THE EFFECT OF EXERCISE ON COGNITIVE FUNCTION AS MEASURED BY IMPACT PROTOCOL: AEROBIC VS. ANAEROBIC

A thesis submitted to the Kent State University College and Graduate School of Education, Health and Human Services in partial fulfillment of the requirements for the Degree of Master of Arts

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The purpose of this investigation was to assess the influence of acute bouts of aerobic versus resistance exercise on cognitive function of college-aged participants as measured by the ImPACT Protocol. Twenty college aged participants (11 females, age = 20.1±0.9; 9 males, age = 20.2± 1.6 yrs) from the Kent State University main campus completed two sessions of being ImPACT tested immediately before, immediately after, and 45 minutes after interventions consisting of either an aerobic exercise session, a resistance exercise session, or seated rest control. Findings indicated significant change in measures of reaction time, impulse control, and visual motor speed across all three groups of participants. No significant change was seen in measures of visual or verbal memory. The results cannot be seen as suggesting that exercise has no effect on cognitive function. Rather, they may suggest a learning effect previously unaccounted for in the ImPACT testing protocol.
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CHAPTER I

INTRODUCTION

Exercise has long been accepted as an intervention to improve physical health and well being or, in the professions of athletic training or physical therapy, to help an injured individual regain physical ability following an injury. This use of exercise has resulted in the diet and exercise industry in the United States to grow into a 100 billion dollar a year venture (Worldmeters.com, 2011).

Recent research has attempted to shift the focus from the physical advantages that result from exercise to explore possible positive effects of exercise on cognitive function. Much of this research has been conducted on the population of Americans that may suffer from cognitive deficits brought on by physical changes in areas of the brain as a result of aging, those sixty years of age or older. The result has been a developing body of research that shows that both aerobic and resistance exercise may have a positive effect on cognitive function in individuals within the groups targeted for participation in the studies (Blumenthal, et al., 1989; Brisswalter, Collardeau, & Rene, 2002; Cassilhas et al. 2007; Colcombe et al., 2003; Colcombe et al., 2004; DiLorenzo et al., 1999; Heyn, Abreu, & Ottenbacher, 2004; McAuley, Kramer, & Colcombe, 2004; Perrig-Chiello, Perrig, Ersham, Staehelin, & Krings 1998; Potempa et al., 1995).

While the focus of that body of research is the aging population, there have been other studies focusing on populations younger than 60 years of age that may suggest that exercise could benefit the cognitive function of those younger than 60 years of age
(Chang & Etnier, 2009). In addition, there have been a few studies that compare the effect of aerobic and resistance exercise that suggest that there is a difference in effect between the two modes of exercise (Penninx et al., 2002; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009).

The authors of one such study that compared the effect of resistance and aerobic exercise on one aspect of cognitive function, namely working memory, made the suggestion that future research should explore the comparison between the two modes of exercise on multiple aspects of cognitive function (Pontifex et al., 2009). Setting this as one goal of the current study the researcher had to select an apparatus that would allow for the testing of effects of exercise on multiple aspects of cognitive function in a way that would be easily administered, easily interpreted, and accessible to the researcher in a cost effective manor. New developments in the treatment and monitoring of sport related head injuries have provided a computer based testing protocol that allows these conditions to be met.

In response to concern over the growing number of incidents of catastrophic head injuries seen in sports there have been multiple position papers and consensus statements from several governing bodies within the world of athletics calling for methods to improve the management and assessment of head injuries (Aubry et al., 2002; Guskiewicz et al., 2004; McCrory et al., 2005; McCrory et al., 2009). A panel led by distinguished scholars in the athletic training field developed a position statement on the management of sports related concussion for the National Athletic Trainers’ Association
In this document, the NATA highly recommends its members and others in the sports medicine professions to implement the outlined practices and procedures to (1) decrease the chances that a head injury will occur and (2) better diagnose and treat athletes who have sustained head injuries (Guskiewicz et al., 2004).

The international sports community has also taken steps in improving diagnosis and care of those with head injuries. The International Ice Hockey Federation (IIHF), The International Olympic Committee (IOC), and the Federation International de Futbol Association (FIFA) organized the First International Symposium on Concussion in Sport in 2001, which was followed by two others in 2004 and 2008.

The first symposium looked to revise and better define concussion and more specifically what signs and symptoms individuals who have suffered concussions might present with or report (Aubry et al., 2002). The second symposium sought to further develop these key ideas since the success of the first symposium brought about a much greater representation of medical personnel and fields yielding a greater depth of input and the development of a wider knowledge base.

The second symposium supported the abandonment of the use of grading scales to diagnose and monitor healing progress in favor of integrated treatment methods using symptom sheets and evaluation protocols that allowed for the evaluation of all of the signs and symptoms the injured athlete may be experiencing. Included in the second symposium report were examples of evaluation sheets and score cards from the SCAT (Sport Concussion Assessment Tool) symptom evaluation protocol (McCrory et al.,
The second symposium also suggested a new classification system for head injuries that would perhaps lead to more proper diagnoses of traumatic head injuries (McCrory et al., 2005). Langlois, Rutland, and Brown point out that a need for better classification and reporting of traumatic head injuries among athletes is necessary. In 2006 the Centers for Disease Control reported that 300,000 sports related head injuries occur yearly. However, the authors point out that this figure only takes into account traumatic head injuries that resulted in a loss of consciousness. They further report that injuries where loss of consciousness occurred could account for as little as 8% to 19.2% of head injuries which extrapolates to as many as 3.1 million sport-related head injuries occur annually (Langlois et al., 2006).

The third symposium sought to further elaborate on the findings of the first two symposiums by refining the measures used to delineate severity of symptoms, and suggesting steps be taken to see how effective current measures in have been in treating sports related concussions (McCrory et al., 2009). The reports from the symposiums as well as the position statement from the NATA agree that the prevention and treatment of sport related head injuries could be improved through the passage and use of rules as well as the development and employment of equipment safety and design standards aimed at keeping the athletes safer while participating (Aubry et al., 2002; Guskiewicz et al., 2004; McCrory et al., 2005; McCrory et al., 2009). Equally important, the third symposium aimed to separate the term “concussion” from the phrase “mild traumatic brain injury”, “because they refer to different injury constructs and should not be used interchangeably”
(McCrory et al., 2009). They defined a concussion as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (McCrory et al., 2009). Mild traumatic brain injury was not defined by the panel at this time. These experts also sought to define simple and complex concussions, identify long term issues that may result from concussions, address issues regarding the most effective return to play protocol for both elite and non-elite athletes, and discuss appropriate testing procedures and return to play protocol for the pediatric athlete (McCrory et al., 2009). In an effort to refine an instrument used to diagnose and monitor symptoms the third symposium introduced the SCAT 2 concussion assessment tool. The panel from this symposium agreed that the future of concussion research should include exploration of the best methods to convey knowledge and information in addition to gathering data related to the effectiveness of changes to rules and equipment standards on the prevention of head injuries (Langlois et al., 2006).

Another important document that has emerged as a result of developing research targeted team physicians. Herring et al., comprised a panel with the mission to adapt a consensus statement similar to that composed by the National Athletic Trainers’ Association that would address the specific needs of team physicians. Acting on behalf of the American Academy of Family Physicians, the American Academy of Orthopaedic Surgeons, the American College of Sports Medicine, the American Medical Society for Sports Medicine, the American Orthopaedic Society for Sports Medicine, and the American Osteopathic Academy of Sports Medicine, the panel sought to give an
overview of the current issues relative to sports related concussions for physicians associated with caring for the physically active. While it is not meant to be a standard operating procedure it does contain many points that are in line with those that came out of the First International Conference on Concussion in Sport and works towards giving physicians a better understanding or awareness of the methods of evaluation and treatment of sport related concussions (Herring et al., 2006).

The effort to better assess the severity of symptoms of athletes with concussions as they progress in their recovery has lead to the development of several computer based neuropsychological testing programs such as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) protocol that was implemented to measure cognitive function in this study (Schatz et al., 2005). With a proven sensitivity of 81.9% and a specificity of 89.4% the ImPACT system is recognized and used by sports health personnel on athletes of all skill levels as a reliable tool in the identification, evaluation, and care of sports related traumatic brain injuries (Schatz et al., 2005).

