive functions regress and effect activities of daily living. The present study represents initial results on the effectiveness of a cycling exercise on improving the quality of life in older adults.

Our results are somewhat consistent with our hypothesis that the ACT group will exhibit greater improvements in balance after exercise compared to those in the VC and NC sessions because both ACT and VC improved in their balance after exercise than the group that did not exercise. Our result is consistent with other research. A review with 34 studies and over 2800 participants, by Howe, Rochester, Jackson, Banks, & Blair concluded that there is statistically significant improvement in balance for exercise interventions compared to usual activity. All exercises showed improvement including gait, balance functional exercises, muscle strengthening and mixed exercise regimens. Improvement in balance on a stationary cycle were also noted (2007). Appropriate types of exercise are important for each individual's level of risk for falls. AC shows promise in increasing the availability of options for exercise to prevent falls by an increase in motor and executive function. Especially in the high risk area of falls where a stationary bike may prevent a fall while exercising.

However, our results did not show any change with the TUG task. While this is not consistent with our hypothesis, it is likely that a more long term exercise intervention is necessary to find improvements in this clinical text. TUG task times have improved in longer interventions. A fourteen week progressive strength training intervention statistically improved TUG results more than control group (Sousa, Sampaio, 2006). Similarly, long term interventions of Tae Chi Chaun (TCC) consist of continuous movement, it is also considered an aerobic exercise. TCC when practiced, has been shown to improve TUG time. This may be associated with internal feedback control which benefit the improvement of balance (Huang, Liu, 2015).

Our results are consistent with our hypothesis that the ACT group will exhibit greater improvements in manual dexterity compared to those in VC and NC sessions. In fact, all of the scores for the Purdue Pegboard demonstrated improvements of significance level for AC with the effect size ($r > 0.45$) suggest that AC intervention has a large effect on motor function task performance.

Our results are also consistent with animal and recent human research. In PD rodent model, it was found that forced exercise resulted in upregulated neurotrophic factors and neuroprotective effects thought to improve functional movement skills (e.g., locomotion, reaching) (Tajiri et al., 2009). This was measured through bromodeoxyuridine (BrdU) detection by injecting rats with BrdU and neural stem/progenitor cells into the central nervous system (CNS) to determine if exercise affected the differentiation of neural stem/progenitor cells and migration of new neurons. In humans with PD, Ridgel and colleagues (Ridgel et al., 2009) compared Forced/AE, and VE, groups in Parkinson’s patients. They measured bimanual dexterity with a bimanual complimentary force control task similar to opening a bottle (Alberts, Elder, Okun, & Vitek, 2004; Alberts, Okun, & Vitek, 2008). They found improved coupling of grasping forces, interlimb coordination, and rate of force production after AE (Ridgel et al., 2009) but not VE. These results are comparative to our assembly task because both are bimanual coordination tasks. Our findings are also consistent with the results the assembly task of the Purdue Pegboard improve following acute bout of ACT in adolescents with Down syndrome (Chen, Ringenbach, Albert, 2013). .

Taken together, our results can be interpreted to suggest ACT may improve whole body movement function. The fact that a lower leg exercise improved upper extremity movement function indicates that improvements are happening at the cortical level. Upregulation of Brain-Derived Neurotrophic Factor (BDNF) is one proposed mechanism accounting for whole body movement function improvement following assisted lower limb exercise (Ridgel et al., 2009). Future research will continue to examine the mechanisms responsible for improvements in whole body movement functioning following long term AC interventions in older adults.

Thus, our results are consistent with previous research on an acute bout of assisted cycle therapy and manual dexterity. Chen et al. (2013) found improvements in both dominant and bimanual Purdue Pegboard measures following a similar ACT intervention, but not in a VC group or a control group. Furthermore, recent data in our lab with adolescents with DS found improvements in fine motor control as measured by the Purdue Pegboard following a chronic (i.e., 8 week) intervention, whereas there were no improvements in fine motor control following VC or a control group (Andrew Jiminez, Undergraduate thesis defense, 2015).

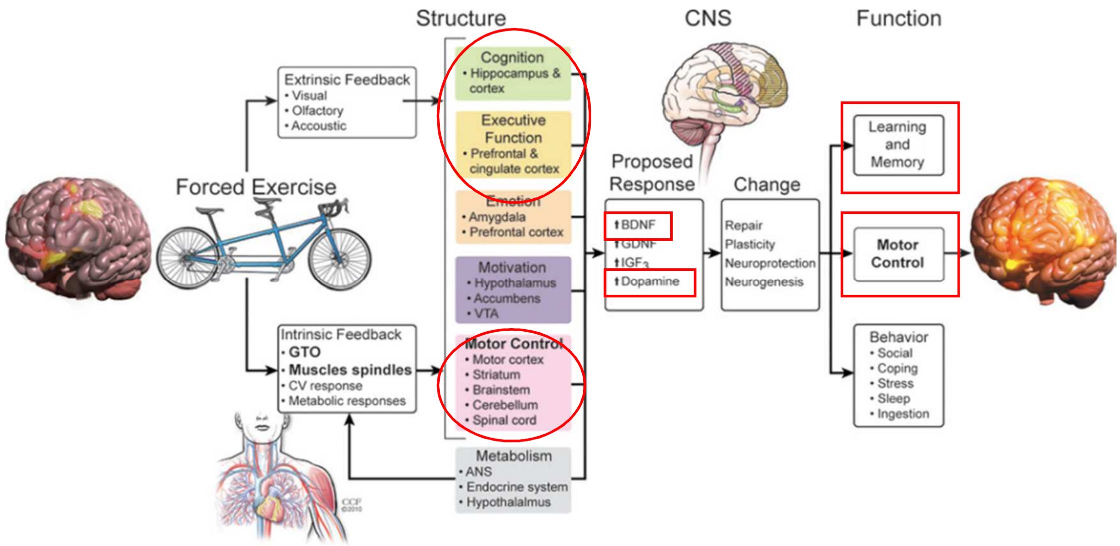
The difference in grip force, as measured by a dynamometer, was not statistically significant from pre-test to post-test for either the VC or the ACT group. This was not consistent with the current literature. For example, Chen et al. (2014) found improvements in grip force in men with DS following aerobic exercise on a treadmill. Additionally, Ridgel et al. (2009) found increased grip force in PD patients following an assisted exercise intervention in which a trainer rode a tandem bike with the patient. Although our results were not significant, they also were not in the predicted direction. In fact, grip strength decreased for both groups after exercise. However, our results are consistent with a recent honors thesis in our lab in older adults with Down syndrome (Gomez, 2015).

