THE EFFECTS OF A BRIEF, WATER-BASED EXERCISE INTERVENTION ON COGNITIVE FUNCTION IN OLDER ADULTS

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by

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Introduction

By 2030, the number of adults over the age of 65 is expected to grow to 72 million, or roughly one in five Americans. This growing proportion of older adults will produce many challenges for the healthcare system. For instance, approximately 30.4% of older adults have been diagnosed with some form of cardiovascular disease, approximately 25% with diabetes mellitus, and 40% are considered obese (National Center for Health Statistics, 2011). An older adult enrolled in Medicare with no chronic health conditions produces an average of $5,520 per year in medical expenses, whereas an older adult with five or more conditions produces an average of $24,658 per year (Federal Interagency Forum on Aging-Related Statistics, 2012).

In addition to these medical conditions, older adults are at elevated risk for adverse neurocognitive outcomes. Many structural brain changes occur with advancing age, including increases in ventricular volume and decreases in overall brain size, with pronounced atrophy found in the frontal regions (Tisserand & Jolles, 2003; Raz & Rodrigue, 2006; Galluzzi, Beltramello, Filippi, & Frisoni, 2008). Recent work using advanced neuroimaging has also identified decreased volume of both white and gray matter, and shrinkage in important structures including the hippocampus and striatum in older adults (Raz & Rodrigue, 2006).

Consistent with these changes to the brain, many older adults also exhibit declines in cognitive function. Some cognitive abilities, such as verbal intelligence and general knowledge, remain relatively preserved (Hedden & Gabrieli, 2004). Unfortunately other abilities such as memory, executive functioning, and processing speed begin to diminish as early as middle age (Hedden & Gabrieli, 2004; Park & Reuter-Lorenz, 2009) and lead to reduced function in
everyday life (Milan-Calenti et al., 2012; Park, Jun, & Park, 2013). This decline in cognitive functioning is known by various monikers including age associated cognitive decline, normal cognitive aging, and age associated memory impairment (Park, O'Connell, & Thomson, 2003). In each case, it refers to a decrease in an individual's cognitive functioning, though the decline is not sufficient enough to meet criteria for any type of mild cognitive impairment or dementia (Deary et al., 2009).

**Moderating factors for age-related cognitive decline**

A growing number of both protective and risk factors for age-related cognitive decline have been identified. For example, older adults with higher levels of education are less likely to exhibit cognitive decline (Meng & D'Arcy, 2012). Similarly, the Mediterranean diet is associated with lower risk for cognitive decline and Alzheimer's disease (Feart, Samieri, Alles, & Barberger-Gateau, 2012; Xingwang et al., 2013).

In contrast to these neuroprotective factors, studies have identified a growing number of medical conditions that appear to accelerate cognitive decline, including cardiovascular disease, type 2 diabetes, and obesity (Okonkwo et al., 2010; Biessels, ter Braak, Erkelens, & Hijman, 2001; Nilsson & Nilsson, 2009). Importantly, these conditions are linked by a common pathway—low levels of physical activity. This pattern raises the possibility that improved physical activity and exercise may ultimately reduce risk for adverse neurocognitive outcomes. The below sections will describe physical activity levels in older adults and present converging lines of research that support the possibility of cognitive benefits of exercise in this population.
Older adults are often sedentary

The American College of Sports Medicine (ACSM) recommends older adults perform a minimum of 150 minutes of moderate intensity (i.e. brisk walking) or 75 minutes of vigorous intensity (i.e. jogging/running) physical activity per week for optimal health (Garber et al., 2011). Unfortunately, many older adults fail to reach these goals (Federal Interagency Forum on Aging-Related Statistics, 2012; National Center for Health Statistics, 2011; Motl & McAuley, 2010; Harris, Owen, Victor, Adams, & Cook, 2008). Recent, large scale studies indicate that older adults spend between 62-75% of waking hours in sedentary activities and just 1-9% of their time engaging in moderate to vigorous physical activity (Arnardottir et al, 2013; Hansen et al., 2012).

Sedentary behavior is associated with adverse consequences

Low levels of physical activity can lead to a wide range of medical and neurological consequences, including:

*Cardiovascular Disease*

Approximately 30% of older adults have some form of cardiovascular disease (CVD) and this number climbs to 75% when including persons with hypertension (Wong et al., 2007; National Center for Health Statistics, 2011). A collection of studies demonstrate that physical inactivity and sedentary lifestyle are important contributors to CVD (Carnethon et al., 2003; Carnethon et al., 2003; Amin-Shokravi, Rajabi, & Ziaee, 2011). Following exercise, individuals diagnosed with cardiovascular disease demonstrate symptom reduction as well as increased cardiac functioning (Kurl et al., 2003; Walsh et al., 2003; Boreham et al., 2004; O'Donovan et
al., 2005). Furthermore, light to moderate intensity physical activity (i.e. walking) has demonstrated to be effective in reducing risk of cardiovascular disease (Manson et al., 2002; Manson et al., 1999; Sesso, Paffenbarger, Ha, & Lee, 1999). Finally, cognitive functioning is also negatively impacted as older adults with CVD demonstrate significant deficits in the areas of attention, executive functioning, memory, and language (Okonkwo et al., 2010).

*Type 2 Diabetes Mellitus and Metabolic Syndrome*

In 2010, just over one in four older adults (26.5%) had type 2 diabetes mellitus (T2DM) and an additional 7% have the condition but are not yet diagnosed (National Center for Health Statistics, 2011; Kim et al., 2012). Research indicates sedentary behavior, such as watching television, is an important factor to the development of T2DM (Hu et al., 2001; Dunstan et al., 2004). From a cognitive perspective, older adults with T2DM demonstrate impairments in the domains of executive function, attention, and memory (Biessels, ter Braak, Erkelens, & Hijman, 2001; Gold et al., 2007; Ruis et al., 2009; Yeung, Fischer, & Dixon, 2009; Alencar, Cobas & Gomes; 2010; Tiehuis et al., 2010; Reijmer et al., 2011; Nooyens, Spijkerman, Baan, & Verschuren, 2010; Rucker et al., 2012).

Closely related to T2DM, metabolic syndrome is defined as having three or more of the following conditions: abdominal obesity (BMI $\geq$ 30), high tryglycerides, low HDL cholesterol, hypertension and/or hyperglycemia (Grundy et al., 2005). Approximately 34% of adults meet criteria for metabolic syndrome, though older adults are more likely to be diagnosed as prevalence rates significantly increasing once an individual advances to the age of 60 (Ford, Li, & Zhao, 2010). As with T2DM, sedentary behavior is identified as a major risk factor to the development of metabolic syndrome (Gao, Nelson, Tucker, 2007; Gardiner et al., 2011;
Bankoski et al., 2011). Despite being relatively common in the general population many adults do not have adequate knowledge of the syndrome. One survey found less than 1% adults reported having metabolic syndrome and less than 15% were aware of the metabolic syndrome (Lewis et al., 2008). The lack of knowledge about this syndrome may prevent older adults from engaging in preventative behaviors. Similar to T2DM, metabolic syndrome is associated with poor cognitive functioning with deficits in aspects of attention, executive functioning, and memory (Reijmer et al., 2011; Cavalieri et al, 2010). When examined longitudinally, older adults with metabolic syndrome at baseline were significantly more likely to have poor memory performance during follow-up testing (Komulainen et al., 2007).

An abundance of research indicates exercise lowers risk of developing both T2DM and metabolic syndrome (Goodrich, et al., 2012; Cardoso et al, 2011; Colberg et al., 2010; Falluca & Pozzilli, 2009; Sui et al., 2008; LaMonte, Blair, & Church, 2005). Diabetic patients who engage in higher levels of exercise demonstrate better control of blood glucose levels, improved insulin functioning (Mikus et al., 2012; Colberg et al., 2010; Madden et al., 2009; Lemos et al., 2009), and have a higher quality of life (Falluca & Pozzilli, 2009). Further, exercise is related to decreased symptom expression in metabolic syndrome (Yassine et al., 2009; Malin et al., 2012; Chen et al., 2013).

Obesity

With increased age, a collection of metabolic and endocrine changes occur in the absence of physical activity and raise the risk for obesity (Mathus-Vliegen, 2012). Starting at age 20, muscle mass progressively declines and amount of fat mass increases, with both rapidly declining in tandem after the age of 70. Metabolic rate also changes, decreasing by about 4% per
decade after the age of 50 (Mathus-Vliegen, 2012). In 2010, 38% of older adults were considered obese, a rise from 22% in 1994 (Federal Interagency Forum on Aging-Related Statistics, 2012). Increased body mass is responsible for an alteration in basic movements such as walking, and standing from a sitting position, thus placing unnecessary stress on the legs and feet (Wearing et al., 2006). In older adults, the stress of excess weight combined with effects of sarcopenia often leads to physical limitations and inability to exercise (Montero-Fernandez & Rexach, 2013; Sykes et al., 2013).