The main goal of the study is to determine if exercise has an impact on cognitive function as measured by the ImPACT testing protocol in college-aged students. In addition the researcher seeks to add to the body of literature on acute exercise and investigations comparing resistance exercise to aerobic exercise. Use of ImPACT for this study seeks to address suggestions made by previous research on the effect of acute exercise on cognition by including more than one aspect of cognitive function in the investigation. The research will explore the effect of exercise on the outcome of cognitive
function testing on uninjured individuals using the composite scores found on the clinical report of the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) program, a tool commonly used to assess and monitor severity and recovery of sports related concussions. The hypotheses for this study are:

1) Exercise will have a positive effect on the performance on computerized tests of neurocognitive function in uninjured young adults; and,

2) There will be no significant difference between the effects of anaerobic and aerobic exercise on cognitive function as measured by ImPACT following acute bouts of exercise.
CHAPTER II

LITERATURE REVIEW

Effect of Aging on Cognition

The post WWII baby boom has provided the United States with a large population of individuals nearing or in the age range where cognitive deficits are most often seen. The growing number of individuals who suffer from cognitive deficiencies and mental health disorders such as Alzheimer’s, dementia, and Parkinson’s disease has resulted in growing medical costs in this country due to the fact that a large percentage of the aging population rely on programs such as Medicare to cover treatment costs. In 2009, 2.5 trillion dollars were spent on health care in the United States which is an increase of 4.0% over what was spent in 2008 (www.CMS.Gov, 2009). Spending on Medicare, which can be directly associated with medical care for individuals over the age of 60, was 502.3 billion dollars, an increase of 7.9% from the amount spent in 2008 (www.CMS.Gov, 2009). Spending on nursing care facilities and retirement communities grew 3.1% to 137.0 billion dollars in 2009. Medicare spending increased at the same rate as in 2008 and although the increase in spending on care facilities slowed from 5.0 percent to 3.1 percent the amount spent still increased (www.CMS.Gov, 2009). In response to the concern over the health and well being of the aging population and cutting the amount being spent on medical care, a line of research into the effects of aging on the brain has been developed.
Much of the recent research on the role of exercise in the reversal of brain tissue loss or damage has focused on the goal of helping the growing population of individuals aged 60 and over maintain or improve their cognitive function as a means of living a longer, healthier life. Studies into the effects of aging on the human brain have shown a decrease in the tissues of the major memory and cognitive function centers in older individuals (Heyn et al., 2004; Jernigan et al., 2001). Following evidence of reduction in brain size during autopsy studies, Jernigan et al. used Magnetic Resonance Imaging (MRI) on 78 living individuals between the ages of thirty and ninety-nine to explore when the losses started and estimate how much degradation takes place and from which areas of the brain (Jernigan et al., 2001). MRI technology can be used to obtain information on soft tissue injuries that may not be apparent on x-rays. In studies on decreasing brain tissue the MRI observed the presence of increased cerebral spinal fluid which indicated a decrease in brain tissue. Using the presence of increased cerebral spinal fluid in the areas of major cognitive function in the brain the resulting estimates were average tissue losses of 13% from the cerebral cortex, 35% from the hippocampus, and 26% from cerebral white matter in general (Jernigan et al., 2001). It is significant that the hippocampus sees a greater decrease in tissue density because it is most important for memory and an individual’s ability to learn. Several researchers suggest that this loss of tissue is the direct cause of loss of cognitive function and the development of mental diseases such as Alzheimer’s, dementia, Parkinson’s Disease and other forms of cognitive and functional disabilities often associated with older adults.
(Heyn et al., 2004; Sutoo, & Akiyama, 2003; Black, Issacs, Anderson, Alcantara, & Greenough, 1990).

**Effect of Exercise on Cognitive Function**

Using meta-analysis, Heyn and Abreu examined the results from 30 studies that included a total of 2020 participants with moderate or severe cognitive impairment, Alzheimer’s disease, dementia, mixed dementia, cognitive disorders, organic brain disease, or individuals who were mentally impaired older adults, cognitively impaired nursing home residents, or geriatric mental patients (Heyn et al., 2004). The exercise programs ranged from 2 weeks to 112 weeks with an average of 23 weeks. The sessions were held 1 to 6 times a week with an average of 3.6 sessions per week and lasted between 20 and 150 minutes with an average of 45 minutes per session (Heyn et al., 2004). The exercise primarily consisted of walking or another form of aerobic exercise or aerobic exercise combined with resistance exercise. Chair exercises, aerobic dance, strength training, and stationary cycling were the modes of exercise used. The authors conclude that regardless of the form of exercise significant improvements were seen in cognitive function, physical well being, and behavioral characteristics in the populations involved in the studies (Heyn et al., 2004). Their work strongly shows that aerobic exercise can improve cognitive function in the aging population. With potential for greater elasticity in the younger brain cells of college aged individuals there is a strong possibility that testing on that younger age group will yield similar results.
Research on Animal Subjects

Sutoo and Akiyama sought to explore why exercise has such a profound effect on cognitive function. They note that calcium ions affect brain function and that exercise can increase serum calcium levels in the brain. In laboratory mice with a convulsive epileptic disorder they observed that the seizures increased serum calcium. The increased serum calcium reduced the seizure effect and returned the animal to normal cognitive function (Sutoo & Akiyama, 2003). They hypothesized that the increase was due to the involuntary muscle movement the mice experienced during their seizures and that exercise might have a similar effect because of muscle movement involved (Sutoo & Akiyama, 2003). To test this theory, male mice were made to run between 15 and 120 minutes on a motor driven wheel cage at a speed of 20 meters per minute (Sutoo & Akiyama, 2003). Following exercise, the levels of serum calcium and behavior were analyzed. They found a rapid increase of serum calcium levels in the brains of mice that exercised between 15 and 60 minutes of exercise ranging between 7 and 18 % over levels in those that were not exercised. The levels appeared to drop to pre-exercise concentrations after 60 minutes (Sutoo & Akiyama, 2003). Serum calcium is transported to the brain where it can stimulate dopamine synthesis. The increase in dopamine in the brain can lead to behavioral and physiological changes which the authors suggest may be a factor that leads to the improvement in symptoms experienced by those with Parkinsons’ Disease or dementia, which are often caused by a reduced ability to synthesize dopamine in the brain (Black et al., 1990).
In other studies employing animal subjects, researchers used both MRI and surgical techniques to explore what effect exercise might have on the brain. Using groups of laboratory rats, researchers looked for differences in the physical effect of exercise on the brain between groups of rats that were made to run for 10 minutes a day for 30 days and those that had to learn to negotiate a new obstacle course every day for that same period (Black et al., 1990). Thirty-eight ten month old female Evan’s long hooded rats were split into four treatment groups: Inactive condition (IC), acrobatic exercise (AC), forced exercise (FX), and Voluntary exercise (VX) (Black et al., 1990).

The acrobatic exercise group was trained to negotiate progressively longer and longer obstacles courses consisting of balance beams, rope bridges and other obstacles with the help of coercion through offering sweetened or chocolate flavored rat chow until they could negotiate five trials of courses containing seven obstacles (Black et al., 1990). The forced exercise group was made to walk at 10 meters per minute on a motorized treadmill for progressively longer periods of time until they were able to maintain that pace for an hour at a time (Black et al., 1990). The voluntary exercise group had free access to a running wheel attached to their cage. The number of rotations made in the wheel was recorded daily for each rat within that group. By the end of three days each rat had recorded over 200 rotations (Black et al., 1990). Rats in the inactive condition group were kept in individual standard laboratory cages with limited chances for learning or exercise (Black et al., 1990). The IC and VX group were handled for a minute daily to compensate for the minute of handling those in the AC and FX groups received daily (Black et al., 1990). At the end of thirty days of sessions it was found that the VX and
FX groups had higher capillary density within their brain tissues than the other groups. While the AC group did not differ in capillary density they did demonstrate a greater volume of overlying molecular layers per Purkinje cell in the cerebellum (Black et al., 1990). The results showed that running increased the number of capillaries while learning new tasks increased the number of nerve synapses within the cortices that effect learning and motor control (Black et al., 1990). As previously discussed, Sutoo and Akiyama also used rats in their exploration of the effect of serum calcium on brain function. They too found that an increase in serum calcium in the blood stream resulting from exercise leads to the increased efficiency of dopamine synthesis, which has been found to combat symptoms of dementia (Sutoo & Akiyama, 2003).

**Research on Human Subjects**

Research on animals has its purpose but conclusions drawn from studies on animals may not be transferable to human participants. Differences in physiology make it necessary to explore the effect of exercise in a population of human volunteers to see if exercise has similar effects. Though not explored in the same manner due to restrictions in what Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) technology can perceive and ethical considerations to human participants, there have been efforts to expand on the evidence found in animal subjects and discover the effect of exercise on the brain. Contemporary research suggests that the same factors at work in animal studies could be found in humans as well, elaborating on the evidence that exercise can slow or stop the reduction of brain tissue density (Colcombe et al., 2003). Using MRI technology, the researchers obtained scans from 55 participants aged 55 to 79
years old. Participants were excluded if they were under the age of 55, scored lower than 20 on the Mini-Mental State Examination (MME) or had a history of stroke or other brain dysfunction not caused by traumatic brain injuries (Colcombe et al., 2003). The MRI scans were completed before the participants underwent treadmill stress testing using the Rockford 1-mile walk protocol. This order was followed to limit any bias that may have been practiced in reading the MRI if the fitness level was known. The MRI scans were then analyzed for the effect of age on tissue, the effect of fitness (VO₂ score) on tissue density, and the effect of age and exercise (Age x Exercise) on tissue density (Colcombe et al., 2003). The tissue density loss was similar to that found in previous studies in both volume and location in relation to age. Results specific to their study showed that areas of the brain that were most affected by age were also most affected by exercise (Colcombe et al., 2003). This means the areas of the brain that experienced the most tissue loss due to aging also showed the greatest effect of exercise in decreasing tissue loss.