Our results were not consistent with our hypothesis that the ACT group would exhibit greater improvements in Dual task performance compared to those in the VC and NC sessions.

Cognitive Function

Our results are somewhat consistent with our hypothesis that the ACT group would exhibit greater improvements in measures of cognitive function compared to those in the VC and NC sessions because this was true for the stroop task but not for the RT task. Our results for improvements in set switching following an acute bout of ACT are consistent with our previous research with adolescents with Autism in which the stroop task improved after an acute bout of ACT (Ringenbach, Lichtsinn, & Holzapfel, in press). Because Inhibitory control and set-switching are both prefrontal tasks, our results can be interpreted to suggest that the dorsolateral prefrontal cortex benefits from ACT (Alvarez & Emory, 2006; Chang et al., 2007; Seidman et al., 2005). These improvements may be due to the upregulation of dopamine as dopaminergic dysfunction is prevalent in older adults who are susceptible to dopamine depletion diseases (Anderson, 1994; Egan et al., 2001; Ernst et al., 1997). Our results are also consistent with the effects of ACT on executive function in Parkinson's patients as demonstrated by activation of the prefrontal cortex found by Alberts and colleagues (Alberts et al., 2011). It has been proposed that increased afferent information produced by the high pedaling rate of ACT but not VC paradigms produces molecular changes at the cortical level, including up-regulation of the neurotrophic factors BDNF, GDNF, and Insulin-Like Growth Factor (IGF_3) as well as dopamine (Alberts et al., 2011). Further studies should continue to examine the cortical level mechanisms associated with increases in executive function following ACT.

Figure 13. Proposed mechanisms for molecular changes by assisted exercise



Alberts et al., 2011

Our results were not consistent with our prediction that reaction time would improve following ACT but not VC or NC. This is also not consistent with our previous research with an acute session of ACT in adolescents with Autism. However, our results may be confounded by the large decreases in reaction time that accompany ageing. It has been noted that in old participants, age 59-65, RT were proximately 120 ms slower than younger aged participants. The processing stages impacted by ageing still have not been clearly identified. Event related potential studies also find a significant age related latency in the time between motor cortex activation and the onset of EMG activity in muscles executing a response. Age-related slowing in RT largely reflects delays in response-selection and motor execution (Woods, Wyma, Yund, Herron, Reed, 2015).

Conclusion

Overall, our results showed that a single bout of ACT can produce clear improvements in manual dexterity in older adults. This is very important for activities of daily living (e.g., getting change, putting keys in locks, cooking, brushing teeth, etc.). In addition there are some benefits to set shifting after a single ACT session, which is helpful to older adults when multi-tasking. Furthermore, generally a single session of exercise can also improve balance and most deaths occur in the elderly due to falls, so this is extremely important. More research needs to be conducted on the effects of a long-term ACT intervention and the influence on improving motor and cognitive performance in older adults.

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APPENDIX A

RECRUITMENT FORM

PARTICIPANTS NEEDED!

The Sensorimotor Development Research Laboratory of the Program of Exercise Science and Health Promotion at Arizona State University is looking for older adults for an Assisted Cycle Therapy (ACT) study. We need volunteers between the ages of 50 and 85. Testing will take place at the ASU Downtown campus.

- You will come in 3 times for 2 ½ hours.
- You will be compensated $20 for each visit.

Dates and times for testing are flexible, including evenings, weekends, and holidays.

If interested, please contact the Sensorimotor Development Research Lab at 480-265-7545 or e-mail ksemken@asu.edu.

ASU IRB IRB # STUDY00001562 | Approval Period 10/3/2014 – 10/2/2015

APPENDIX B

CONSENT FORM

CONSENT FORM

The Evaluation of Cycling Exercise on Motor, Cognitive and Clinical Functions for Adults
Sensorimotor Development Research Laboratory, PEBE 159
DEPARTMENT OF KINESIOLOGY, ARIZONA STATE UNIVERSITY

Introduction

The purposes of this form are to provide you with information about the nature of this research study. Signing this form indicates that you have been so informed and you give your consent for to participate. Federal regulations require written informed consent prior to participation in this research study so that you know the nature and risks of your participation and can decide whether or not you consent to your participation in a free and informed manner.

Researchers

Shannon D. R. Ringenbach, Ph.D., Associate Professor of Kinesiology invites your voluntary participation in a research study being performed at Arizona State University.