Obese older adults often exhibit declines in basic activities of daily living (i.e. bathing, dressing, grooming) (Jenson & Friedmann, 2002; Snih et al., 2007; Lang, Llewellyn, Alexander & Melzer, 2008) and instrumental activities of daily living (IADL) such as traveling, food preparation, and shopping (Jenson & Friedmann, 2002). Obese older adults are also less likely to recover from functional limitations, thus suffering longer (Reynolds, Saito, & Crimmons, 2005; Reynolds & McIlvane, 2008). In obesity, cognitive functioning deficits are seen in memory (Nilsson & Nilsson, 2009; Gunstad, Paul, Cohen, Tate, & Gordon, 2006), attention, and executive functioning (Fergenbaum et al., 2009; Gunstad et al., 2007; Sabia, Kivimaki, Shipley, Marmot, Singh-Manoux, 2009).

Physical activity offers benefits for neurocognitive conditions

The relationship between sedentary behavior and medical consequences is well established in the literature. Recently however, an increasing amount of research suggests a close relationship between sedentary behavior and severe neurocognitive outcomes. As just one example, older adults who walked less than one quarter mile per day are significantly more likely
to develop dementia (Abbott et al., 2004). Likewise, older adults who are in the highest quartile of energy expenditure had a significantly lower risk of developing dementia than those in the lowest quartile (Podewils et al., 2005). These findings have encouraged research to more closely investigate the connection between sedentary behavior and neurocognitive outcomes.

Epidemiological evidence suggests physical activity and exercise protect against cognitive decline in healthy populations (Wang, Karp, Winblad, & Fratiglioni, 2002; Verghese et al., 2003; Abbott et al., 2004; Podewils et al., 2005). Similarly, individuals with Mild Cognitive Impairment (MCI) that participate in moderate to high levels of physical activity show better memory at 6 and 18 month follow-ups (Scherder et al., 2005; Lautenschlager et al., 2008; van Uffelen et al., 2009; Baker et al., 2010). In a more detailed study, Larson and colleagues (2006) followed a group of older adults for an average of 6 years assessing exercise frequency, cognition, and risk factors for dementia every 2 years. Results of the study indicate greater exercise is associated with reduced risk for development of dementia, including Alzheimer’s disease. Randomized control trials (RCTs) also suggest exercise is beneficial for those with Alzheimer's disease (Erickson et al., 2011; Yaguez et al., 2011; Denkinger et al., 2012; Hamer & Chida, 2009; Rolland, van Kan, & Vellas, 2010).

Exercise also improves cognitive function in healthy older adults

Exercise is valuable to those with disease pathology, whether medical or neurocognitive, and a rapidly growing literature demonstrates that exercise interventions are beneficial in older adults. Older adults who engage in exercise demonstrate an extensive range of positive health outcomes including increased cardiovascular fitness (Langlois et al., 2012; Colcombe & Kramer,
2003; Kara et al., 2005), balance, and muscle strength (Seco et al., 2013; Taaffe et al., 1999), higher bone mineral density (Goodpaster et al., 1996; Mussolino et al., 2001), and are slower to develop disabilities (Wang et al., 2002). Further, exercise participation is associated with lower risk of both depression and anxiety (Blumenthal et al., 1999; Mather et al., 2002).

Improved performance across multiple cognitive domains including global cognition, attention, executive functioning, and memory (Angevaren, et al., 2008; Kara et al., 2005; Langlois et al., 2012; Colcombe & Kramer, 2003) has also been demonstrated following regular exercise in this population. With regular exercise, older adults are at lower risk of developing vascular dementia (Minami et al., 1995; Verghese et al., 2003; Abbott et al., 2004; Podewils et al., 2005; Ravaglia et al., 2008; Aarsland et al., 2010). Finally, exercise has been shown to increase the volume of the hippocampus, a brain structure important for memory (Colcombe et al., 2006).

Approaches to exercise interventions in older adults

Regular exercise has demonstrated to be effective in older adults, though the exact nature of exercise interventions vary greatly across studies. Length of past interventions range from one month (Plummer-D-Amato et al., 2012) to 12 months (Roma et al., 2012) , with most being approximately three months long (Bento et al., 2012; Bocalini et al., 2008; Fransen et al., 2007; Hale, Waters, & Herbison, 2012; Wang et al., 2006). These programs typically require participants to exercise three times per week for one approximately 60 minutes per day. Exercise modalities commonly used include walking (Roma et al., 2012), cycling (Macaloso et al., 2003), resistance training (Forte et el., 2013) , and aerobics (DiPietro et al., 2006). Exercise intensity
also varies among studies from low (Yokokawa et al., 2008) to moderate (Roma et al., 2012) to vigorous (Malin et al., 2012; Fukimoto et al., 2010). Despite difficulties in comparing across studies, research appears to suggest higher intensity, longer interventions produce more favorable results (Malin et al., 2012; DiPietro et al., 2006).

However, this pattern is also a key factor that may prevent older adults from adhering to exercise programs. For instance, a study in which individuals participated in three 45 minute exercise sessions per week for 16 weeks had a 20.5% participant attrition rate (Blumenthal et al., 1999), a pattern that has since been replicated (Kelly & Kelly, 2013). A recent meta-analysis on this topic identified length of intervention as being a key predictor of lower adherence (McPhate et al., 2013). This effect may be particularly pronounced in older adults.

Fortunately, a recent line of research suggests individuals do not need to engage in prolonged exercise interventions to receive benefits. For example, a collection of recent studies demonstrates older adults with type 2 diabetes who engaged in an exercise intervention for just 7 days showed improved glycemic control (Kirwan et al., 2009; Mikus et al., 2012). Obese older adults show improvement in insulin functioning and metabolic processes (e.g. hormone secretion) after just 7 consecutive days of exercise (Kelly et al., 2012; Solomon et al., 2009). Past work also suggests improvements in cognitive functioning can be achieved with exercise programs shorter in duration (Labelle et al., 2013; Nanda, Balde, & Manjunatha, 2013). However, these studies were conducted with young adult populations, and no study has examined the possible cognitive benefits of a one week exercise intervention in older adults.
Older adults may have difficulty engaging in land based exercise

As noted above, many older adults may not be able to adhere to lengthy or high intensity exercise programs. Older adults identify numerous obstacles to exercise participation including time constraints, lack of motivation/determination, lack of familiarity with recreation facilities, fear of falling, poor physical health, and lack of knowledge about recommended type and intensity of activity (Schutzer & Graves, 2004; Lees et al., 2005; Wilcox et al., 2009; Mathews et al., 2010; Costello et al., 2011; Irvine et al., 2013). Another common obstacle to physical activity for older adults is lower extremity osteoarthritis (Wang et al., 2007), which leads to pain and stiffness (Wang et al., 2007; Egan & Mentes, 2010; Federal Interagency Forum on Aging-Related Statistics, 2012).

One alternative approach is the use of water-based (rather than land-based) exercise programs. This type of exercise places less stress on an individual's joints, as well as reduces the risk of falling (Hale et al., 2012). When exercise takes place in the water, movement is effected by forces which are not present in land-based exercise. Exercise in the water is influenced by several factors including speed of movement, acceleration, directional resistance, inertia, and number of times a participant changes direction (Aquatic Exercise Association, 2010). During water exercise, the level of resistance increases with an increase in speed. Inertia can also influence exercise, as it takes a greater amount of energy to start to stop a movement in water, than on land. This is primarily due to water having increased viscosity over air (Aquatic Exercise Association, 2010). The viscosity of water, along with other participant characteristics such as shape, and size, contributes to the resistance force of drag. Drag is important because
muscles are put under a constant workload throughout the full range of motion, whereas during land exercise, muscle load decreases if constant speed is maintained. These forces acting on the body during water-based exercise all help to increase muscle workload, without adding additional strain.