Other similar research demonstrated that aerobic exercise may slow or stop the depletion of brain tissue as well as increase the plasticity of brain tissue in older individuals (Colcombe et al., 2004). This group employed the same cognitive function protocol, the Mini-mental State Examination (MME) and pre-treatment MRI scans, as in the previous exploration led by Colcombe et al. (2004). These were completed one week before a 6-month long exercise intervention and again 1 week after the 6 month intervention. After the baseline MRI and testing participants were placed into either an
aerobic exercise group or a control group (Colcombe et al., 2004). The aerobic exercise consisted of treadmill walking beginning at 40-50% of VO\textsubscript{2} max and increasing gradually to 60-70% of VO\textsubscript{2} max within the session. The length of time on the treadmill started between 10 and 15 minutes per session and was increased by one minute per session until the participants were walking between 40 and 45 minutes per session. This usually occurred within the third month of participation and the length of walking time was maintained for the remainder of the study (Colcombe et al., 2004). The control group consisted of participants following an instructor through a whole body stretching, limbering, and toning exercise program designed for individuals aged 60 and over. Intensity of exercise was increased as the flexibility and ability of the participants to complete the exercise improved (Colcombe et al., 2004). At the end of the six months, the aerobic exercise group showed significant improvements in cardiovascular fitness and a greater level of task-related activity in attention control areas of the brain (Colcombe et al., 2004). In other words those in the control group demonstrated greater brain activity during the posttest, compared to the pretest, in areas that are necessary to focus when asked to perform tasks that required concentration (Colcombe et al., 2004). The changes in activity levels in those areas of the brain in participants in the control group were not as significant (Colcombe et al., 2004). These two studies also saw improvements in symptoms of depression, self-reported sense of well-being, and overall health in participants (Colcombe et al., 2003, Colcombe et al., 2004).

Similar improvements have also been reported in other studies employing both aerobic and resistance forms of exercise (Blumenthal et al., 1989, Brisswalter,
Potempa et al., (1995) used 42 participants randomly assigned to the exercise group or the control group. Participants in the exercise group exercised 30 minutes per session, three times a week, for 10 weeks on an adapted cycle ergometer (Potempa et al., 1995). The control group was taken through passive stretching routines for 30 minutes three times a week for 10 weeks to increase range of motion in their joints (Potempa et al., 1995). Only those that participated in the exercise group showed significant improvement in maximal oxygen consumption, ability to increase exercise duration, and ability to increase intensity of exercise (Potempa et al., 1995). Participants in the exercise group also showed an improvement on sensorimotor tasks that was significantly related to the improvement in aerobic capacity (Potempa et al., 1995). Other researchers found that increases in aerobic capacity have positive effects on both short term and long term effects on psychological outcomes (Di Lorenzo et al., 1999). Using a sample of 111 individuals between the ages of 18 and 39 who were placed into either an aerobic exercise group or a control group the researchers sought to explore the effects of controlled increases in aerobic fitness on psychological outcomes. The aerobic exercise took one of two forms: (1) a 24 minute variable intensity exercise program four times a week for twelve weeks or (2) a 48 minute continuous intensity program four times a week for twelve weeks (Di Lorenzo et al., 1999). Those that participated in either of the exercise groups reported an improved sense of well being, feeling more energetic, and experiencing less symptoms of depression.
Similarly in their study of 101 older men and women taken through either a 4 month aerobic exercise routine, a yoga and flexibility group, or a waiting list control group Blumenthal, et al. found that those that completed the aerobic exercise reported self-perceived improvements on psychological and behavioral measures (Blumenthal et al., 1989).

In their meta-analysis, McAuley, Kramer and Colcombe reviewed the literature current up to 2003 on the topic of the effect of exercise on cognitive function in older adults and likewise concluded that aerobic exercise has a positive effect on cognitive performance and depressive symptomology (McAuley et al, 2004). Furthermore, they point out that exercise programs that combined strength and flexibility exercises saw a greater improvement in these measures then those that only employed aerobic exercise (McAuley et al., 2004). One possible explanation for the increase in cognitive function and decrease in depressive symptoms with exercise is that increased arousal levels immediately following exercise can lead to improved decision making ability and performance as well as an increased ability to focus on target stimuli while ignoring distracters (Brisswalter et al, 2002).

In addition, there have been two studies conducted that sought to compare the effect of resistance exercise to aerobic exercise on cognitive function (Penninx et al., 2002; Pontifex et al., 2009). In their comparison of the effects of resistance and aerobic exercise on emotional and physical function in older persons with high and low depressive symptomology, Pennix et al. sought to examine the effect of exercise on mood and physical well being while distinguishing differences between the effect of aerobic
and resistance forms of exercise, if any existed (Penninx et al., 2002). This extensive study of 439 participants aged 60 and over (mean=68.8) with knee osteoarthritis randomly assigned subjects to either the control group (education), resistance exercise, or aerobic exercise groups (Penninx et al., 2002). Participants’ depressive symptoms were assessed using the Center for Epidemiologic Studies Depression scale at the start of the study and at 3, 9, and 18 months (Penninx et al., 2002). Physical function was also assessed at this time using self-reported disability, a 6-minute walking speed test, and reported knee pain (Penninx et al., 2002). The participants in the control received monthly educational sessions taught by a nurse on issues related to arthritis pain management for the first three months of the study. The participants were then called twice a month during months 4, 5, and 6 and then monthly from months 7 to 18 to be provided additional information and support (Penninx et al., 2002). Those in the aerobic exercise group underwent a three month walking program at a recreational facility under the supervision of an exercise leader three times a week for an hour at a time. Each session consisted of a ten minute stretch and warm-up period before the exercise, 40 minutes of walking at 50-70% of maximal heart rate, and a 10 minute cool down and stretching period (Penninx et al., 2002). From months 4 through 18 the participants were to continue the walking sessions at home. During months 4 through 6 the instructors visited the participants 4 times and called them six times to offer support in developing a home exercise routine. For the remainder of the time phone calls were made every three weeks during months 7 through 9 and monthly during months 10 through 18 (Penninx et al., 2002). Participants signed in prior to the sessions conducted at the recreational
facility but at home they were to keep their own exercise logs (Penninx et al., 2002). The resistance exercise group also participated in a 3 month exercise program lasting one hour per session and consisting of a 10 minute stretch and warm up period, 40 minutes of exercise performing upper and lower body exercises using dumbbells and weight cuffs, and a ten minute stretch and cool down period (Penninx et al., 2002). The participants continued their exercise program using dumbbells and leg cuffs provided by the researchers. Weights were exchanged on the request of the participants. The face to face contacts to exchange the weights or follow up phone calls were made on the same schedule as the aerobic group (Penninx et al., 2002). Due to individuals discontinuing participation, follow up data on depressive symptoms was available on 407 of the 439 participants. Participants in the aerobic group reported significantly lower depression symptom scores over time than those in the control group (Penninx et al., 2002). Those in the resistance exercise group reported a change in symptoms but it was not significantly different from the change reported by the control group (Penninx et al., 2002).

Evidence that aerobic and resistance exercise may vary in how they effect cognitive function is further supported by the work of Pontifex et al. in which a population of undergraduate students participated in either 30 minutes of sub-maximal treadmill running, sub-maximal resistance training consisting of three sets of eight to twelve repetitions of seven different exercises, or sitting for thirty minutes with the option of reading magazines to stay awake (Pontifex et al., 2009). The participants were subjected to tests of working memory before, immediately following, and thirty minutes
after the treatment interventions (Pontifex et al., 2009). Aerobic exercise had a
significant effect on working memory of the participants while no such result was seen in
the resistance exercise group (Pontifex et al, 2009). Again, this suggests that aerobic and
resistance exercise differ in their effect of working memory, but the authors recognize
that working memory is only one aspect of cognitive function and point out that perhaps
the results would be different if other aspects of cognitive function were investigated
(Pontifex et al., 2009).

**Physical and Cognitive Effects of Concussion**

**Physiological Effects**

Cognitive deficits are not isolated to the aging population, nor are older
individuals the only group that can experience a loss of brain tissue density. In a study on
individuals who have suffered sport related concussions, Giza and Hovda discovered that
similar losses of tissue brought on by levels of ischemia due to a disrupted
neurometabolic cascade occur as a result of traumatic brain injuries (Giza & Hovda,
2001). They conducted a meta-analysis of basic science and clinical medical literature
available as of 2001 and found that the primary effects of concussion are due to the
disruption of the pathophysiologic cascade following traumatic brain injuries that could
result in abrupt neuronal depolarization, a release of excitatory neurotransmitters, shifts
of ions in the brain, changes in glucose metabolism, an alteration of cerebral blood flow,
and an impairment of axonal function (Giza & Hovda, 2001). Shaw corroborates this
evidence that the physiology of those who suffer from epileptic disorders and the
symptoms of those suffering from traumatic head injuries are caused by the same
underlying processes of malfunctioning neurometabolic cascades (Shaw, 2002).

However, these studies seem to contradict the suggestion of Sutoo and Akiyama (2003) by pointing out that an increase in calcium, which can last from 2 to 4 days following a traumatic brain injury, can actually lead to an energy crisis in the brain resulting in further damage (Sutoo & Akiyama, 2003). Apart from the disruption of the neurometabolic cascades, there is also a disruption of axonal connections and activity following injury as well as a disruption of normal blood flow to the area (Shaw, 2002). Perhaps physical changes that the brain undergoes as a result of exercise would help to resolve the effects of the disruption of the neurometabolic cascade.

**Observable Signs and Symptoms of Concussion**

The physical effects of concussion often cannot be seen without the use of MRI or PET technology. However, the symptoms can also manifest themselves in ways that sport medicine personnel can observe and document. Common observable signs of a concussion include headache, nausea, and dizziness or balance problems. In addition those who have suffered a head injury may experience nystagmus, ringing in the ears, blurred vision, sensitivity to noise or light, feeling slowed down, and difficulty concentrating or remembering. Those who have suffered concussions may also experience changes in mood or display emotions that are out of character. The injured individual may experience fatigue or low energy, have trouble falling asleep, be more emotional or irritable, or report sadness or being more anxious or nervous. These emotional symptoms are also common in those who have been diagnosed with depression. Symptoms of depression can often be overlooked when treating athletes who
have suffered concussions. They may be dismissed as just having a bad day or feeling out of sorts for the moment but will recover soon. However, athletes who have suffered a concussion might be experiencing depression as a result.