Purpose

You are being invited to participate in a research study to investigate the effects of stationary cycling exercise on motor, cognitive, and clinical functions in adults. The information gained in this study will allow us to understand the potential to improve exercise in adults, which may improve their function of physical, cognitive and activities of daily living.

Selection Criteria

Any adult, between 50 and 85 years old with no physical disabilities is invited to participate. If you have or have had an injury or condition that might affect your ability to perform the cycling activities in this experiment, you will not be allowed to participate at this time.

In addition all participants have been prescreened for cardiovascular fitness by answering 'No' to all seven questions of the Physical Activity Readiness Questionnaire or have received exercise clearance from their physician using the Physical Activity Readiness Medical Exam.

Procedures

Intervention (40 min each)

All participants will come to the Sensorimotor Development Research lab on three occasions.

1. Voluntary Exercise in which they will pedal at their self-selected rate.
2. Assisted Exercise in which a motor on the bicycle will move their legs at 35% of self-selected rate if they are not doing so.
3. No Exercise in which they will sit quietly and watch a video.

Each intervention will be separated by approximately two days.

Exercise intensity, from an aerobic perspective, will be matched for all exercise groups. Intensity will be determined on an individual basis based on the results of initial cardiovascular testing. Maximum
Heart Rate (MHR) intensity will be determined using the Karvonen formula. During exercise, all participants will be kept within 60-80% of their MHR. The participants will be instructed to exercise during the 30 minute main exercise set. The main exercise set will occur between a 5 minute warm-up and a 5 minute cool-down phase. Some participants may need more rest. Therefore, if necessary, the 30 minute main exercise set will include 'on the cycle' rest breaks of 2 minutes, every 10 minutes.

To monitor participant's exercise intensity, participants will be asked to visually point to rate their perceived rate of exertion (RPE) on a scale from 6 (easy) to 20 (difficult) every two minutes. If any participant exhibits signs of cardiac distress (e.g., pressure, tightness, aching, or burning in their upper back, neck, shoulders, and arms, or even in their jaw, or shortness of breath, fatigue, stomach pain, cold sweats, dizziness, indigestion, or nausea, etc.) 911 will be called immediately. All participants will be supervised at all times and all study personnel with any participant contact will have completed a Cardiac Life Support training course.

We would like to videotape some of the sessions to examine individual differences and to aid in interpretation of the data. You will have an opportunity to consent to this separate from participation in the study.

Motor, Cognitive and Clinical Tests

Before and after each intervention session we will conduct neuropsychological assessments to measure non-motor (e.g., task switching, planning, inhibition, working memory, reaction time), motor (e.g., manual dexterity) functions.

Total testing time on each occasion will be approximately 2 ½ hours.

Risks

It is possible that feelings of fatigue or muscle tension may be uncomfortable. We will provide individualized rest to minimize these feelings.

There may be cardiovascular risks in participating in any exercise program, which is why we are requiring all participants to complete the Physical Activity Readiness Questionnaire or receive exercise clearance from their physician using the Physical Activity Readiness Medical Exam.

An exercise cycle was used instead of a treadmill to eliminate balance and other safety risks.

If a medical emergency were to occur during the study we will call 911 to bring emergency medical technicians to the study. For minor complications, you may be treated by a physician at the Campus Health Center.

There are no other known risks to participants with this experiment. As with any research, there is some possibility that there are risks that have not yet been identified. There are no known alternatives available for this study.

Benefits

You will not personally benefit from participation. However, the possible benefit of participation is to develop educational and rehabilitation strategies that will serve to reduce the impact of difficulties with motor, cognitive and clinical tasks for adults.

New Information

If the researcher finds new information during the study that would reasonably change your decision about participating, they will provide this information to you.

Confidentiality

All information obtained and recorded in this study is strictly confidential. The identity of participants will not be revealed in publications that may result from this study, nor will names be used in other research communications such as lectures to scientific meetings. Only summary statistics such as the participants' age and gender will be included in published experimental results.

After the experiment is completed, the principal investigator, Shannon D. R. Ringenbach, Ph.D., will store and lock the signed documents with personal information and data stored on in a filing cabinet in the principal investigator's lab (PEBE 159, Program of Kinesiology). All data (written, electronic) can be accessed only by the Principal Investigator and her authorized personnel (i.e., graduate research assistants, postdoctoral associates, and research associates) and will be stored indefinitely.

Withdrawal Privilege
It is okay to say that you do not want to participate. If you agree to participate now, you will are free to withdraw without any penalty at any time. If you decide not to participate it will not affect you or harm any relationship you have with Arizona State University.

Costs and Payments
The researcher wants your decision to be absolutely voluntary. Yet, the researcher recognizes that participation may pose some inconvenience. In order to compensate you, the participant (the person of whom you have legal guardianship) will be paid $20 in cash for each visit and for a total of $60 for all three visits.

Liability
Side effects or harm are possible in any research program despite the use of high standards of care and could occur through no fault of yours, your participant's, or the investigator involved, and may require care. You do not give up any of your legal rights by signing this form. In the event of medical emergency arising from this study neither Arizona State University nor the researcher are able to give you any money, insurance, free medical care or compensation.

Voluntary Consent
Any questions you have concerning the research study or your participation in it, before or after consent can be answered by the Principal Investigator, Dr. Shannon D. R. Ringenbach (shannon.ringenbach@asu.edu). If you have any questions about the person of whom you have legal guardianship's rights as a participant in this research, or if you feel that he/she will be placed at risk, you may contact the Chair of Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788.