Water-based exercise has also been shown to increase levels of cardiovascular fitness in older adults (Bocalini et al., 2008; Wang et al., 2007; Bocalini et al., 2010; Campbell et al., 2003) and by participating in water exercise, older adults are better able to meet guidelines for recommended levels of physical activity (Campbell et al., 2003; Bocalini et al., 2008; Nikolai et al., 2009). Older adults who participate in water exercise are able to achieve significantly higher levels of cardiovascular fitness (Masumoto et al., 2008) and show improvements in physical functioning (Suomi, & Collier, 2003; Fransen et al., 2007; Bento et al., 2012). Finally, older adults who participate in water-based aerobics achieve better sleep quality than those in land-based aerobics (Alencar et al., 2006).

Given the relationship land-based exercise has with reduction of medical conditions and improved cognitive functioning, it is possible that water-based exercise would provide similar benefits. The current study addressed the following aims and hypotheses:

**Aim #1 Participants who complete the exercise intervention will show improvements in cardiovascular fitness.**

*Hypothesis #1.* Participants in the exercise group will exhibit significant increases in performance on the 2 Minute Step Test. Control participants’ performance on the 2 Minute Step Test will remain unchanged.
**Aim #2** Participants who complete the exercise intervention will show improved cognitive functioning in multiple cognitive domains.

*Hypothesis #2.* Participants in the exercise group will demonstrate significant increases in cognitive functioning as evidenced by improved scores in the domains of attention, executive function, and memory. Control participants’ performance on measures of cognitive functioning will remain unchanged.

**Aim #3** Improvements in cardiovascular fitness will moderate change in cognitive functioning.

*Hypothesis #3.* The change in cardiovascular fitness, as measured by the 2 Minute Step Test, will moderate the change in cognitive functioning in the exercise group.

**Methods**

**Participants**

A sample of 69 older adults were recruited for the study from local community recreation and wellness centers. Participants were eligible for the study if they were between the ages of 50 and 80 and native English speakers. Participants were excluded if they reported a lifetime history of any of the following conditions: neurological disorders (e.g. stroke, epilepsy), sleep apnea, severe mental illness (e.g. bipolar disorder, schizophrenia), brain injury with resulting loss of consciousness greater than 5 minutes, unexplained recurrent chest pain, abnormal heart rhythm, narrowing of aortic valve, blood clot in the lungs, inflammation of the heart, ruptured blood vessel, acute infections, or impaired heart valve functioning.
Participants were asked to consult with their primary care provider before participation if they had history of any of the following conditions: electrolyte abnormalities, severe hypertension, any neuromuscular, muscoskeletal, or rheumatoid disorders exacerbated by exercise, pacemaker insertion, ventricular aneurysm, uncontrolled metabolic diseases (e.g. diabetes), or mononucleosis. See Appendix A.

The exercise group was composed 33 participants, was 78.8% female, had an average age of 63.52 (± 7.33), and 14.30 (± 2.49) years of education. Those in the exercise group most often reported a history of hypertension (39.4%), cancer (18.2%), type 2 diabetes mellitus (15.2%), and thyroid abnormalities (15.2%). The average BMI for the exercise group was 30.12 (± 6.1), which falls in the Obese classification.

The control group was composed of 36 participants, was 72.2% female, had an average age of 65.78 (± 7.33), and 15.94 (± 2.91) years of education. Those in the control group most often reported a history of hypertension (38.9%), cancer (25%), and thyroid abnormalities (13.9%). The average BMI for the control group was 25.81 (± 5.50), which falls in the Overweight classification.

**Measures**

**Neuropsychological Test Battery**

Participants completed a brief battery of neuropsychological measures to assess function across multiple cognitive domains, including global cognitive functioning, executive functioning/attention, and memory. Measures were chosen on their known sensitivity to cognitive dysfunction in this population as well as limited practice effects and/or availability of alternate forms. Specific measures included:
Global Cognitive Functioning

The Montreal Cognitive Assessment (MOCA: Nasreddine et al., 2005). This test is a brief measure of global cognitive functioning with an alternate form administered during follow-up testing to eliminate potential practice effects. Alternate forms have been shown to be equivalent (Costa et al., 2012). The total score of the MOCA was used in primary analyses. Past work has indicated the MOCA to be a valid and reliable measure of cognitive function in older adults (Luis et al., 2009). The MOCA is also positively associated with level of physical activity ($r = .67$) as measured by step count in older adults (Ihara, Okamoto, Hase, & Takahashi, 2012), suggesting it may be sensitive to the effects of exercise in this population.

Executive Functioning/Attention

Adaptive Rate Continuous Performance Test (ARCPT; Cohen, 1993). The ARCPT is a computerized measure of vigilance and sustained attention. This task requires participants to respond when a specific combination of letters appears on the screen. Indices measuring accuracy (Task Sensitivity), reaction time (Final ISI), and vigilance (Vigilance Decrement) were used. These three indices demonstrate significant associations with cognitive performance on other commonly used clinical measures in prior research (Jerskey et al., 2009; Alosco et al., 2012).

Trail Making Test A and B (Reitan, 1958). The Trail Making A (TMT-A) task, asks participants to connect a series of 25 numbered dots in ascending order as quickly as they can (e.g. 1-2-3, etc). Trail Making B (TMT-B) adds a set-shifting component to Trail Making Test A and requires participants to alternate between numbers and letters in ascending order (e.g. 1-A-2-B, etc.). Time to completion was used for both TMT-A and TMT-B. Both tasks are strong predictors
of future impairment as those in the lowest quartile of performance were significantly more likely to develop impairments on other measures after a 6 year follow-up (Vazzana et al., 2010).

Additional, research suggests exercise improves performance on these tasks (Tanne et al., 2005).

**Frontal Assessment Battery** (FAB; Dubois, Slachevsky, Litvan, & Pillon, 2000). This test employs several short tasks to provide a broad measure of executive function. More specifically, participants are asked to identify similarities among two words (e.g., table, chair), name as many words as they can that start with a target letter (e.g. words that begin with ‘S’), complete frontal-motor hand movements, and tap patterns with their dominant hand. The total score on the FAB was used. The FAB has been shown to be sensitive to frontal lobe dysfunction in older adults (Yoshida et al., 2009).

**Stroop Test** (Golden, 1978). This test measures selective attention and mental flexibility. Participants are asked to first read columns of words spelling out colors printed in black ink (word subtest). They are then asked to identify the color a series of Xs is printed in different colors (color subtest), and finally to indicate the color of the ink a word (which spells out a color) is printed in, regardless of the verbal content (color-word subtest). An interference score (predicted color word vs. actual color word) was used. The Stroop Test is effective in detecting cognitive dysfunction in older adults, particularly with frontal lobe impairments \( (r = -0.30) \) (Alvarez & Emory, 2006).

**Memory**

**Hopkins Verbal Learning Test Revised** (HVLT-R; Brandt, 1991). This test asks participants to learn and remember a list of 12 words. Approximately 20 minutes after the three learning trials, participants are administered a Delayed Recall, and a Recognition trial. Total
number of words recalled across all learning trials and recognition discriminability indices were used. The HVLT exhibited strong psychometric properties in a sample of older adults when detecting dementia, including a sensitivity of 0.96 and specificity of 0.80 (Frank & Byrne, 2000). An alternate version of the HVLT was administered during follow-up testing to minimize potential practice effects.

*Rey-Osterrieth Complex Figure Test* (RCFT; Rey, 1941; Osterrieth, 1944). This test asks participants to copy a complex geometric figure. Immediately after completion of this learning trial, participants are asked to draw as much of the figure from memory (Immediate Recall). Following a delay, participants are again asked to draw the figure from memory (Delayed Recall). The figure is broken down into 18 potential components, with each receiving a score from 0-2 based on accuracy and placement. The scoring procedure is repeated for the Copy, Immediate Recall, and Delayed Recall trials. The total score from the Immediate and Delayed Recall trials was used in analyses. The Taylor Complex Figure (TCF) was administered as an alternate form to eliminate potential practice effects as this measures has been shown to be comparable to the RCT (Awad, et al., 2004).

**Physical Activity Measurement**

*Cardiovascular Fitness.* In order to assess cardiovascular fitness, each participant will complete the 2 Minute Step Test (2MST; Rikli & Jones, 1999). During this test, participants are asked to march in place for two minutes raising the knee to a predetermined height. The required height for the knee raise was measured to be the midpoint between the individual’s hip and knee. The number of times the right knee is raised to the required height was used. The 2MST has been demonstrated to be a feasible and accurate option for assessing cardiovascular fitness in
older adults (Rikli & Jones, 2002; Garcia et al, 2013). Though treadmill stress testing is considered by most to be the gold standard for measuring cardiovascular fitness it can be expensive, time consuming, and difficult to obtain in older adults (Lan et al., 1996; Garber et al., 2011). A recent study suggests the 2MST correlates strongly with stress test performance in older adults (Garcia et al., 2013). See Table 1

**Self-Report Questionnaires**

Participants completed a collection of self-report measures assessing medical history, estimated intellectual ability, and level of physical activity. See Appendix B.