**Tests of Cognitive Function Used to Measure the Effects of Exercise on the Brain**

Several tests and methods of measuring cognitive function have been developed (Benton, 1974; Weschler, 1981; Reitan, 1979; Benton, 1978; Ruff, Evan, & Light, 1986). For the purpose of developing a line of research on the effect of exercise on cognitive function researchers have employed many of these tests to investigate if exercise influenced how the study participants performed on the instrument being used. Given the health status and activity level of most of those in the targeted population of recent research, individuals 60+ years of age, cardiovascular exercise in the form of treadmill walking or jogging protocols are more commonly used in the studies of the effects of exercise on cognitive function (Blumenthal et al., 1989; Brisswalter et al., 2002; Colcombe et al., 2003; Colcombe et al., 2004; DiLorenzo et al., 1999; Heyn et al., 2004; McAuley et al., 2004; Potempa et al., 1995). However, if increased arousal is a factor in improving cognitive functioning, there is a possibility that resistance exercise routines can cause similar excitatory responses and likewise result in improved performances on cognitive function tests.

One concern with prior studies is that when resistance exercise was used it was often in conjunction with an aerobic routine. However, three studies have addressed the effects of resistance exercise alone on varying aspects of the health and well being of
middle aged and older participants. These studies also reported evidence of faster task processing ability, improved free recall and recognition, decreased anxiety, improved self-reported sense of well being, and increased muscle strength in the research participants (Casshilhas et al., 2007; Chang & Etnier, 2009; Perrig-Chiello et al., 1998).

In their study on the effect of resistance exercise on cognitive function in the elderly researchers took 62 volunteers through a control condition, moderate intensity exercise, or high intensity exercise for a 24 week period (Casshilhas et al., 2007). The control group participated in warm up and stretching exercises. The moderate exercise group completed a workout at 50% of their one repetition maximum on exercises using both lower and upper extremities, and the high intensity exercise group completed the same exercises at 80% of their one repetition maximum on those exercises (Casshilhas et al., 2007). Greater gains in lean muscle mass were seen in those in the high intensity exercise group compared to the other two, however, moderate intensity exercise had a stronger impact on mood than the other two groups (Casshilhas et al., 2007). Their study employed several instruments to measure changes in the participants. The Medical Outcomes Study SF-36 questionnaire was used to measure quality of life, the Geriatric Depression scale was used to measure depression, and the Profile of Mood States was used to measure participant state of mood (Casshilhas et al., 2007). Both exercise groups saw an improvement in performance on the measures of cognitive function tested with no significant differences apparent between the two groups (Casshilhas et al., 2007).

The previously noted studies have provided evidence that resistance exercise over time has an effect on cognitive function but the current investigation is looking at the
effect of acute exercise. In addition to studying the effect of acute exercise, Chang and Etnier (2009) also move away from testing elderly subjects and closer to the target age range of this study by using a sample of middle aged adults (Chang & Etnier, 2009). The exercise group completed 2 sets of 10 repetitions on six exercises while the control group read magazines about resistance exercise training for approximately the same period of time (Chang & Etnier, 2009). Immediately before and after the conditions, the participants in both groups were administered the Stroop-Word Color Test and the Trail Making test. The Stroop-Word Color Test is a test of directed attention. There are three levels of the test: I. Quickly choose the word that matches the color with the rectangle on top; II Quickly choose the word that matches the word on top; III Quickly choose the color that matches the color of the word, rather than the color the word names. The Trail Making Test asks the participant to use a pen and paper to connect dots to form patterns and measures how fast it takes to form those patterns (Chang & Etnier, 2009). While no significant change was seen on the trail making test following exercise an improvement was seen in the Stroop Word-Color test (Chang & Etnier, 2009). This displays that resistance exercise can have an acute effect on both higher and lower level cognitive function. There is a version of the Stroop Word-Color task, testing directed attention, included in the ImPACT protocol in which participants are asked to click on the screen only if the word and color of that word match, as in RED. The Trail Making Test is included in the form of participants being asked to remember if a line drawn in a given pattern was shown. With evidence that performance on the Stroop Word-Color test was improved with acute exercise perhaps performance on the Color Matching task found
within the ImPACT test will improve as well showing that resistance exercise can be beneficial to cognitive processes.

In a different population, researchers found that resistance exercise can have significant effect on free recall and recognition in elderly volunteers (Perrig-Chiello et al., 1998). The researchers guided 46 volunteers through either an 8 week exercise program or control condition. Tests of psychological and physical well being, control beliefs, and aspects of memory (free recall, recognition, and psychomotor speed) were administered one week before the start of the exercise routine or rest condition, and one week after the exercise program (Perrig-Chiello et al., 1998).

Free recall and delayed recall were assessed by giving the participants a list of 8 two syllable words. Distractors were added to the list and the participants were asked to remember which words were in the original list. Cognitive speed was assessed using a digit-symbol test aimed at measuring visual-motor coordination, attention, and information processing speed adapted from the WAIS (Perrig-Chiello et al., 1998). Though the gains were modest and not seen on all aspects of cognitive function tested evidence of improved concentration and recall following resistance exercise suggests that this form of exercise can benefit at least some aspects of cognitive function.

A version of this task is found in the ImPACT protocol in which those being tested are shown a list of words for a short time. Then they are shown a second list of words and asked to click ‘yes’ if the word was in the original list and ‘no’ if it was not.

Another study that sought to compare the effect of acute resistance and aerobic exercise on working memory employed a modified Sternberg task in which participants
were asked to pick a single letter from a series of 3, 5, or 7 letters. A version of this task appears in the ImPACT protocol in which those being tested are shown three letters, participate in a distractor task, then are asked to recall the three letters and type them into empty boxes.

**The Current Study**

The goal of the current study is to investigate the effect of resistance exercise and aerobic exercise on the five areas of cognitive function tested by the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) system in an attempt to determine if exercise has a positive effect on cognitive function, as measured by ImPACT, in physically active college students between the ages of 18 and 24. Furthermore, if an effect is seen does it differentiate between the two modes of exercise?

While ImPACT is targeted toward use with those who have suffered concussions the testing will be on non-injured individuals. Exercise has been shown to have a positive effect on aspects of cognitive function in uninjured middle aged volunteers, uninjured individuals between the ages of 18 and 39, and uninjured elderly volunteers suffering from deficits similar to those experienced by athletes who have suffered head injuries as a result of aging. There is the possibility of improved scores on the composites reported within the clinical report on the target population of uninjured college-aged volunteers.
The ImPACT Protocol

The ImPACT test consists of five sections: Demographic Information & Health History Questionnaire, Current Symptoms and Conditions, Neuropsychological Tests, Section Injury Description, and ImPACT Test Scores (About Impact Impacttest.com).

The demographic information and health history questionnaire section requests the athlete's name, age, height, weight, gender, sport, sports position, years of experience in that sport, and injury history to build a descriptive profile of the athlete (Impacttest.com). The current symptoms and conditions section asks the athlete to rank, on a seven point Likert scale, the severity of 22 common concussion symptoms they might be experiencing (Impacttest.com). The section also asks for the date of their most recent concussion, how many hours they slept last night, and if they are taking any medication to treat symptoms of concussion (Impacttest.com).

The third section is the neuropsychological test section which contains six modules: Word Discrimination, Design Memory, X's and O's, Symbol Matching, Color Match, and Three Letter Memory, that seek to test how well the athlete is functioning cognitively (Impacttest.com).

In the Word Discrimination (Figure 1) task the participant is twice shown a list of twelve words, each word for a period of “750 milliseconds”, to facilitate the learning of the words. They are then shown a list of 24 words and are asked to respond ‘yes’ if the word was in the original list and ‘no’ if it was not (Impacttest.com).

The Design Memory (Figure 2) task follows the same format as the Word Discrimination task. A series of 12 patterns, shown for a period of “750 milliseconds”
each, are twice shown to the participant. They are then shown a series of 24 designs and are instructed to click ‘yes’ if the pattern was in the initial series and ‘no’ if the design was not in the initial series (Impacttest.com). The tests are repeated at the end of the ImPACT protocol when the participant is asked to recall the original word and design list and again answer ‘yes’ if the word or design was in the original list and ‘no’ if it was not. Scores for modules 1 and 2 are given as percent correct on the respective tasks (Impacttest.com).
The X’s and O’s module (Figure 3) asks the participant to concentrate on a screen filled with black X’s and O’s shown for 1.5 seconds to remember the position of three X’s or O’s highlighted in yellow (Impacttest.com). They are then asked to complete a distractor task of clicking on the left mouse button if a blue square is shown and clicking on the right mouse button if red circle is shown (Impacttest.com). After the distractor task the participant is asked to click on the location of the yellow X’s and O’s, this time presented in black like the rest of the field (Impacttest.com). This test measures reaction time in the distractor task, number of incorrect clicks in the distractor test, and correct identification of the position of the X’s and O’s (Impacttest.com). The test is repeated four times.