Your signature below indicates that you consent to participation. Before giving your consent for ________________________________ (participant's name) participation by signing this form, the methods, inconveniences, risks, and benefits have been explained to you and your questions have been answered. You understand that you or your participant may ask questions at any time. Your participant is free to withdraw from the project at any time with no penalty. Participation in this project may be ended by the investigator for reasons that would be explained. This consent form will be filed in a locked filing cabinet with access restricted to the principal investigator, Shannon D. R. Ringenbach, Ph.D., or authorized representatives of the Program of Kinesiology. You understand that you do not give up any of your legal rights by signing this form. A copy of this consent form will be given to you.

____ ____________________________
Participant Printed Name Date

____ ____________________________
Participant Signature Date

Investigator's Affidavit

I have clearly explained to the participant the nature of the above research project. I hereby certify that to the best of my knowledge, the person who is signing this consent form clearly understands the nature, demands, benefits, and risks involved in his/her participant's participation and his/her signature is legally valid. A medical problem or language or educational barrier has not precluded this understanding.

______________________________________ ______________________

Signature of Investigator Date

APPENDIX C

VOLUNTARY CYCLING GROUP EXERCISE SESSION DATA SHEET

1. Calibrate bike computer (see instructions)

2. Complete medication, diet and exercise recall log

3. Put on Heart rate monitor.
    - -Wet strap with water prior to putting it on
    - -The strap must sit flush on participant's chest
    - -Sit participant on bicycle chair for approx 3-4 minutes or until HR stabilizes

Take heart rate reading from SRM bike computer – this is RHR.
Rest HR: ______

4. Adjust bicycle seat. Seat Height: __________ Seat Distance: __________

5. Have participant sit on the bike and strap their feet into the pedals.

6 .Orient the participant to the bicycle and allow them five minutes of practice on the bike at a self-selected rate. Then, **RESET the computer by clicking 'pro' and 'set' simultaneously.**

7. Thirty-minutes of cycling exercise intervention

9. Calculate average cadence and HR during 5 minute intervals. **Record average cadence and HR from SRM monitor at the end of each minute and calculate averages for each 5 minute interval at the end of the session.**

Minutes	Cadence					Avg Cadence	RPE				HR					Avg HR
05:00	**Warm up**															
05:00							1	2	3	4						
10:00							1	2	3	4						
15:00							1	2	3	4						
20:00							1	2	3	4						
25:00							1	2	3	4						
30:00							1	2	3	4						
05:00	**Cool Down**															
Notes	**Peak Cadence: ________**															

9. Remove HR monitor
10. Let the participant rest for 5 minutes before walking to their car
11. Remind them of their next appointment.

APPENDIX D

ASSISTED CYCLING GROUP EXERCISE SESSION DATA SHEET

1. Calibrate bike computer (see instructions)

2. Put on Heart rate monitor.

    -Wet strap with water prior to putting it on
    -The strap must sit flush on participant's chest
    -Sit participant on bicycle chair for approx 3-4 minutes or until HR stabilizes

Take heart rate reading from SRM bike computer – this is RHR.
Rest HR: ______

3. Complete medication, diet and exercise recall log

4. Adjust bicycle seat. Seat Height: __________ Seat Distance: __________

5. Have participant sit on the bike and strap their feet into the pedals.

6. For day 1, have participant ride the bike for five minutes at their self-selected rate. When five minutes are up hit 'mode' to scroll through and find the average heart rate on the bike computer; record **Avg Cadence_____.** Then **RESET the computer by clicking 'pro' and 'set' simultaneously.**

7. Multiple **(Avg Cad x 1.35)** to find **Target Cadence_____.**

8. Turn on the bicycle and set the cadence to **Target Cad** and **30 minutes duration**

9. Calculate average cadence and HR during 5 minute intervals. **Record average cadence and HR from SRM monitor at the end of each minute and calculate averages for each 5 minute interval at the end of the session.**

Minutes	Cadence					Avg Cadence	RPE				HR					Avg HR
05:00	**Warm up**															
05:00							1	2	3	4						
10:00							1	2	3	4						
15:00							1	2	3	4						
20:00							1	2	3	4						
25:00							1	2	3	4						
30:00							1	2	3	4						
05:00	**Cool Down**															
Notes	**Peak Cadence: ________**															

10. Remove HR monitor
11. Let the participant rest for 5 minutes before walking to their car
12. Remind them of their next appointment.

APPENDIX E

STROOP TEST DATA SHEET

Stroop Test:

The Stroop Task will be used to examine inhibition (Anderson-Hanley, Tureck, & Schneiderman, 2011). It was administered using an iPad application which gives participants 30s to complete the task. Before testing, participants will be given a practice session to test reading ability to ensure validity (Adams & Jarrold, 2009). For the Stroop Task, the outcome measure will be time per word, and will be calculated by dividing 30s by the score (number of correct responses). Lower time per word indicates better performance. Good test-retest reliability (r = 0.71 – 0.79) has been reported for the Stroop Task (Strauss, Allen, Jorgensen, & Cramer, 2005) and it has been shown to be a test of frontal lobe function (Demakis, 2004; Perret, 1974; Stuss, Floden, Alexander, Levine, & Katz, 2001).

In each version the participant must tap the color of the word and not what the color described by it. The participant gets one point for each correct answer and minus one point for every incorrect answer. Each participant has 30 seconds to complete each task. The number of points were recorded. This tasked each participant was tested on the intermediate level of the Stroop Effect. This test was downloaded to an iPad and was designed by Bebebe Co. version 1.2.