*Medical History Questionnaire* (MHQ). Participants provided detailed educational, medical, neurological, and psychiatric history using self-report checklists.

*Spot the Word Test* (STW; Baddeley et al., 1993). This test presents pairs of words to participants, one of which is real, the other is a foil. Participants are asked to identify the real word from each pair. The total number of correctly identified words is converted to a scaled score to provide an estimate of intellectual ability. In an older adult population, the STW demonstrates significant correlations with other measures of premorbid functioning ranging from 0.35 (Wechsler Adult Intelligence Scale-Revised Vocabulary Subtest) to 0.66 (Shipley Institute of Living Vocabulary subtest) (Yuspeh & Vanderploeg, 2000). For the current study, estimated IQ was used primarily as a covariate to ensure exercise and control groups did not differ at baseline.

*Rapid Assessment of Physical Activity* (RAPA; Topolski, et al., 2006). This is a 9 item questionnaire designed to assess level of physical activity in older adults. Total score, ranging from 0-10 was used, with higher scores indicating greater levels of physical activity. The RAPA
has a positive predictive power of 0.77 and a negative predictive power of 0.75 when compared to other measures of physical activity (Topolski et al., 2006).

**Exercise Intervention**

The exercise intervention consisted of participants attending one moderate intensity water aerobics class per day for six consecutive days. This intensity was chosen as research previously discussed has demonstrated higher levels of intensity to be effective in producing both changes in physical functioning (Malin et al., 2012; DiPietro et al., 2006). Participants were free to choose which class time worked best for their individual schedules (e.g. 6:00am or 9:00am). Water aerobics classes were held at the Cuyahoga Falls Natatorium and conducted by certified trainers. All classes were monitored by lifeguards certified in first aid. Instructors utilized various exercises including water walking and leg and/or arm resistance maneuvers with the assistance of flotation devices. Adherence to the intervention was monitored through actigraphy, by a small watch-like device (Actiwatch; Koninkiike Philips, Eindoven, Netherlands) worn around the participants wrist for the duration of the study.

While completing the intervention, a subset of those in the exercise group wore heart rate monitors (Polar FT1; Polar Electro Inc, Lake Success, NY) to ensure they were reaching the desired 60-70\% of their maximum heart rate indicating moderate to high intensity activity level (Malin et al., 2012). Approximately 42\% of participants in the exercise group were randomly selected to wear heart rate monitors during an exercise class. Those participants were able to achieve a moderate level of exercise intensity, as evidenced by an average of 66\% of their maximum heart rate during those sessions. The average maximum heart rate achieved was 113 (± 21.60). Participants in the exercise group self-reported what exercise class they attended
each day during the designated intervention week. The intervention appeared to be well
tolerated by participants as they reported attending an average of 5.85 (± 0.36) exercise classes
during the week. Four participants attended only 5 days of exercise.

Procedures

All procedures were approved by the Kent State University Institutional Review Board, and participants provided written informed consent prior to study enrollment. Participants were recruited from the Cuyahoga Falls Natatorium and the Kent State University Recreation and Wellness Center. In an effort to generate interest in the study, employees at both the Natatorium and Kent State Recreation Center were informed of the study and subsequently informed potential participants about the project. Recruitment flyers were also posted in both locations, and study personnel were available in answer any questions. Interested individuals were contacted by telephone to complete an initial screening interview to determine eligibility. Once determined to be eligible, participants were scheduled for baseline testing. Participants were assessed at two time points over the course of two weeks.

At the baseline testing session, participants in the exercise group completed self-report questionnaires, neuropsychological test battery, and the 2MST. Individuals were then instructed to participate in one water aerobics class per day for six consecutive days. Water aerobics were designated as moderate to high intensity, and designed as to allow participants to safely reach 60-70% maximum heart rate. As previously discussed, water-based exercise is a feasible alternative for older adults to increase cardiovascular fitness and meet recommended physical activity guidelines. Also previously discussed, the duration of the intervention was chosen as past research demonstrates physiological improvements can be achieved in as little as one week.
Following the intervention, participants completed follow-up testing which included the neuropsychological test battery and the 2MST. Baseline and follow-up testing sessions were conducted at the Cuyahoga Falls Natatorium approximately two weeks apart.

Participants in the control group completed the same recruitment and screening procedure as the exercise group. At baseline testing, participants in the control group completed the same self-report questionnaires, neuropsychological test battery, and the 2MST. However, these participants were instructed to continue their typical daily routine until follow-up testing. Baseline and follow-up testing sessions were conducted at the both the Natatorium and in the Neuropsychological Laboratory on the campus of Kent State University approximately two weeks apart.

**Preliminary Analyses**

In order to facilitate interpretation of data, all raw cognitive test scores were converted into T-scores (a distribution with a mean of 50 and a standard deviation of 10) using normative data based on age, and when possible, gender and education. Composite scores were created for the domains of attention, executive functioning, and memory by using the mean of the T-scores for the selected indices within each domain. In keeping with convention of many clinical settings, impairment in domains for the current study was defined as T-score < 35 (i.e. < 1.5 deviations below the mean) (Alosco et al., 2012). Missing data on measures that comprise cognitive domain composite scores was addressed by using the average of the remaining participants with available data on that particular measure. Univariate normality and possible outliers on measures of cognitive functioning and fitness were identified by examination of
histograms and variable z-scores. Descriptive statistics were performed on medical and demographic variables to further characterize the sample.

Results

Preliminary Analyses

Missing Data and Participant Screening

Participants were screened for clinical levels of cognitive impairment using their baseline MOCA score. Consistent with established cutoffs, any participant with a baseline MOCA score below 23 was removed from analyses (Luis et al., 2009; Tsai et al., 2012). Analyses identified 8 cases that met criteria for removal. These cases were removed from primary analyses in an effort to detect improvements in functioning in a cognitive healthy older adult population. Participants excluded from analyses had a significantly lower estimated intelligence score than those retained (t(67) = -2.74, \( p = < .01 \)). However, no significant differences emerged in terms of age (t(67) = -0.68, \( p = 0.50 \)), gender (\( \chi^2(1, N = 69) = 0.81, p = 0.37 \)), education (t(67) = 0.97, \( p = 0.34 \)), or baseline levels of physical activity (t(67) = 0.22, \( p = 0.82 \)).

Following screening for cognitive impairment, other variables of interest were screened for missing data. One participant had missing data on the SCWT at both pre and post testing. Missing data was also found for one participant on the ARCPT during pre-testing. Both values were addressed using mean imputation. No participant in the control group had missing data on cognitive variables. There were no cases with missing data on any of the demographic variables (i.e. age, gender, years of education, estimated intelligence, or baseline levels of physical activity).
Examination of Statistical Assumptions

Outliers and subsequent violations of univariate normality were identified through histograms and examination of z-scores for cognitive domains and physical fitness. Any z-score that was ± 3 SD from the mean was considered to be an outlier. Analyses of baseline data revealed one case with a z-score greater than 3 on the 2MST (Raw Score = 200), thus this case was removed from further analyses. No outliers were present in the domains of attention, executive function, or memory.

Baseline Comparisons of Exercise and Control Groups

The final sample consisted of 60 older adults: 27 in the exercise group and 33 in the control group. No between group differences emerged in terms of age (t(58) = -1.28, p = 0.21), gender ($\chi^2 = 0.03, p = 0.85$), education (t(58) = -1.95, p = 0.06), or estimated intelligence (t(58) = -0.86, p = 0.40). The groups were significantly different in terms of self-reported baseline physical activity (t(58) = -3.11, p = 0.003) with the control group reporting more activity on the RAPA. The groups were also significantly different in terms of the 2MST (t(58) = -2.22, p = 0.03) with the control group demonstrating higher step count.

See Table 2.

Correlations among baseline demographic variables revealed a significant negative relationship between age and estimated intelligence ($r = -0.30, p = 0.013$). A significant positive relationship was also found between education and estimated intelligence ($r = 0.54, p < 0.001$). See Table 3.