![Example of X’s and O’s Module](image)

*Figure 3: Example of X’s and O’s Module. (Copyright ImPACT Applications, Inc. 2011 Used with permission all rights reserved.)*

In the Symbol Matching Module (Figure 4) the participant is presented with a screen displaying 9 common symbols such as a triangle, cross, or square, etc. Directly under each symbol is a number from 1 to 9 (Impacttest.com). Below this grid, a symbol
is presented. The athlete is required to click the matching number as quickly as possible and to remember which symbol is paired with which symbol (Impacttest.com). Correctly matching the symbol and number results in the correct number appearing in GREEN and incorrectly matching the symbol and number results in the number appearing RED (Impacttest.com). After 27 trials are completed, the symbols disappear from the top grid. The symbols appear below the grid and the athlete is asked to recall the correct symbol to number match by clicking the appropriate number (Impacttest.com). This module scores average reaction time and symbol/number pair memory.

![Image of Design Memory Module](https://impacttest.com)

**Figure 4:** Example of Design Memory Module (Copyright ImPACT Applications, Inc. 2011 Used with permission all rights reserved.)

With the Color Matching task (Figure 5) the participant is initially asked to click a red, blue or green square as they are presented on the screen (Impacttest.com). This is to assure that following trials will not be affected by color blindness. Next, a word is displayed on the screen in the same colored ink as the word, as in RED, or in a different colored in, such as GREEN or BLUE (Impacttest.com). The athlete is instructed to click
in the box as quickly as possible only if the word is written in the matching color. This task provides both a reaction time score and an error score.

*Figure 5:* Example of Color Matching Module practice task. (Copyright ImPACT Applications, Inc. 2011 Used with permission all rights reserved.)

For the Three Letter Memory module (Figure 6) the participant is allowed to practice a distractor task, which consists of 25 numbered buttons in a 5 x 5 grid, before the trials (Impacttest.com) The participant is instructed to click on the numbers in reverse order moving from 25 to 1 as quickly as possible. Following the completion of the distractor practice task the participant is presented with three consonant letters displayed on the screen. Immediately after the three letters are displayed, the numbered grid re-appears and the participant is instructed to click the numbers in reverse order from 25 to 1 as quickly as possible (Impacttest.com). The numbered grid disappears after 18 seconds and the participant is asked to recall the three letters by typing them in order into three empty boxes. Five trials of this test are presented (Impacttest.com). Both the letters displayed and number positions within the grid are randomized for each trial. This module yields a memory score for the number of correctly remembered letters and a
score for the average number of correctly clicked numbers per trial from the distractor test.

*Figure 6:* Example of Three Letter Memory Module distractor task. (Copyright ImPACT Applications, Inc. 2011 Used with permission all rights reserved.)

The trials in each of the modules are combined into composite scores separated into 5 categories: visual memory, verbal memory, visual motor speed, reaction time, and impulse control that are then reported in the clinical report (Figure 7) (Impacttest.com).

*Figure 7:* Sample Clinical Report. (Copyright ImPACT Applications, Inc. 2011 Used with permission all rights reserved.)
Ideally an athlete would be ImPACT tested prior to the start of the season to obtain an individual baseline. Then should they suffer a concussion during the season the symptoms and cognitive ability post-injury could be compared to their baseline scores. Without a baseline examination the post-injury values could be compared to the norms available for their respective age group but this may not reveal true deficits because the athlete’s abilities prior to injury are not known.

**Other Cognitive Tests Considered for Use**

Among the advantages of using the ImPACT computer based protocol are ease of accessibility and administration by the researcher. Other tests of cognitive function were considered but not deemed appropriate for this study. Paper and pencil tests of cognitive function were considered but were not used for various reasons such as difficulty of use, cost effectiveness, time considerations, and the researcher’s qualifications as an interpreter of the measures.

The Revised Visual Retention Test in which subjects are asked to draw a series of geometric shapes after seeing them for 10 seconds was not used because it would only measure one aspect of cognitive function (Benton, 1974). It is included in the modules within the ImPACT test in the form of a recall test in which the subject is shown a series of drawn lines. They are then shown another series and asked if the lines shown appeared in the first series.

The Wechsler Adult Intelligence Scale, WAIS-R (Weschler, 1981) was considered as a method of testing various aspects of cognitive function within the same
testing module. It would have been fairly easy to administer, has reliability (0.96 to 0.98) and validity values that exceed that of the ImPACT protocol, and the researcher would be able to interpret the results of the test to obtain data for the current study (Weschler, 1981). This module was not used because it was cost prohibitive and the testing would take roughly two to three times as long as it takes individuals to complete a session of ImPACT testing.

The Finger Tapping Test and Grip Strength Test found in the Manual for Administration of Neuropsychological Test Batteries for Adults and Children (Reitan, 1979) were considered. However, the material for the Finger Tapping test is no longer in print and, upon further research, the Grip Strength test did not seem to be an appropriate measure of what the current research is hoping to determine.

Similarly, the test of Verbal Fluency contained within the Multilingual Aphasia Examination (Benton & Hamsher, 1978) was rejected as a testing method because it is only part of a series of tests that would examine only one aspect of cognitive function, the use and recognition of language. In addition the researcher would not be qualified to interpret the results of the exam in order to arrive at usable data.

A test of selective attention, Automatic Detection vs. Controlled Search was considered as a measure of the subjects ability to track items amidst distractors (Ruff, Evan & Light, 1986). There is a module that tests this aspect of cognitive function within the ImPACT protocol.
The Need for the Development of ImPACT

As athletes have the tendency to deny or underreport symptoms of concussions, Van Kampen et al. recognize that relying on athletes self reporting symptoms often leads to under diagnosis of concussion (Van Kampen, Lovell, Pardini, Collins, & Fu, 2006). Their research found that only 64% of those diagnosed using only self reported symptoms were diagnosed with a concussion. The percentage improved to 83% when neurocognitive testing was used as the diagnostic tool, and was as high as 93% when self-reported symptoms were combined with neurocognitive testing to reach a diagnosis (Van Kampen et al., 2006). When used in conjunction with the self-reported symptoms neurocognitive testing greatly increases the likelihood of diagnosis of a concussion (Van Kampen, Lovell, Pardini, Collins, & Fu 2006). Those involved with the international symposiums concur that use of a multi-level approach is most effective in the diagnosis and monitoring of concussion symptoms (Aubry et al., 2002; McCrory et al., 2005; McCrory et al., 2009).

The developers of the ImPACT protocol have acted upon this research and developed a reliable method of measuring cognitive function before and after a concussion that is currently in use by professional sports leagues both in the United States and international sporting community such as the NFL, NHL, and FIFA. Use at the collegiate and high school level is gaining popularity and ImPACT is available to the researcher through Kent State University. Though meant for use in measuring the
severity of concussion in injured individuals the tests included in the ImPACT protocol are adapted versions of cognitive function tests that have proven reliable in measuring the cognitive function of healthy individuals.

The current investigation seeks to explore the effect of exercise on the aspects of cognitive function measured by the ImPACT protocol. Participants will undergo four exercise sessions, two during orientation and two during the testing trials. The sessions were conducted as outlined in the methods section in chapter III. The researcher is aiming to focus on a population that has not commonly been used in the current research into the effect of exercise on cognitive function. The ImPACT program was chosen because of strong validity and reliability, ease of administration, aspects of cognitive function tested, length of test sessions, cost, and accessiblility to the researcher.
CHAPTER III

METHODS

Pre-Trial Recruitment

Twenty undergraduate students (11 females, age= 20.1±0.9; 9 males, age= 20.2±1.6 yrs, Table 1) recruited from the Kent State University campus who exercised at least three times a week or participated in one or more intramural sports seasons per year participated in the study. Individuals who had suffered a self-reported concussion within the past 12 months as well as those on intercollegiate sports teams were excluded from participation. Participants were recruited through on campus advertising flyers (Appendix I) posted according to university guidelines in the MACC Annex, MACC, and university Health and Wellness Recreation Center on the main campus of Kent State University.

Day 1 and 2: Orientation

Participants completed an informed consent form acknowledging that they understood the risks and benefits of participation, as well as a PAR-Q (Appendix II) and health screening questionnaire (Appendix III) to screen for previous health issues that may have been aggravated by acute exercise.(Certified Personal Trainer Tool Kit Pg. 3, ACSM.org; Certified Personal Trainer Tool Kit Pg. 4, ACSM.org ) Participants completed the forms on the first orientation day prior to engaging in the treadmill portion of orientation. On day one the target heart rate to be used by the participants in the
Table 1

*Participant Average Fitness Values*

<table>
<thead>
<tr>
<th>Measure</th>
<th>All</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>20</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Age</td>
<td>20.2±1.3</td>
<td>20.2±1.6</td>
<td>20.1±0.9</td>
</tr>
<tr>
<td>Height (in)</td>
<td>66.4±3.1</td>
<td>68.4±1.9</td>
<td>64.7±2.9</td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>145.6±22.1</td>
<td>158±17.6</td>
<td>135±19.7</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td>139.9±1</td>
<td>139.9±1.1</td>
<td>139.8±0.7</td>
</tr>
<tr>
<td>Tricep Press max (lb.)</td>
<td>118.5 ±45</td>
<td>160±27.4</td>
<td>81.7±16.6</td>
</tr>
<tr>
<td>Lat pull max (lb.)</td>
<td>103.5 ±41.7</td>
<td>140±30.8</td>
<td>71±14.5</td>
</tr>
<tr>
<td>Fly max (lb.)</td>
<td>110.9 ±52.1</td>
<td>157.5±37.3</td>
<td>69.4±15.7</td>
</tr>
<tr>
<td>Leg curl max (lb.)</td>
<td>63.8 ±14.7</td>
<td>76.9±8.3</td>
<td>52.2±7.9</td>
</tr>
<tr>
<td>Leg press max (lb.)</td>
<td>142.4 ±56.3</td>
<td>161.3±50.4</td>
<td>125.6±56</td>
</tr>
<tr>
<td>Bicep curl max (lb.)</td>
<td>114.7 ±48.3</td>
<td>160±30.8</td>
<td>74.4±10.7</td>
</tr>
<tr>
<td>Chest press max (lb.)</td>
<td>82.4 ±48</td>
<td>123.8±38.4</td>
<td>45.6±13.4</td>
</tr>
</tbody>
</table>
aerobic exercise was determined using the equation $[220 - \text{(participants age)}] \times 70\%$ (Target Heart Rate and Estimated Maximum Heart Rate, CDC.gov). Once it had been determined, the participants ran or walked on motor driven treadmills for 30 minutes to allow the participant to become accustomed to the use of the treadmills and the intensity of the exercise. The investigator monitored the volunteers’ heart rate using Polar Heart Rate Monitors every minute for the first five minutes and every five minutes after that to ensure that they reached and maintained their target heart rate for the remainder of the treadmill session.