Score ___________.

APPENDIX F

DUAL TASK

Dual Task

Counting backwards from 100 by 2 was used for this dual task. The participant was explained that they should walk around cones that are 20 meters away, while they serial subtract 2 from 100. Counting backwards requires both working memory and attention. This serves as a cognitive task while a motor task (walking) is being performed.

Walking protocol: Participants will walk 20 meters at their self-selected pace for one minute, on level ground, obstacle free corridor and will turn at the end each time. They will do this under two conditions: 1) with no subtraction task and 2) with subtraction task.

APPENDIX G

TIMED UP AND GO

Timed up and go

Timed Get Up and Go Test

Measures mobility in people who are able to walk on their own (assistive device permitted)

Name__________________________

Date___________________________

Time to Complete_________________seconds

Instructions:

The person may wear their usual footwear and can use any assistive device they normally use.

1. Have the person sit in the chair with their back to the chair and their arms resting on the arm rests.

2. Ask the person to stand up from a standard chair and walk a distance of 10 ft. (3m).

3. Have the person turn around, walk back to the chair and sit down again.

Timing begins when the person starts to rise from the chair and ends when he or she returns to the chair and sits down.

The person should be given 1 practice trial and then 3actual trial. The times from the three actual trials are averaged.

Predictive Results

Seconds	Rating
<10	Freely mobile
<20	Mostly independent
20-29	Variable mobility
>20	Impaired mobility

Source: Podsiadlo, D., Richardson, S. The timed ‘Up and Go’ Test: a Test of Basic Functional Mobility for
Frail Elderly Persons. Journal of American Geriatric Society. 1991; 39:142-148

APPENDIX H

FULLERTON ADVANCED BALANCE SCALE (FAB)

Test Administration Instructions for the

Fullerton Advanced Balance (FAB) Scale

1. Stand with feet together and eyes closed

Purpose: Assess ability to use somatosensory (i.e., ground and body position) cues to maintain upright balance while standing in a reduced base of support and vision unavailable.

Equipment: Stopwatch with lanyard (for placing around neck).

Safety Procedures: Position person being tested in a corner (If available) or close to a wall. Stand close to participant In case of loss of balance. Hold watch at eye level so participant and time can be monitored simultaneously.

Testing procedures: Demonstrate the correct test position and then instruct the participants to move the feet independently until they are together. If some participants are unable to achieve the correct position due to lower extremity joint problems, encourage them to bring their heels together even though the front of the feet are not touching. Have participants adopt a position that will ensure their safety as the arms are folded across the chest and they prepare to close the eyes. Begin timing as soon as the participant closes the eyes. (Instruct participants to open the eyes if they feel so unsteady that a loss of balance is imminent.)

Verbal instructions: “Bring your feet together, fold your arms across your chest, close your eyes when you are ready, and remain as steady as possible until I instruct you to open your eyes.”

2. Reach forward to retrieve an object (pencil) held at shoulder height with outstretched arm

Purpose: Assess ability to lean forward to retrieve an object without altering the base of support; measure of stability limits in a forward direction.

Equipment: Pencil and 12-inch ruler

Safety Procedures: Position person facing out from corner (If available) or close to wall. Position self to side of participant's outstretched hand. Use arm holding pencil In horizontal position to manually assist client If a loss of balance occurs.

Testing procedures: Provide participant with sagittal view of desired movement. Instruct the participant to raise the preferred arm to 90o and extend it with fingers outstretched. Use the ruler to measure a distance of 10 inches from the end of the fingers of the outstretched arm. Hold the object (pencil) horizontally and level with the height of the participant’s shoulder. Be sure not to move the pencil once the Instructions are provided. Instruct the participant to reach forward, grasp the pencil, and return to the initial starting position without moving the feet, if possible. (It is acceptable to raise the heels as long as the feet do not move while reaching for the pencil.) If the participant is unable to reach the pencil within 2-3 seconds of initiating the forward lean, indicate to the participant that it is okay to move the feet in order to reach the pencil. Record the number of steps taken by the participant in order to retrieve the pencil.

Verbal instructions: “Try to lean forward to take the pencil from my hand and return to your starting position without moving your feet.” After allowing 2-3 seconds of lean time: “You can move your feet in order to reach the pencil.”

3. Turn 360 degrees in right and left directions

Purpose: Assess ability to turn in a full circle in both directions in the fewest number of steps without loss of balance

Equipment: None

Safety Procedures: Position person being tested about one foot In front of a wall and facing you. Stand close enough during test to provide manual assistance If a loss of balance occurs.

Testing procedures: Verbally explain and then demonstrate the task to be performed, making sure to complete each circle in four steps or less and pause briefly between turns. Instruct the participant (who is facing you) to turn in a complete circle in one direction, pause, and then turn in a complete circle in the opposite direction. Count the number of full steps taken to complete each circle. Stop counting steps as soon as the participant is facing you after completing each turn. Allow for a small correction in foot position before a turn in the opposite direction is initiated.

Verbal instructions: “In place, turn around in a full circle, pause, and then turn in a second full circle in the opposite direction. Do not begin the full circle in the opposite direction until you are facing me."

4. Step up onto and over a 6-inch bench

Purpose: Assess ability to control body in dynamic task situations; also a measure of lower body strength and bilateral motor coordination.