Primary Analyses

Hypothesis #1
In order to examine possible changes in cardiovascular fitness (2MST) from baseline to post-testing, a repeated measures Analysis of Covariance (ANCOVA) was conducted in both the exercise and control groups adjusting for baseline levels of the RAPA. Overall, a significant group by fitness interaction was observed \( (F(1, 57) = 7.97, p = .007) \). Analyses revealed the exercise group significantly improved from baseline to post-testing on the 2MST \( (F(1, 26) = 6.22, p = 0.019) \), exhibiting a 12.27% increase in cardiovascular fitness. Interestingly, the control group demonstrated a significant decrease in performance on the 2MST \( (F(1, 32) = 4.07, p = .05) \).

**Hypothesis #2**

To investigate possible changes in cognitive functioning composite scores from baseline to post-testing, a series of repeated measures Analysis of Covariance (ANCOVA) were conducted in both the exercise and control groups adjusting for baseline RAPA and 2MST.

When examining changes on executive functioning, a significant interaction was observed between executive function and group \( (F(1, 53) = 10.64, p = .002) \). The exercise group demonstrated a significant increase from baseline to post-testing \( (F(1, 24) = 58.46, p < .001) \). Conversely, the control group did not change from baseline to post-testing \( (F(1, 31) = 1.63, p = 0.21) \).

Similar to executive function, the exercise group demonstrated a significant increase from baseline to post-testing on the attention composite score \( (F(1, 24) = 12.82, p = 0.002) \). The control group did not significantly change \( (F(1, 32) = 2.65, p = 0.11) \) and no significant interaction was observed \( (F(1, 54) = 0.36, p = 0.55) \).
Finally, the exercise group demonstrated a significant increase in performance on the memory composite score from baseline to follow-up testing ($F(1, 24) = 11.37, p = 0.003$). The control group did not change from baseline to follow-up testing ($F(1, 31) = 0.39, p = 0.54$) and no significant interaction was observed ($F(1,54) = 1.72, p = .07$). See Table 4.

**Hypothesis #3**

In order to explore the possible moderation effect of the change in fitness being related to change in cognitive functioning, a hierarchical linear regression analysis was conducted. This analysis was performed in block format. In the first block, baseline levels of cardiovascular fitness (2MST) and cognitive functioning were entered. In the second block, post-testing levels of fitness were entered. The post-testing composite score on cognitive functioning served as the dependent variable.

In regards to attention, the overall model for the prediction of post-testing cognitive functioning was significant ($F(3,22) = 7.75, p = .001$). However, when the change in cardiovascular fitness was added to the model it did not provide any predictive validity over the initial model consisting of baseline fitness, and attentional performance ($\Delta R^2 = 0.00, p = 0.99$).

Similar to attention, the overall model for executive function was significant ($F(2,23) = 17.30, p < .001$). Though, the change in cardiovascular fitness did not provide any predictive ability over the initial model ($\Delta R^2 = 0.00, p = 0.59$).

Finally, the overall model for memory was significant ($F(3,22) = 6.76, p = 0.002$), though the change in cardiovascular fitness provided no additional predictive ability ($\Delta R^2 = 0.00, p = 0.88$). See Table 5.
Exploratory Analyses

Given the absence of significant effects of fitness on cognitive function, exploratory analyses were performed to help identify possible risk and protective factors. Specifically, bivariate correlations were conducted between demographic (e.g. age, gender) and medical (e.g. BMI) variables and the change score on the 2MST. Analyses revealed estimated intelligence to have a significant negative relationship with age \((r = -0.32, p = 0.01)\), as well as a significant positive relationship with education \((r = 0.54, p < .001)\). Finally, physical activity was negatively related to a diagnosis of type 2 diabetes \((r = -0.35, p = 0.01)\). Analyses revealed no significant relationships between variables of interest and the change score on the 2MST. See Table 6.

Discussion

The results of the current study show even a short exercise program provides numerous benefits for an older adult population. Building from previous literature, it was hypothesized that one week of water aerobics would lead to improvements in cardiovascular fitness and cognitive functioning. Consistent with these expectations, the exercise intervention produced significant increases in both cardiovascular fitness and cognitive functioning across multiple domains. Several aspects of the study warrant further discussion.

One week of water-aerobics improves cardiovascular fitness

The current study found that one week of water aerobics produced a significant increase in cardiovascular fitness. Few studies have examined the effects of water aerobics on cardiovascular fitness (Meridith-Jones et al., 2011), though most suggest similar or even greater
benefits relative to land-based interventions. As previously mentioned, the human body is subjected to different forces when moving through the water and the cardiovascular system adapts accordingly. When placed in water, the body is subjected to forces (i.e. hydrostatic pressure) which are not found during land based exercise (Meridith-Jones et al., 2011). During water immersion, the lower body is subject to increased pressure, causing blood to be diverted to the thoracic area placing the heart under an increased workload (Chu et al., 2002). Additionally, the pressure of the water inhibits the body's ability to fully expand the lungs during an inhalation, increasing the workload of the lungs by as much as 60% (Agostoni et al., 1966). Participants in the current study reached an average of 66% of their maximum heart rate, which is similar to past work using land-based exercise programs (Roma et al., 2012), and this moderate-to-high intensity has been suggested to be beneficial for older adults (Brown et al., 2012). The physiological changes effectively challenge the cardiovascular system during water-based exercise and may help account for the rapid improvement in fitness found in the current study. Future studies are needed to confirm these effects and further clarify the possible advantages of water-based exercise in older adult populations.

The current study found an average increase of 12.25% in cardiovascular fitness at post-testing, an improvement that is similar to past research using longer exercise interventions in middle-aged to older adults. This increase falls within the percentage increase reported by past work with a low of 5% (Saavedra, De La Cruz, Escalante, & Rodriguez, 2007) to a high of 42% (Bocalini, et al., 2008). The rate is also similar to previous studies in this area. In a randomized control study, using a group of sedentary older women, Takeshima et al. (2002) reported a 12% increase in cardiovascular fitness following 12 weeks of water-based exercise. Similarly, a 12%
increase in fitness was reported by Taunton et al (1996) using an uncontrolled study design. The results of the current study indicate a lengthy exercise intervention may not be needed to see changes in cardiovascular fitness and encourages further work on the benefits of short, higher intensity exercise interventions. Such programs may be particularly beneficial, as they may promote greater adherence and lower risk of injury.

One week of water-aerobics resulted in improved performance in across cognitive domains

Consistent with expectations, the current study also found one week of water aerobics produced significant increases in executive function, attention, and memory performance. The cognitive benefits of land-based exercise for older adults are well established and can improve global cognition, executive function, attention, and memory (Angevaren, et al., 2008; Kara et al., 2005; Langlois et al., 2012; Colcombe & Kramer, 2003). Fewer studies have examined the potential benefits of water aerobics on cognitive functioning. Cancela Carral & Ayan Perez (2007) used a combined water aerobics and strength training program for older women. Though specific cognitive domains were not examined in that study, results indicated an improvement in general cognitive ability, as measured by the Mini Mental Status Exam (MMSE), following 5 months of exercise. Munguia-Izquierdo & Legaz-Arrese (2007) used water aerobics with a group of middle-aged women diagnosed with fibromyalgia. The authors reported significant increases in measures of attention, executive functioning, and memory following 16 weeks of water aerobics. Further, Hawkins et al. (1992) found a significant improvement in attention following 10 weeks of water aerobics with an older adult population.

Though these studies demonstrated the benefits of water aerobics on cognitive functioning, important differences from the current study in design and methodology exist.
Although the activities of water aerobics classes are likely comparable across studies, the duration and intensity of the intervention may vary considerably across programs. As the current study achieved benefits similar to past work in a much shorter duration, it appears that exercise intensity may be a key factor for providing cognitive benefit. When exercising at higher intensities, such as 60 to 80 percent of maximum heart rate, older adults show improvements in cognitive functioning (Blumenthal et al., 1989; Emery & Gatz, 1990; Panton 1990; Whitehurst, 1991). As water-based exercise has similar properties to land-based exercise, future work is needed to determine how intensity may influence outcomes, particularly those related to cognitive functioning.

Despite improved performance in cognitive functioning, past research in this area remains mixed. The current results may be due to the nature of the exercise intervention. Previous research indicates a short bout of exercise (e.g. 1-2 days) can improve alertness and executive functioning in older adults (Cordova at el., 2009), supporting the results of the current study. Other research indicates chronic exercise is beneficial to prevent cognitive decline in older adults (Muscari et al., 2010). Thus, continued studies are needed to determine the most effective and feasible exercise intervention in this group.