Day two consisted of strength tests to measure the maximal amount the participant was able to lift for one repetition (1-repetition maximum, 1RM) on triceps press down, bicep curls, bench press, latissimus dorsi pulls, chest fly, single leg curl using the dominant leg, and single leg press using the dominant leg using a multi-station gym or resistance exercise equipment (Pontifex et al., 2009). The participants were given a chance to warm up on each exercise by performing a set of an exercise prior to attempting to lift their 1 repetition maximum. The participants were allowed to continue attempting to lift higher resistances until failure. Each attempt was followed by a 60 second rest period and each exercise followed by a 90 second rest period (Pontifex et al., 2009). The participants were allowed to move from one exercise to the next with no set order given by the researcher. The amount lifted on the last successful attempt was recorded as their 1 repetition maximum (1 RM). This process was repeated on each of the exercises until the session was complete. The 1RM values were recorded by the researcher. All measurements were recorded in standard units of pounds.
Following the resistance exercise session during orientation each participant was asked to pick a piece of paper from a closed container that holds an equal number of pieces of paper with either “aerobic”, “anaerobic” or “control” printed on them to determine if they would be in the aerobic, resistance, or control group. After they were placed in a group they scheduled an initial trial session in time slots pre-determined by the researcher.

The first trial session was conducted at least 48 hours after the second day of orientation to allow for proper recovery from the initial evaluations. There was also at least one recovery day between each of the testing sessions. Participants were instructed not to perform any formal exercise activities on the days between the sessions. Participants were ImPACT tested before the exercise session on the days of the trials to determine a baseline reading immediately before they exercised. The volunteers participated in two trials in an attempt to minimize any possible learning effect that may have influenced the post-exercise results on day one.

As previously stated, with a proven sensitivity of 81.9% and a specificity of 89.4% the ImPACT system is recognized and used by sports health personnel on athletes of all skill levels as a reliable tool in the identification, evaluation, and care of sports related traumatic brain injuries (Colcombe et al., 2003). ImPACT testing consists of the participant completing tests in verbal memory, visual memory, visual motor speed, reaction time, and impulse control on a computer with the results to be stored in a data base that is accessible by the principle investigator using a password and username combination setup through the ImPACT Corporation. There are multiple trials of the
same tasks within certain tests. These trials result in composite scores reported on the clinical report. Testing took place in a quiet, comfortable room with steps being taken to minimize distractions and outside influences. If two individuals were testing at the same time then they were stationed with at least one computer between them or the screens were facing in opposite directions. Each participant was allowed to take as long as they need to complete the sessions. The ImPACT test typically took between 20 and 25 minutes. Some personal information such as name and age was required and used solely for the purpose of compiling the scores from each ImPACT testing session for comparison.

Conducting the Trials

Most portions of the study, with the exception of the resistance exercise sessions, were conducted in the competency laboratories and lobby of the Athletic Training Education Program, or a university computer lab in the Gym Annex on the main Campus of Kent State University.

Once the participants were placed in their group the first test day was scheduled. The sessions were scheduled to take into consideration the class and work schedules of the volunteers. While the goal was to have them rest at least one day between the orientation sessions and the testing sessions there were at times as many as three days in between. One individual developed an unrelated upper respiratory infection between the orientation sessions and the trials. He received medical attention on his own merit, was allowed to regain health, and restarted participation in the study.
Regardless of the group placement all participants reported to the competency laboratory for the start of their trials. They were tested on ImPACT using computers provided by Kent State University for general use among athletic training and exercise science majors. The sessions were scheduled at times that would provide the lowest possibility for outside distractions and the investigator made every attempt to control for those distractions and provide a quiet comfortable testing environment. Signs were conspicuously placed to notify others that might be in the department of the ImPACT testing and the investigator was present to monitor the activity around the testing area.

**Resistance group.** Following the baseline ImPACT tests those in the resistance group were led to the faculty weight room where the one repetition maximum (1 RM) tests were conducted. The exercises were conducted at 80% of their 1 repetition maximums on the same machines at the same settings that were used during the orientation session. They were given a 60 second rest period in between sets and a 90 second rest period in between exercises (Pontifex et al., 2009). It was not essential to keep the participants separate during the exercise sessions but the numbers were kept to small groups of two or three participants so the investigator could monitor the rest periods and facilitate the transition between exercises. The walk back from the weight room took two minutes. The participants were to use that time to recover from the exercise session and ready themselves to test on ImPACT again.

Following the resistance exercise session the participants and investigator returned to the computer used for the baseline test. The participants completed another ImPACT test and were given a 15 minute rest period as timed by the investigator.
Following that time period the participant returned to the computer for the final ImPACT
test of the trial that day. When that test was done the trial was completed for the day and
the participants were asked to schedule the next session or thanked for participating and
given a t-shirt if they had completed the second trial day.

One participant in the resistance exercise group had to repeat the second trial due
to a computer error that occurred at the end of the third ImPACT test of trial two. At the
end of each ImPACT test the data from the test is saved to the ImPACT website data
base. An error occurred resulting in the data from the third test of trial two to not save
and to not be retrievable by the investigator for use in the data set. The error was
explained to the participant and it was explained that in order to use her data in the study
the second trial would have to be repeated. The participant was given the opportunity to
accept or decline repeating the session. They agreed to repeat the trial and promptly
scheduled for the next available testing date.

**Aerobic exercise group.** Those in the aerobic exercise session were fitted with a
Polar heart rate monitor and taken to the room with the treadmill. The participants started
walking on the treadmill while the investigator increased the speed and adjusted the
incline between 0.0 and 1.0 percent to the settings where the target heart rates were
reached and maintained during the orientation session. The heart rate was monitored
every minute for the first five minutes and every five minutes after that for the remainder
of the exercise to reach and maintain the target heart rate as determined by the equation

\[
[(220 - \text{participants age})] \times 0.70 \text{ (CDC.gov).}
\]

After 30 minutes of walking or running the
speed of the treadmill was decreased to two miles an hour and the participants were allowed to walk at that speed for 1 minute.

At the end of that minute the treadmill was slowed by another one mile per hour and the participant walked for another minute to complete a two minute cool down period. Following the treadmill exercise the participants were lead back to the computer for another ImPACT session. Following that ImPACT test the participants were given a 15 minute rest period, timed by the investigator. After the rest period the participants were lead back to the computer for the third and final ImPACT test of the trial. Following the third ImPACT test the participants were either asked to schedule for the second trial date and time or thanked for their participation and given a t-shirt for their effort if they had completed the second trial.

**Rest group.** Participants in the rest group completed a baseline ImPACT test then were taken to the lobby of the athletic training education offices. They were required to sit in silence for thirty minutes. Magazines were provided for reading to allow all individuals access to the same material but they were also allowed to read books they had brought. They were not allowed to talk to other participants, sleep, get up and walk around, or study text books. Following the 30 minute period, as timed by the investigator, the participants were taken back to the same computers on which they were previously tested and completed another ImPACT test. Following the third ImPACT test of the session the participants were either asked to schedule for the second trial date and time or thanked for their participation and given a t-shirt for their time and effort if they had completed the second trial.
Data Collection

The participants completed two rounds of testing that included three ImPACT test sessions per day (Table 2). The resulting composite scores were gathered after each day and added to the participants profile in the data base on the ImPACT website. The records were kept anonymous and referred to by numbers assigned to each participant.

Table 2

Example Trial Schedule

<table>
<thead>
<tr>
<th>Participant 1</th>
<th>Day One</th>
<th>Day Two</th>
<th>Day Three</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test on ImPACT</td>
<td>Rest</td>
<td>Test on ImPACT</td>
</tr>
<tr>
<td></td>
<td>Exercise</td>
<td>Exercise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test on ImPACT</td>
<td>Test on ImPACT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wait 15 minutes after</td>
<td>Wait 15 minutes after</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ImPact test (total of</td>
<td>ImPact test (total of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45 min. Post Exercise)</td>
<td>45 min. Post Exercise)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ImPACT Test</td>
<td>ImPACT Test</td>
<td></td>
</tr>
</tbody>
</table>
Stastical Analysis

One way analyses of variance (ANOVA) were used to compare participant characteristics (age, height, weight) between the three intervention groups (control, aerobic exercise, resistance-training exercise). Two day (day 1, day 2) by three time point (pre-intervention, immediately post-intervention, 45 minutes post-intervention) by three intervention group ANOVAs with repeated measures on day and time point were conducted to examine differences in: reaction time, impulse control, visual memory, verbal memory and visual motor speed. Post-hoc analyses were performed on any significant main or interaction effects using independent and paired-samples T-tests. A-priori significance was set at $\alpha \leq 0.05$ and all analyses were performed using SPSS (version 17.0, SPSS Inc, Evanston, IL).
CHAPTER IV

RESULTS

Participant Characteristics

Participant characteristics are shown in Table 3. The aerobic groups average (p=0.07) weight (166±16.8) demonstrated the trend of being greater (p=0.07) than the control (153.9±19) or resistance group (130±16.1). There was no significant difference (p=0.18) in average height or age between the study groups.