Equipment: 6-inch-high bench (18- by 18-inch stepping surface)

Safety Procedures: Position bench close to a wall and self on opposite side of bench. Adopt close supervisory position and move with participant as she/he steps up and over the bench In each direction.

Testing procedures: Verbally explain the movement to be performed before demonstrating the step up onto and over the bench (at normal speed) in both directions. Instruct the participant to step onto the bench with the right foot, swing the left leg directly up and over the bench, and step off the other side, then repeat the movement in the opposite direction with the left leg leading the action.

Encourage the participant not to touch the wall or you to maintain balance during the test. During performance of the test item, watch to see that the participant's trailing leg (a) does not make contact with the bench, or (b) swing around, as opposed to directly up and over, the bench. Verbally cue which leg should be leading the action just prior to the start of the movement In each direction.

Verbal instructions: "Step up onto the bench with your right leg, swing your left leg directly up and over the bench, and step off the other side. Repeat the movement in the opposite direction with your left leg as the leading leg."

5. Tandem walk

Purpose: Assess ability to dynamically control center of mass with an altered base of support

Equipment: Masking tape

Safety Procedures: Set the tandem walk line approximately 12 Inches away from a wall. Monitor the participant closely during performance of the test Item and walk forward with the client as he/she completes the test Item. Be ready to provide manual assist If a loss of balance occurs.

Testing procedures: Verbally explain and demonstrate how to perform the test item correctly before the participant attempts to perform it. Instruct the participant to walk on the line in a tandem position (heel-to-toe) until you tell him/her to stop. Allow the participant to repeat the test item one time if unable to achieve a tandem stance position within the first two steps. The participant may elect to step forward with the opposite foot on the second attempt. Score as interruptions any instances where the participant (a) takes one or more steps away from the line when performing the tandem walk or (b) is unable to achieve correct heel-to-toe position during any step taken along the course.

Do not ask the participant to stop until 10 steps have been completed.

Verbal instructions: “Walk forward along the line, placing one foot directly in front of the other such that the heel and toe are in contact on each step forward. I will tell you when to stop.”

6. Stand on one leg

Purpose: Assess ability to maintain upright balance with a reduced base of support.

Equipment: Stopwatch and lanyard.

Safety Procedures: Position the person being tested In a corner (If one Is available) or close to a wall. Stand In a close supervisory position and on the side of the raised leg.

Testing procedures: Instruct the participant to fold the arms across the chest, lift one leg off the floor, and maintain balance until instructed to return the foot to the floor. Begin timing as soon as the participant lifts the foot from the floor. Stop timing if the legs touch, the raised leg contacts the floor, or the participant lifts the arms off the chest before the 20 seconds has elapsed. Allow the participant to perform the test a second time with the other leg raised if they touch down quickly on the first attempt or are unsure as to which leg should be raised.

Verbal instructions: “Fold your arms across your chest, lift one leg off the floor (without touching your other leg), and stand with your eyes open until I ask you to put your foot down.”

7. Stand on foam with eyes closed

Purpose: Assess ability to maintain upright balance while standing on a compliant surface with eyes closed

Equipment: Stopwatch and lanyard; two Airex® pads, with a length of nonslip material placed between the two pads and an additional length of nonslip material between the floor and first pad if the test is being performed on an uncarpeted surface.

Safety Procedures: Position person to be tested In a corner (If one Is available) or close to a wall. After demonstrating the test Item, place the Airex® pads In front of the person If standing In a corner. Adopt a close supervisory position and hold watch at a height that allows for simultaneous monitoring of the participant's arm position and eyes as well as the time. Instruct the participant to open the eyes if she/he feels so unsteady that a loss of balance is imminent. Manually assist the client off the foam pads if he/she appears unsteady.

Testing procedures: Following a demonstration of the task, instruct the participant to step up onto the foam pads without assistance, position the feet shoulder width apart, fold the arms across the chest, and close the eyes when ready. Begin timing as soon as the eyes close. Stop the trial if the participant (a) opens the eyes before the timing period has elapsed, (b) lifts the arms off the chest, or (c) loses balance and requires manual assistance to prevent falling. Instruct the participant to step forward off the foam at the completion of the test item. Provide manual assistance if needed.

Verbal instructions: “Step up onto the foam and stand with your feet shoulder-width apart. Fold your arms over your chest, and close your eyes when you are ready. I will tell you when to open your eyes.”

8. Two-footed jump for distance (Do not introduce this test Item if participant cannot perform test item 4 safely, has a diagnosis of osteoporosis, or complains of lower body joint pain. Score a zero on the test form and move immediately to test item #9.)

Purpose: Assess upper and lower body coordination and lower body power.

Equipment: 36-inch ruler; masking tape.

Safety Procedures: Position the person close to a wall and adopt a close supervisory position during the jump. Demonstrate the jump but do not jump more than twice the length of your own feet. Stand to the side of the participant and move forward as he or she jumps. Place your hand on the participant's back to steady him/her as soon as the feet contact the ground following the jump.

Testing procedures: Instruct the participant to jump as far but as safely as possible while performing a two-footed jump (i.e., leave the floor with two feet and land on two feet).

Demonstrate the correct movement prior to the participant performing the jump. Use the ruler to measure the length of the foot and then multiply by two to determine the ideal distance to be jumped. Observe whether the participant leaves the floor with both feet and lands with both feet. Position the ruler on the floor and on the opposite side of the participant and close to the wall so that you can glance down and see how far the participant jumped.

Verbal instructions: “Jump as far but (emphasize) as safely as you can. Try and make sure that both feet leave the floor and land at the same time.”