*Cardiovascular fitness does not moderate the change in cognitive function*

In the current study, improvement in cardiovascular fitness did not moderate improvement in cognitive function after the exercise intervention. The exact reason for this finding is not entirely clear. One possible explanation may be the magnitude of the change in cardiovascular fitness. The current study demonstrated a statistically significant increase in performance on the 2MST, though the increase may not be of significant magnitude to influence
subsequent change in cognitive functioning. As a result, improvements in other physiological indices may underlie cognitive benefits. One such possibility is improved glycemic control. Approximately 15.2% of those in the exercise group reported a diagnosis of T2DM and such persons are at risk for impairments on measures of executive functioning, attention, and memory (Yeung, Fischer, & Dixon, 2009; Tiehuis et al., 2010). Other prior research has suggested those with T2DM can achieve better control of blood glucose levels following 7 days of high intensity exercise (i.e. 70% of maximum heart rate) (Kirwan et al., 2009). It is possible that similar improvements occurred in the current study and may help account for the gains in cognitive function. Unfortunately, the current study did not measure participants levels of blood glucose and future studies utilizing a wide range of biomarkers are much needed.

It is also possible that psychological factors may be contributing to the change in cognitive functioning. Exercise is associated with lower levels of psychological distress, depression, and anxiety (Blumenthal et al., 1999; McHugh & Lawlor, 2012). In turn, individuals with lower psychological distress have demonstrated increased memory performance (Head, Singh, & Bugg, 2012). This pattern raises the possibility that engagement in the exercise intervention may have lowered psychological distress, thus leading to the observed increase in cognitive functioning. Studies directly examining the possible psychological benefits of a brief exercise intervention are much needed.

Change in cardiovascular fitness is not related to demographic or medical variables

The findings in the exploratory analyses are consistent with past work related to factors influencing estimated intelligence.
Analyses revealed no significant correlations between demographic or medical variables and the change in performance on the 2MST. One possible explanation for the lack of findings in this area may be due to the small sample size, resulting in reduced variability (i.e. range restriction). However, the findings are not surprising when viewed in the context of inconsistency regarding research on exercise and cognitive functioning. Differences across studies such as duration, intensity, type of exercise used, age, health, pre and post fitness levels of participants, assessment methods for cardiovascular fitness, and the choice of neuropsychological tests are present (McAuley, Kramer, & Colcombe, 2004). Furthermore, a meta-analysis conducted by Colcombe and Kramer (2003) established a beneficial effect of cardiovascular fitness on cognitive functioning, though the authors concluded future research is needed to understand what variables are related to the change in cardiovascular fitness.

**Limitations**

Several limitations of the current study require further discussion. A primary limitation is found in the lack of randomization to study condition. Future studies utilizing random assignment of participants are needed to resolve any possible confounds due selection bias. This is important as past work has identified poor health as a reason older adults chose not to join an exercise program (Biedenweg et al., 2014). This raises the possibility the current results are attenuated due to participants’ greater than average baseline health. Another limitation is found in the modest sample size of the current study. The excluding of participants for impaired cognition at baseline resulted in a smaller than expected sample available for analysis, ultimately limiting statistical power. This may be particularly notable for analyses examining the possible contribution of fitness to cognitive changes over the one week interval. Further, the current
study was not equally balanced between genders. Prior research (Rubia et al., 2010; Misteli et al., 2011, Wu et al., 2012; Maylor et al., 2007) has demonstrated differential cognitive performance and age-related cognitive decline between genders. A balanced gender sample would help understand the effects exercise may have on different genders.

Participants in the current study were allowed to attend which ever exercise class was convenient for their schedules. Classes were taught by different instructors, thus the possibility exists for differences in intensity, frequency, duration, and type of various exercises performed. A standardized class time, instructor, and routine for each class would limit confounds introduced by different classes and/or instructors. Similarly, more rigorous methodology may help provide greater insight, as the measure of cardiovascular fitness (i.e. the 2 Minute Step Test) is not as sophisticated as a treadmill stress test. Comprehensive and detailed physiological assessment including treadmill stress testing, circulating biomarkers, and neuroimaging would help clarify mechanisms for the cognitive benefits of exercise.

Clinical Implications and Future Directions

The results of the study have significant implications for clinicians. Past research (Middleton et al., 2011) suggests older adults need to engage in long-term physical activity and exercise to prevent cognitive decline. However, the current results suggest the same improvements in cognitive function can be achieved in a shorter duration when performed at a higher intensity level. The short duration is essential, given the many barriers which prevent older adults from regular exercise (McPhate et al., 2013). Another important feature of the current study is the use of water-based exercise over traditional land-based exercise. Moving exercise into the water eliminates many concerns related to falling and lower extremity arthritis.
(Lees et al., 2005; Wang et al., 2007). In combination, the results suggest older adults do not need to engage in long-term, land-based exercise, for cognitive benefit. Rather, alternative modalities (i.e. water aerobics) conducted in a shorter time span can be equally effective in improving cognitive function, as long as participants are safely able to exercise at a higher intensity.

When designing future interventions, several methodological issues need to be taken into account. The current study was limited to a pre and post testing design, with no long term follow up included. Adding a later follow-up visit (e.g. 3 months later) would provide the first data on the possible persistence of cognitive gains after a week of exercise.

Conclusions

In summary, the current study shows older adults exhibit improved cardiovascular fitness and cognitive function after a brief, water-based exercise program. The results advance to the majority of research in this area, which argues the traditional philosophy of "more is better." While future research is needed to confirm these effects, the current study raises the possibility that even brief exercise interventions can provide meaningful benefits.


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Table 1: Neuropsychological test performance of exercise and control groups

<table>
<thead>
<tr>
<th></th>
<th>Exercise Group</th>
<th>Control Group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Baseline Testing</td>
<td>Post Testing</td>
</tr>
<tr>
<td></td>
<td>T-Score Mean (SD)</td>
<td>% Impaired</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T-Score Mean (SD)</td>
</tr>
<tr>
<td><strong>Global Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MoCA</td>
<td>40.88 (10.29)</td>
<td>20.8%</td>
</tr>
<tr>
<td><strong>Attention</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARCPT- Accuracy</td>
<td>58.54 (4.98)</td>
<td>0%</td>
</tr>
<tr>
<td>ARCPT- Reaction</td>
<td>47.08 (17.17)</td>
<td>30.8%</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARCPT- Vigilance</td>
<td>57.88 (9.88)</td>
<td>3.8%</td>
</tr>
<tr>
<td>TMT-A</td>
<td>49.78 (10.41)</td>
<td>7.4%</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMT-B</td>
<td>48.67 (13.58)</td>
<td>14.8%</td>
</tr>
<tr>
<td>FAB</td>
<td>45.04 (14.46)</td>
<td>25.9%</td>
</tr>
<tr>
<td>Stroop Interference</td>
<td>40.15 (9.73)</td>
<td>26.9%</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVLT- Learning</td>
<td>47.48 (9.72)</td>
<td>7.4%</td>
</tr>
<tr>
<td>HVLT- Discrim.</td>
<td>44.85 (9.90)</td>
<td>11.1%</td>
</tr>
<tr>
<td>CFT- Immediate</td>
<td>43.67 (11.94)</td>
<td>22.2%</td>
</tr>
<tr>
<td>CFT- Delay</td>
<td>40.96 (12.13)</td>
<td>25.9%</td>
</tr>
</tbody>
</table>
Table 2: Demographic characteristics of exercise and control groups

<table>
<thead>
<tr>
<th></th>
<th>Exercise Group (N = 27) Mean (SD)</th>
<th>Control Group (N = 33) Mean (SD)</th>
<th>Statistic (t or $\chi^2$)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>63.26 (7.64)</td>
<td>65.67 (6.96)</td>
<td>-1.28</td>
<td>0.20</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>6/21</td>
<td>8/25</td>
<td>0.03</td>
<td>0.85</td>
</tr>
<tr>
<td>Years of Education</td>
<td>14.63 (2.39)</td>
<td>16.00 (2.94)</td>
<td>-1.95</td>
<td>0.05</td>
</tr>
<tr>
<td>Estimated Intelligence</td>
<td>9.78 (3.61)</td>
<td>10.52 (3.05)</td>
<td>-0.86</td>
<td>0.40</td>
</tr>
<tr>
<td>Self Reported Physical Activity (RAPA)</td>
<td>7.44 (1.81)</td>
<td>8.70 (1.31)</td>
<td>-3.11</td>
<td>0.00</td>
</tr>
<tr>
<td>Fitness (2MST)</td>
<td>94.74 (30.15)</td>
<td>110.24 (24.05)</td>
<td>-2.22</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Note: **Bold text** indicates significant values at $p < .05$
Table 3: Correlations among demographic variables