Table 3

*Participant Average Demographics and Fitness Values*

<table>
<thead>
<tr>
<th>Measure</th>
<th>All</th>
<th>Resistance</th>
<th>Aerobic</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>20</td>
<td>9</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Age</td>
<td>20.2±1.3</td>
<td>19.7±0.9</td>
<td>21.3±1.1</td>
<td>20.1±1.5</td>
</tr>
<tr>
<td>Height (in)</td>
<td>66.4±3.1</td>
<td>65.2±3</td>
<td>66.8±4.3</td>
<td>67.7±1.5</td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>145.6±22.1</td>
<td>130±15.1</td>
<td>166±14.6</td>
<td>153.9±19</td>
</tr>
</tbody>
</table>

Reaction Time

There was a significant main effect (p=0.008) of time for reaction time (Figure 8, Table 4). Post-hoc analysis revealed that reaction time was significantly faster 45 minutes post-intervention (0.52±0.05 seconds) than pre-intervention (0.54±0.04). There were no additional significant (p≥0.09) main or interaction effects for day or intervention
Figure 8: Change in Average Reaction Time Composite Scores as a function of time (baseline, post exercise, 45 minutes post exercise) over the two days of the study.

Table 4

Average Reaction Time Composite Scores (Seconds) Over Time

<table>
<thead>
<tr>
<th></th>
<th>Pre intervention</th>
<th>Immediately Post Intervention</th>
<th>45 minutes post intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time Scores (seconds)</td>
<td>0.54±0.04</td>
<td>0.53±0.05</td>
<td>0.52±0.05</td>
</tr>
</tbody>
</table>
group. The average scores for the three groups for the three test sessions on each day are in Table 5.

Table 5

*Average Reaction Time Composite Scores by Group for Trial Days 1 and 2*

<table>
<thead>
<tr>
<th>Reaction Time Composite</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
</tr>
<tr>
<td>Resistance</td>
<td>0.55±0.05</td>
<td>0.52±0.03</td>
</tr>
<tr>
<td>Aerobic</td>
<td>0.49±0.19</td>
<td>0.47±0.18</td>
</tr>
<tr>
<td>Control</td>
<td>0.56±0.06</td>
<td>0.56±0.07</td>
</tr>
</tbody>
</table>

**Impulse Control**

There was a significant main effect (p=0.008) of time for impulse control. Post hoc analysis revealed impulse control composite scores were significantly lower pre-intervention (5.5±3.1) than they were immediately post-intervention (6.3±3.9), or 45 minutes post-intervention (6.2±3.9) (Figure 9, Table 6).

In addition there was a main effect of day (p=0.04) for measures of impulse control (Figure 10, Table 7). Impulse control measures were greater during day two (6.8±4.6) than day one (5.18±3). There were no additional main or interaction effects (p≥0.103) for intervention group (Table 8).
Figure 9: Change in Impulse Control Composite Scores as a function of time (baseline, post exercise, 45 minutes post exercise) over the two days of the study.

Table 6

<table>
<thead>
<tr>
<th>Time</th>
<th>Average Impulse Composite Scores for All Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre intervention</td>
<td>5.5±3.1</td>
</tr>
<tr>
<td>Immediately Post intervention</td>
<td>6.3±3.9</td>
</tr>
<tr>
<td>45 minutes post intervention</td>
<td>6.2±3.9</td>
</tr>
</tbody>
</table>
Comparison of Average Impulse Control Composite Scores

Figure 10: Bar graph of average impulse control on day one versus day two.

Table 7

Average of Impulse Control Composite Scores for Trial Days 1 and 2

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.18±3</td>
<td>6.8±4.6</td>
</tr>
</tbody>
</table>

Table 8

Average Impulse Control Composite Scores by Group for Days 1 and 2 of the Trials

<table>
<thead>
<tr>
<th>Impulse Control Composite</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
</tr>
<tr>
<td>Resistance</td>
<td>5.4±2.9</td>
<td>6.4±4.7</td>
</tr>
<tr>
<td>Aerobic</td>
<td>5±2.1</td>
<td>5.5±1.7</td>
</tr>
<tr>
<td>Control</td>
<td>3.9±3.7</td>
<td>4.1±1.9</td>
</tr>
</tbody>
</table>
Visual Motor Composite

There was a significant main effect (p=0.03) of time (Figure 11, Table 9). The average scores were significantly higher immediately post-intervention (44.3±8.9) and 45 minutes post intervention (44.6±8.5) than pre-intervention scores (42.9±8.8) There were no additional main or interaction effects (p≥0.12) for time or intervention group.

The averages for the three groups for the three test sessions on each day are in Table 10.

---

**Table 9**

*Average Visual Motor Speed Composite Scores (% correct) Across Time.*

<table>
<thead>
<tr>
<th>Time</th>
<th>Pre-intervention</th>
<th>Immediately post intervention</th>
<th>45 minutes post intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42.9±8.8</td>
<td>44.3±8.9</td>
<td>44.6±8.5</td>
</tr>
</tbody>
</table>

*Figure 11*: Change in Average Visual Motor Speed Composite Scores as a function of time (baseline, post intervention, 45 minutes post intervention) over the two days of the study.
Table 10

*Average Visual Motor Composite Scores by Group for Trial Days 1 and 2*

<table>
<thead>
<tr>
<th>Visual Motor Composite</th>
<th>Day 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
<td>45 minutes post intervention</td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
<td>45 minutes post intervention</td>
</tr>
<tr>
<td>Resistance</td>
<td>43.3 ± 2.8</td>
<td>46.2 ± 3.9</td>
<td>46.7 ± 3.00</td>
<td>45.3 ± 5.3</td>
<td>47.5 ± 3.7</td>
<td>46.2 ± 4.8</td>
</tr>
<tr>
<td>Aerobic</td>
<td>36.1 ± 19.9</td>
<td>36.7 ± 18.7</td>
<td>35.5 ± 17.8</td>
<td>37.2 ± 18.8</td>
<td>37 ± 18.7</td>
<td>37.5 ± 19.8</td>
</tr>
<tr>
<td>Control</td>
<td>39.6 ± 5.7</td>
<td>41.3 ± 6.7</td>
<td>42.4 ± 8</td>
<td>42.9 ± 7.6</td>
<td>43.5 ± 6.9</td>
<td>45.6 ± 4.1</td>
</tr>
</tbody>
</table>

**Verbal Memory and Visual Memory Composites**

There were no significant effects seen on either the verbal memory (p=.198) or visual memory (p=0.08) composites. The averages for the three groups for the three test sessions on each day are in Table 11 for visual memory and Table 12 for verbal memory.

Table 11

*Average Verbal Memory Composite Scores by Group for Trial Days 1 and 2*

<table>
<thead>
<tr>
<th>Verbal Memory Composite</th>
<th>Day 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
<td>45 minutes post intervention</td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
<td>45 minutes post intervention</td>
</tr>
<tr>
<td>Resistance</td>
<td>91.2 ± 7.7</td>
<td>88.2 ± 8.7</td>
<td>90.4 ± 11</td>
<td>92.6 ± 6.8</td>
<td>90.3 ± 5.3</td>
<td>89 ± 6.9</td>
</tr>
<tr>
<td>Aerobic</td>
<td>88.5 ± 9</td>
<td>89 ± 9.8</td>
<td>87 ± 8.9</td>
<td>92.8 ± 3.1</td>
<td>86.8 ± 5.7</td>
<td>79.8 ± 18.9</td>
</tr>
<tr>
<td>Control</td>
<td>392.3 ± 6.4</td>
<td>92 ± 9.2</td>
<td>89.9 ± 8.4</td>
<td>95.6 ± 7.2</td>
<td>91.9 ± 11.5</td>
<td>96 ± 3.6</td>
</tr>
</tbody>
</table>
Table 12

**Average Visual Memory Composite Scores by Group for Trial Days 1 and 2**

<table>
<thead>
<tr>
<th>Visual Memory Composite</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre intervention</td>
<td>Immediately post intervention</td>
</tr>
<tr>
<td>Resistance</td>
<td>76±9.9</td>
<td>69±4–18.3</td>
</tr>
<tr>
<td>Aerobic</td>
<td>79±13.1</td>
<td>84±7.7</td>
</tr>
<tr>
<td>Control</td>
<td>79.4±11.2</td>
<td>78.4±11.2</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION

The findings of the current investigation show significant within subjects differences between ImPACT testing sessions on measures of reaction time, visual motor speed, and impulse control. There were no significant differences found on the other two composite scores, visual memory and verbal memory, reported on the clinical reports.