9. Walks with head turned

10. Reactive postural control

Purpose: Assess ability to efficiently restore balance following an unexpected perturbation

Equipment: None

Safety Procedures: Position the client approximately 3-4 feet In front of a wall. Stand immediately behind the participant and adopt a wide base of support during the leaning portion of the test. Be ready to move your feet quickly once you release your hand and the participant begins to lose balance. Flex the elbow and release your hand as soon as you determine that the participant Is exerting sufficient pressure against your hand to require that he/she must step backwards one or more times to restore balance. This release should be unexpected, so do not prepare the participant for the moment of release or allow the participant to lean too far back onto your hand before releasing it.

Testing procedures: Instruct the participant to stand with his or her back to you. Extend your arm with the elbow locked and place the palm of your hand In the middle of the participant’s back. Instruct the participant to lean back slowly against your hand until you tell him or her to stop. Quickly flex your elbow until your hand is no longer in contact with the participant’s back at the moment you estimate that a sufficient amount of force has been applied to require a movement of the feet to restore balance. Try to quickly release your hand while you are still giving the verbal instructions.

Verbal instructions: “Slowly lean back into my hand until I ask you to stop.”

APPENDIX I

CHOICE REACTION TIME

Reaction Time

Visual

Trial	Reaction time	Note
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

APPENDIX J

GRIP STRENGTH

Force Production:

- Make sure the participant sits down in a chair in an upright position
- Allow 15sec rest between trials

	Trial One	Trial Two	Trial Three	Trial Average
Dominant Hand (10s)				
Non-Dominant Hand (10s)				

‘

APPENDIX K

PURDUE PEGBOARD DATA SHEET

<u>Purdue Pegboard Score</u>:

- **"This is a task to see how quickly and accurately you can work with your hands."**

Instruction to right/left hand (begin with dominant hand:

- **"Pick up one pin at a time with your right (left) hand from the right (left) -handed cup. Starting with the top hole, place each pin in the right (left) -handed row, starting from the first hole and working down the line. Now, you can practice this by putting some pins into the holes."**
- **"When I say 'Begin', place as many as pins possible in the right (left) -handed row, starting with the top hole and working down the line. Make sure to pick up one pin at a time and you use only your right (left) hand only. Work as fast as you possibly can until I say 'Stop'"**
- Have the participant do 2 practice trials and ensure they understand the instructions
- Count the number of pins inserted and record it as right (left) hand score.

Instruction to both hands:

- **"This time you will use both hands at the same time. Pick up a pin with your right hand from the right-handed cup and at the same time pick up a pin with your left hand from the left-handed cup. Starting with the top hole of both rows and working down. Make sure that you are placing both of the pins into the holes at the same time. Now, you can practice by putting some pins into the holes."**
- **"When I say 'Begin', place as many pins as possible in both rows starting with the top holes and working down the line. Work as fast as you can until I say 'Stop'"**
- Have the participant do 2 practice trials and ensure they understand the instructions
- Count the number of pins inserted and record it as both hands score.

Instruction to Right + Left + Both:

- Add the scores for right hand, left hand and both hands. This is the score for R+L+B.

Instruction to Assembly:

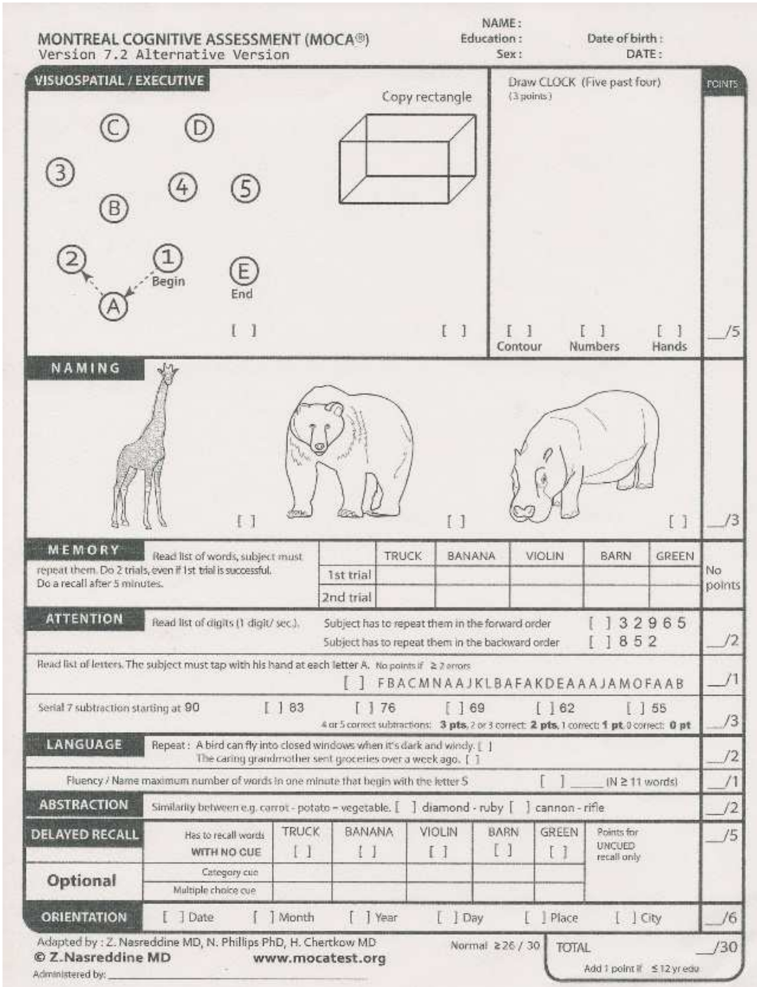
- **"Pick up one pin at a time with your right hand from the right-handed cup. While you are placing the pin in the hole in the right-handed row, pick up a washer with your left hand. As soon as the pin has been placed, drop the washer over the pin. While the washer is being placed over the pin with your left hand, pick up a collar with your right hand. While the collar is being dropped over the pin, pick up another washer with your left hand and drop it over the collar."**
- **"Now, you can practice assemblies."** Have the participant do 2 practice trials and ensure they understand the instructions.
- Each assembly consists of a pin, a washer, a collar and a washer.
- Count the number of completely assembled objects inserted and record the score.