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Education</th>
<th>Estimated Intelligence</th>
<th>Self Reported Physical Activity</th>
<th>Fitness (2MST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>--</td>
<td>-0.06</td>
<td>-0.32*</td>
<td>0.14</td>
<td>-0.16</td>
</tr>
<tr>
<td>Education</td>
<td>--</td>
<td>--</td>
<td>0.54***</td>
<td>0.16</td>
<td>-0.09</td>
</tr>
<tr>
<td>Estimated Intelligence</td>
<td>--</td>
<td>--</td>
<td>0.05</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Self Reported Physical Activity (RAPA)</td>
<td>--</td>
<td>--</td>
<td></td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Fitness (2MST)</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
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</table>

Note: **Bold text** indicates significant values
* Correlation significant at $p = 0.05$
*** Correlation is significant at $p = 0.001$
Table 4: Comparison of performance on fitness testing, and cognitive functioning composites from pre to post testing between groups

<table>
<thead>
<tr>
<th></th>
<th>Exercise Group</th>
<th>F-Value</th>
<th>Sig</th>
<th>Control Group</th>
<th>F-Value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Testing Mean T-Score (SD)</td>
<td>Post Testing Mean T-Score (SD)</td>
<td></td>
<td>Pre Testing Mean T-Score (SD)</td>
<td>Post Testing Mean T-Score (SD)</td>
<td></td>
</tr>
<tr>
<td>Fitness (2MST) (Raw Score)</td>
<td>94.74 (30.15)</td>
<td>106.37 (29.04)</td>
<td>6.22</td>
<td>0.01</td>
<td>110.24 (24.05)</td>
<td>102.24 (20.57)</td>
</tr>
<tr>
<td>Executive Function Composite</td>
<td>45.00 (7.01)</td>
<td>50.91 (5.66)</td>
<td>58.46</td>
<td>&lt; .001</td>
<td>48.46 (6.01)</td>
<td>49.15 (6.11)</td>
</tr>
<tr>
<td>Attention Composite</td>
<td>52.44 (7.21)</td>
<td>56.36 (7.33)</td>
<td>12.83</td>
<td>&lt; .01</td>
<td>56.68 (8.62)</td>
<td>58.65 (6.76)</td>
</tr>
<tr>
<td>Memory Composite</td>
<td>44.24 (7.39)</td>
<td>48.62 (8.42)</td>
<td>11.37</td>
<td>&lt; .01</td>
<td>48.39 (8.41)</td>
<td>48.72 (6.34)</td>
</tr>
</tbody>
</table>

Note: **Bold text** indicates significant value
### Table 5: Hierarchical linear regression between cardiovascular fitness and cognitive functioning composite scores

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t</th>
<th>p</th>
<th>ΔR²</th>
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<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
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<tr>
<td>Control Variables</td>
<td>0.66</td>
<td>0.09</td>
<td>0.84</td>
<td>7.25</td>
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<td>0.08</td>
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</tr>
<tr>
<td>Control Variables</td>
<td>-0.04</td>
<td>0.03</td>
<td>-0.17</td>
<td>-1.08</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.99</td>
<td>0.00</td>
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<tr>
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<td></td>
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<tr>
<td>Control Variables</td>
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<td>&lt; .001</td>
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<tr>
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<td>-0.02</td>
<td>-0.15</td>
<td>0.88</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note: Control variables included baseline cognitive functioning, and baseline 2 Minute Step Test Performance
Table 6: Correlations between demographic/medical variables and change on 2MST in the exercise group

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Education</th>
<th>Estimated Intelligence</th>
<th>BMI</th>
<th>Hypertension</th>
<th>Type 2 Diabetes</th>
<th>Physical Activity (RAPA)</th>
<th>Change on 2MST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>--</td>
<td>-0.17</td>
<td>-0.09</td>
<td>-0.32*</td>
<td>-0.23</td>
<td>0.09</td>
<td>0.09</td>
<td>0.13</td>
</tr>
<tr>
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<td>--</td>
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<td>-0.03</td>
<td>-0.13</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Education</td>
<td>--</td>
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<td>-0.05</td>
<td>-0.17</td>
<td>-0.06</td>
<td>0.11</td>
<td>-0.03</td>
<td></td>
</tr>
<tr>
<td>Estimated Intelligence</td>
<td>--</td>
<td>-0.19</td>
<td>0.19</td>
<td>-0.04</td>
<td>0.00</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>--</td>
<td>0.14</td>
<td>-0.02</td>
<td>-0.23</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>--</td>
<td>0.24</td>
<td>-0.02</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2 Diabetes</td>
<td>--</td>
<td></td>
<td></td>
<td>-0.35**</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Activity (RAPA)</td>
<td>--</td>
<td></td>
<td></td>
<td>-0.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change on 2MST</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: **Bold Text** indicates significant correlations
* Significant at $p = 0.05$
**Significant at $p = 0.01$
*** Significant at $p = 0.001$
Appendix A: Recruitment Script

Participant Eligible?_________ (if not, please explain):
If yes, Scheduled? ________________ Date/time
Comments about this participant_________________________________

Subject Name:___________________________________________ Date__________
Phone:____________ email:_____________________________________

Telephone Screening Script
Water Aerobic Exercise and Cognition

Hello, my name is_________________________ and I am calling from the Kent State
Neuropsychology Lab in regards to your interest in the exercise study at Cuyahoga Falls
Natatorium.

You are being contacted because you have responded to an advertisement for a study related to
how exercising impacts your memory and other thinking abilities. If you are still interested, I'll
give you some additional information about the research study and I will also need to ask you a
few questions. The questions are arranged so that if you are not eligible to participate you will be
screened out as we go down the list of questions. This will save your time and avoid any
inconvenience. All information collected and discussed during this conversation will be kept
strictly confidential. It will take about 10 minutes to complete this initial screening. Is this ok to
do now?

YES → Continue
NO → Is there a more convenient time I can call you back? When?_______________

Before we begin, I would like to determine if you are available during times we run the study. We
require participants to come to the Natatorium for three different events over two weeks- the
baseline day, the intervention procedure, and our follow-up meeting. (Exact times and dates will
be inserted after IRB approval). Are you able to attend all of these meetings?

yes_____ no_____

1. First, I need to verify your contact information. (Verify contact info against what we have.)

2. Do you have an alternate telephone number you’d like to be contacted at (such as a cell or
(work/home) phone)?

Alternate contact number:____________________________

Now we need go over your background/health information to see if you qualify for the study and then I will
briefly explain the study to you. Again, all health and personal information will remain confidential.
3. Date of Birth  
Age _____ (must be at least 50 yrs)  
Male                Female

4. Height _____ feet _____ inches

5. Weight _____ lbs

6. BMI _____

7. Do you have, or have you ever had any of the following conditions?
   Sleep Apnea        Yes _____     No ____
   Stroke or Aneurysm Yes _____     No ____
   Epilepsy           Yes _____     No ____
   Brain Injury (except LOC < 5 min) Yes _____     No ____
   Mental illness     Yes _____     No ____

   A recent change in the resting ECG (electrocardiogram) suggesting ischemia, recent myocardial infarction (within 2 days) or other acute cardiac event. (Decreased blood flow to organs, recent heart attack)
   Yes _____     No ____

   Unexplained recurrent chest pain Yes _____     No ____
   Abnormal rhythms or sequence of heartbeats that causes poor blood circulation Yes No _____

   Narrowing or stiffening of the aortic valve Yes _____     No ____

   Symptoms of heart failure including, but limited to, decreased blood flow to organs, swollen legs, shortness of breath)
   Yes _____     No ____

   Blood clot in the lung Yes _____     No ____
   Acute myocarditis (Inflammation of the heart muscle) Yes _____     No ____
   Rupturing of the blood vessel walls Yes _____     No ____
   Acute infections Yes _____     No ____

NO → Continue to 8.
YES → I'm sorry you are not eligible to participate, ____________ condition is part of the exclusion criteria for this particular study. Would you mind if we held onto your name in the event you qualify for a future study?  YES  NO

8. Now I am going to ask you about more medical history. Having one of these conditions does not make you ineligible, but it is unadvisable for you to participate without consulting with your doctor.