A previous study employing similar exercise routines, but testing only working memory, showed that aerobic exercise improved reaction time on tasks of working memory while no such effect was seen in those that underwent a resistance exercise routine (Pontifex et al., 2009). Those findings are paralleled here in that reaction time improved following aerobic exercise. However the change in performance on the reaction time composite, as well as the visual motor speed and impulse control composites, may be the result of a learning effect as there was no significant difference in improvement between the exercise groups or the exercise groups and the rest group. The producers of ImPACT suggest that there was no observable learning effect in repeated testing over a short period of time (Schatz et al., 2005). However, the study that derived this conclusion tested the participants at once per day at 36 hours, four, and seven days after initial testing if in the uninjured group or after suffering a head injury if in the injured group (Schatz et al., 2005) In the current study the participants underwent six tests in a period of two days with at least one day, and no more than three, between
testing sessions. It is possible that multiple tests over a shorter period of time would amplify a learning effect that was not evident in previous studies. The fact that the learning effect expressed itself over two days of testing would argue that daily testing using ImPACT as a way of monitoring signs and symptoms of concussion is inappropriate and perhaps the 36 hour, 4 and 7 day spacing used by the developers is most appropriate.

This is the first known study to use ImPACT to investigate the effect of exercise on healthy individuals. Though the ImPACT protocol itself is meant to be used to diagnose and monitor symptoms of concussion, tests within the battery have been individually, or in combination, used to demonstrate the effect of exercise on the brain. In the study that established the sensitivity and specificity of ImPACT a group of athletes with head injuries and a group of uninjured athletes were used to determine that ImPACT was capable of differentiating between the injured and uninjured athletes (Schatz et al., 2005).

A main goal of this study was to add to the body of literature on acute exercise and investigations comparing resistance exercise to aerobic exercise. Use of ImPACT for this study sought to address suggestions made by previous researchers that future research on the effect of acute exercise on cognition should be expanded to include more than one aspect of cognitive function in the investigation.

A limitation of the study was the lack of balance between the number of volunteers in the resistance and aerobic group. The method used to randomly assign participant groups resulted in a greater number of individuals being in the resistance
group than in the aerobic group. A possible solution for this would have been to wait until all volunteers had signed up to start orientation then use a different method to assign and match groups but that would have been extremely unrealistic to accomplish. While there were times when several volunteers signed up at the same time there long periods where no new individuals contacted the researcher. To postpone the participation of those who had agreed to participate until a larger group was assembled could have been a frustrating factor that may have lead to more attrition than what occurred. In addition, the limited number of researchers would have made it quite cumbersome to attempt to conduct trials on a larger group of individuals. The difference in group size may prohibit the results from being generalized to a larger population.

Despite many studies, numerous articles, and position papers (Aubry et al., 2002; Byard & Vink, 2009; Covassin, Swanwik & Sachs, 2003; Guskiewicz et al., 2005; Herring et al., 2006; Langlois et al., 2006; McCrory et al., 2005; McCrory et al., 2009) that have led to improvements in the methods of detecting signs and symptoms of head injuries there seems to be little thought to the potential of incorporating rehabilitation exercise into the treatment of concussions as a means of restoring brain health. With evidence suggesting that such interventions may be beneficial, a move toward exploring the benefits of exercise on individuals recovering from head injuries should be made. Callaghan (2004), a noted nurse and PhD. with City University in Philpot England, argues that there should be more consideration into the possibility of incorporating exercise regimens in the treatment for some mental disorders. With evidence that those who have suffered concussions may experience early onset of cognitive deficits (Langlois
et al., 2006), exercise may be seen as an intervention that could be utilized to reduce the impact of the head injury and decrease the chances of subsequent cognitive deficits. To address this, another direction for future research would be to test the effect of exercise on populations of those who have suffered head injuries to investigate if exercise has an effect on the rate at which they improve in areas of cognitive function measured by the ImPACT test battery. Further investigation narrowing the focus to specifically test the effect of different modes of acute exercise on each aspect of cognitive function would also prove beneficial in adding to the body of literature on the effects of acute exercise on cognition. This study focused on the effect of acute exercise but future research may benefit from examining the effects of sustained exercise regimens on the outcome of ImPACT testing in either injured or uninjured populations. In addition to receiving potentially greater benefit from sustained exercise, increasing the time between the ImPACT testing sessions may result in a decreased learning effect.

In summary, improvements in cognitive performance occurred on three out of five composite scores measured by the ImPACT test battery. Improvement on two of those composite scores, reaction time and visual motor control, may be attributed to a learning effect as there was no significant difference in the effect between groups. There was also no significant difference in effect between the groups on the third measure, impulse control, again suggesting that a change in performance on that composite was influenced more by a learning effect than changes brought on by exercise.

While it is unknown at this time what aspect of the physiological effect of exercise on the brain caused the discrepancy between the performances the results would
suggest that resistance exercise could play a beneficial role in improving performance on tests of cognitive function in healthy individuals. Furthermore, this may provide a basis to explore the idea that both resistance and aerobic exercise may be beneficial for the recovery of those who have suffered sports related concussions.
APPENDICES
APPENDIX I

RECRUITMENT POSTER
Sure exercise is good for your body, but can it help your brain too? Is Running better for your brain than Lifting Weights?

If you would like to help find the answers to these questions here is your opportunity! We are looking for undergraduate students who exercise at least three times a week and or play at least one intramural sport to participate in a study on the effects of exercise on the brain immediately following either running, resistance exercise. If Interested please email Jbrutvan@kent.edu for more information.
APPENDIX II

PARTICIPANT ACTIVITY READINESS QUESTIONNAIRE
PAR-Q & YOU
APPENDIX II

PARTICIPANT ACTIVITY READINESS QUESTIONNAIRE

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly. Check YES or NO.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td></td>
</tr>
<tr>
<td>2. Do you feel pain in your chest when you do physical activity?</td>
<td></td>
</tr>
<tr>
<td>3. In the past month, have you had chest pain when you were not doing physical activity?</td>
<td></td>
</tr>
<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td></td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?</td>
<td></td>
</tr>
<tr>
<td>6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?</td>
<td></td>
</tr>
<tr>
<td>7. Do you know of any other reason why you should not do physical activity?</td>
<td></td>
</tr>
</tbody>
</table>

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal.

Tell your doctor about the PAR-Q and which questions you answered YES.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Delay Becoming Much More Active:

- If you are not feeling well because of a temporary illness such as a cold or the flu — rest until you feel better; or
- If you are or may be pregnant — talk to your doctor before you start becoming more active.

Please Note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name

Signature

Date

Registrar of Parent or Guardian (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...
APPENDIX III

HEALTH QUESTIONNAIRE
APPENDIX III

HEALTH QUESTIONNAIRE

Name_________________________________________ Date________________
Height_________________ Weight_________________

Address________________________________________________________________________

Gender______ Birthday____________

E-mail________________________________________

Telephone (W)_______________________ Telephone (H)_______________________

Regular physical activity is fun and healthy and for most people safe. However, some individuals may have health-related risks that might require them to check with their physician prior to starting an exercise program. To help determine if there is a need for you to see your physician before starting an exercise program, please read the following questions and answer carefully.

All information will be kept in the strictest confidentiality. In addition to the health history questions, we have also listed several questions pertaining to your interests and goals for participating in an exercise/physical activity program.

I. PHYSICAL ACTIVITY SCREENING QUESTIONS

Yes No

1. Have you suffered a head injury in the past twelve months? Yes_____ No_____

2. Has your physician ever told you that you have a heart condition? Yes_____ No_____

3. Do you experience pain in your chest when you are physically active? Yes_____ No_____

4. In the past month, have you experienced chest pain when not performing physical activity? Yes_____ No_____
5. Do you lose balance because of dizziness or do you ever lose consciousness?  
   Yes____   No_____  

6. Do you have a bone or joint problem that could be aggravated by a change in your level of physical activity? Yes______ No______  

7. Is your physician currently prescribing medications for your blood pressure or heart condition? Yes_____ No_____  

8. Do you know of any other reason why you should not participate in a program of physical activity? Yes_____ No_____  

If you answered yes to any of the above questions, it is recommended that you consult with your physician via phone or in person before having a fitness test or participating in a physical activity program.  

II. GENERAL HEALTH HISTORY QUESTIONS  

Yes No  

1. Have you ever experienced a stroke? Yes_____ No_____  

2. Do you have diabetes? If yes, are you currently taking any medications or receiving other treatment related to the diabetes? Yes______ No_____  

3. Do you have asthma or another respiratory condition that causes difficulty with breathing?  
   If yes, please describe. Yes_____ No_____  
   If Yes:  
   __________________________________________________________  
   __________________________________________________________  
   __________________________________________________________  

4. Do you have any orthopedic conditions that would restrict you in performing physical activity? If yes, please describe. Yes_____ No_____  

5. Have you ever been told by a physician that you have one of the following? (check Applicable boxes) High blood pressure______ .  
   Elevated blood lipids including cholesterol ________
6. Do you currently smoke? Yes_____ No_____

7. Have you experienced within the past 6 months back pain or discomfort that prevented you from carrying out normal daily activities? Yes_____ No_____

8. Are you pregnant? Yes_____ No_____

9. Do you currently exercise less than one hour per week? If you answered no, please describe your activities: Yes_____ No_____ if No:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

10. Are you currently taking any medications that might impact your ability to safely perform physical activity? Yes_____ No_____
REFERENCES


Chang, Y. & Etnier; J. (2009) Effects of an Acute Bout of Localized Resistance Exercise on Cognitive Performance in Middle-aged Adults: A Randomized Controlled Trial Study. Psychology of Sport and Exercise, 10:19-24