	Trial One	Trial Two	Trial Three	Trial average
Right Hand (30s)				
Left Hand (30s)				
Both Hands (30s)				
Right + Left + Both				
Assembly (60s)				

APPENDIX L

MONTREAL COGNITIVE ASSESSMENT (MOCA)

Montreal Cognitive Assessment (MOCA)



MONTREAL COGNITIVE ASSESSMENT (MOCA®)
Version 7.2 Alternative Version

NAME :
Education :
Sex :
Date of birth :
DATE :

VISUOSPATIAL / EXECUTIVE — POINTS

[ ]

Copy rectangle [ ]

Draw CLOCK (Five past four) (3 points)

[ ] Contour [ ] Numbers [ ] Hands — ___/5

NAMING

[ ] [ ] [ ] — ___/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	TRUCK	BANANA	VIOLIN	BARN	GREEN	
1st trial						No points
2nd trial						

ATTENTION Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 3 2 9 6 5
Subject has to repeat them in the backward order [ ] 8 5 2 — ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B — ___/1

Serial 7 subtraction starting at 90 [ ] 83 [ ] 76 [ ] 69 [ ] 62 [ ] 55
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** — ___/3

LANGUAGE Repeat : A bird can fly into closed windows when it's dark and windy. [ ]
The caring grandmother sent groceries over a week ago. [ ] — ___/2

Fluency / Name maximum number of words in one minute that begin with the letter S [ ] _____ (N ≥ 11 words) — ___/1

ABSTRACTION Similarity between e.g. carrot - potato = vegetable. [ ] diamond - ruby [ ] cannon - rifle — ___/2

DELAYED RECALL	Has to recall words WITH NO CUE	TRUCK [ ]	BANANA [ ]	VIOLIN [ ]	BARN [ ]	GREEN [ ]	Points for UNCUED recall only	___/5
Optional	Category cue							
	Multiple choice cue							

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City — ___/6

Adapted by : Z. Nasreddine MD, N. Phillips PhD, H. Chertkow MD
© Z.Nasreddine MD www.mocatest.org
Administered by: ________________

Normal ≥26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

APPENDIX M

STANFORD LEISURE-TIME ACTIVITY CATEGORICAL ITEM

Stanford Leisure-Time Activity Categorical Item (L-Cat)

During the past month, which statement best describes the kinds of physical activity you usually did? Do not include the time you spent working at a job. Please read all six statements before selecting one.

1. I did not do much physical activity. I mostly did things like watching television, reading, playing cards, or playing computer games. Only occasionally, no more than once or twice a month, did I do anything more active such as going for a walk or playing tennis.

2. Once or twice a week, I did light activities such as getting outdoors on the weekends for an easy walk or stroll. Or once or twice a week, I did chores around the house such as sweeping floors or vacuuming.

3. About three times a week, I did moderate activities such as brisk walking, swimming, or riding a bike for about 15–20 minutes each time. Or about once a week, I did moderately difficult chores such as raking or mowing the lawn for about 45–60 minutes. Or about once a week, I played sports such as softball, basketball, or soccer for about 45–60 minutes.

4. Almost daily, that is five or more times a week, I did moderate activities such as brisk walking, swimming, or riding a bike for 30 minutes or more each time. Or about once a week, I did moderately difficult chores or played sports for 2 hours or more.

5. About three times a week, I did vigorous activities such as running or riding hard on a bike for 30 minutes or more each time.

6. Almost daily, that is, five or more times a week, I engaged in a regular program of physical fitness involving some kind of heavy or vigorous physical activity for 30 minutes or more each time.

Montero-Odasso, M., Casas, A., Hansen, K. T., Bilski, P., Gutmanis, I., Wells, J. L., & Borrie, M. J. (2009)

APPENDIX N

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE FOR EVERYONE

2014 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

☑ **If you answered NO to all of the questions above, you are cleared for physical activity.**
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

⚠ **Delay becoming more active if:**

- ✓ You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- ✓ You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- ✓ Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c	If **NO** ☐ go to question 2
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐
2.	**Do you have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b	If **NO** ☐ go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐
3.	**Do you have a Heart or Cardiovascular Condition?** *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm* If the above condition(s) is/are present, answer questions 3a-3d	If **NO** ☐ go to question 4
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐
4.	**Do you have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b	If **NO** ☐ go to question 5
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐
5.	**Do you have any Metabolic Conditions?** *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes* If the above condition(s) is/are present, answer questions 5a-5e	If **NO** ☐ go to question 6
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6. Do you have any Mental Health Problems or Learning Difficulties? *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you **ALSO** have back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:
You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________ DATE ______________________

SIGNATURE ______________________ WITNESS ______________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

For more information, please contact
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The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.