   Left main cardiac stenosis Yes _____     No ____
   Heart valve with impaired function Yes _____     No ____
   Electrolyte abnormalities Yes _____     No ____
   Severe arterial hypertension (SBP>200 mmHg and/or DBP > 100 mmHg at rest) Yes _____     No ____

   Fast and/or irregular heart rhythm Yes _____     No ____
   Hypertrophic cardiomyopathy Yes _____     No ____
   Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise Yes _____     No ____
   Pacemaker Yes _____     No ____
   Ventricular aneurysm Yes _____     No ____
   Uncontrolled metabolic diseases (e.g. diabetes, kidney disease) Yes _____     No ____
   Chronic infection (e.g. mononucleosis) Yes _____     No ____
NO → Continue to 9.
YES → To continue participation in this study we would need your physician's approval for you to participate. Would you be willing to seek out his approval? (If yes continue, if no tell them they are no longer eligible)

8. Do you exercise? YES NO
   YES → Continue to 12a/b/c
   NO → Continue to 13 (Female) or 15 (Male).


9. Are you fluent in English?
   YES NO
If yes, which one(s)?: __________________________________________
If no: I'm sorry you are not eligible to participate, fluency in English is part of the criteria for this particular study

From the initial answers you have provided, you are a likely candidate to qualify for the current study. Would you like to hear some additional information about participating in the study?
   YES → Continue to Study Overview
   NO → Thank you for your time

STUDY OVERVIEW

You are being invited to participate in this research study because you are a healthy individual which qualifies you to take part in our exercise regimen. This study will collect information about how our brief exercise protocol affects your memory and other thinking skills.

The study will consist of various study visits. As stated before, your first visit will be your baseline visit where you will be given more information about the study, fill out medical history information and questionnaires, as well as be given a small physical activity device which you will wear on your wrist or clothing. During this visit you will also complete a number of baseline cognitive tests (i.e. memory and concentration) and fitness testing will also be conducted. This entire visit will take approximately 60 minutes. This visit will be completed on (insert time and date after IRB approval).

You will then start your intervention on (insert time and date after IRB approval). You will be asked to attend water aerobics classes during the scheduled intervention week of (insert time and date after IRB approval).

A few days after your last exercise class you will again return to the natatorium to do the cognitive testing again. As before, this should take about 30 minutes and will take place on (insert time and date after IRB approval). During this visit you will also drop off your physical activity device and receive feedback regarding the study.

You will be compensated $100 for completion of the entire study, $10 for the 8 visits, and a $20 bonus for completing all visits.

I will be happy to answer any questions you may have about the study.
Appendix B: Self-report Questionnaires

Medical History Questionnaire (MHQ)

Age:______________

Gender: Male Female

Developmental History
As a child did you have any difficulties with the following?

- Learning to read (dyslexia) Yes_______ No_______
- Learning to spell Yes_______ No_______
- Learning mathematics Yes_______ No_______
- Attention Deficit Disorder Yes_______ No_______

Educational/Occupational History
Years of education:__________________
(12 = completed high school, 13 = freshman in college etc.)

Occupation:____________________________

Retired: Yes No

Medical History
Have you ever had any of the following GENERAL MEDICAL conditions?

- Blood pressure problems Yes_______ No_______
- Heart attack Yes_______ No_______
- Heart Surgery Yes_______ No_______
- Diabetes Yes_______ No_______
- Thyroid problems Yes_______ No_______
- Kidney Problems Yes_______ No_______
- Cancer Yes_______ No_______
- Allergies Yes_______ No_______

If you answered yes to any of the above, please explain. Try to be as descriptive as possible.

________________________________________________________________________
________________________________________________________________________
Have you ever had any of the following NEUROLOGIC conditions?

- Concussion/brain injury
  - Yes ________
  - No ________
- Seizures/epilepsy
  - Yes ________
  - No ________
- Fainting/dizzy spells
  - Yes ________
  - No ________
- Severe or persistent headaches
  - Yes ________
  - No ________
- Brain hemorrhage
  - Yes ________
  - No ________
- Stroke
  - Yes ________
  - No ________
- Brain tumor
  - Yes ________
  - No ________
- Multiple Sclerosis
  - Yes ________
  - No ________
- Sleep Apnea
  - Yes ________
  - No ________

If you answered yes to any of the above, please explain. Try to be as descriptive as possible.

________________________________________________________________________

________________________________________________________________________

Please specify any surgeries (and dates) you have had performed. __________________________

________________________________________________________________________

________________________________________________________________________

**Medications**

Please list current prescription and non-prescription medications and dosages:

<table>
<thead>
<tr>
<th>Name</th>
<th>Dose</th>
<th>Reason and Relevant Side Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Psychological History**

Have you ever been treated or hospitalized for psychological problems? Yes No

If yes, please specify: ________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Have you ever seen a psychologist, psychiatrist, social worker, or counselor? Yes No

If yes, please specify: ________________________________________________________________

________________________________________________________________________
Spot the Word (STW) - Each pair of words below contains 1 real word and 1 fake word. Please circle the word from each pair that you believe is the real word.

<table>
<thead>
<tr>
<th>broxic – oasis</th>
<th>flexipore – viscera</th>
<th>quince – bostry</th>
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</thead>
<tbody>
<tr>
<td>pineapple – strummage</td>
<td>agitect – almond</td>
<td>lignovate – epicene</td>
</tr>
<tr>
<td>mannerism – whitten</td>
<td>tarantula – hostent</td>
<td>gibbon – wonnage</td>
</tr>
<tr>
<td>daffoldil – gomie</td>
<td>treling – rafters</td>
<td>hipple – osprey</td>
</tr>
<tr>
<td>bellissary – cyan</td>
<td>legify – archaico</td>
<td>element – pargler</td>
</tr>
<tr>
<td>vellicle – sampler</td>
<td>obisdian – plassious</td>
<td>viridian – psynoptic</td>
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<tr>
<td>necromancy – ghoumic</td>
<td>restance – zombie</td>
<td>glorvant – onyx</td>
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<td>narwhal – epilair</td>
<td>pimple – brizzler</td>
<td>plankton – whippen</td>
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<tr>
<td>venady – monad</td>
<td>frellid – static</td>
<td>akimbo – periasty</td>
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<td>plargen – savage</td>
<td>hilfren – domain</td>
<td>centaur – tritionial</td>
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<td>cleggar – minim</td>
<td>livid – trasket</td>
<td>vinady – bargain</td>
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<td>knibbet – mandrake</td>
<td>thrash – lisid</td>
<td>prinodal – mango</td>
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<tr>
<td>canticle – gammule</td>
<td>holomator – dross</td>
<td>reticule – flexent</td>
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<td>threnody – epigrot</td>
<td>orifice – serple</td>
<td>frembulous – ontology</td>
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<td>brastome – banshee</td>
<td>phalanx – distrivial</td>
<td>loxeme – legerdemain</td>
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<td>hoyden – clinotide</td>
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<td>aboriginal – hostasis</td>
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<td>archipelago – zampium</td>
<td>clavanome – bestiary</td>
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<td>rouse – choffid</td>
<td>groudy – toga</td>
<td>zando - albatross</td>
</tr>
<tr>
<td>goblet – prely</td>
<td>moxid – tangible</td>
<td>moralist – florrisal</td>
</tr>
</tbody>
</table>
**Rapid Assessment of Physical Activity (RAPA)**

Physical activities are activities where you move and increase your heart rate above its resting rate, whether you do them for pleasure, work, or transportation.

The following questions ask about the amount and intensity of physical activity you usually do. The intensity of the activity is related to the amount of energy you use to do these activities.

Examples of physical activity intensity levels:

- **Light activities** - walking leisurely, stretching, vacuuming or light yard work
- **Moderate activities** - fast walking, aerobics class, strength training, swimming gently
- **Vigorous activities** - stair machine, jogging or running, tennis, racquetball, pickleball or badminton

**How physically active are you?** (Check one answer on each line)

| I rarely or never do any physical activities | Yes ☐ | No ☐ |
| I do some light or moderate physical activities, but not every week | Yes ☐ | No ☐ |
| I do some light physical activity every week | Yes ☐ | No ☐ |
| I do moderate physical activities every week, but less than 30 minutes a day or 5 days a week | Yes ☐ | No ☐ |
| I do vigorous physical activities every week, but less than 20 minutes a day or 3 days a week | Yes ☐ | No ☐ |
| I do 30 minutes or more a day of moderate physical activities, 5 or more days a week | Yes ☐ | No ☐ |
| I do 20 minutes or more a day of vigorous physical activities, 3 or more days a week | Yes ☐ | No ☐ |
| I do activities to increase muscle strength, such as lifting weights or calisthenics, once a week or more | Yes ☐ | No ☐ |
| I do activities to improve flexibility, such as stretching or yoga, once a week or more | Yes ☐ | No ☐ |