The Effects of Moderate Exercise on Cognitive, Cervical, and Vestibulo-ocular Functioning in

Healthy Individuals: A Pilot Study

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Abstracts

While cognitive and physical rest have long been the protocol that most physicians have recommended for concussions, there has been an increase in interest with regards to the prescription of low intensity symptom-limited aerobic exercise in this population. This highlights a gap in the research examining the impact of moderate intensity aerobic exercise as well as cervical strengthening in healthy controls to serve as a baseline for future testing. The purpose of this research was to examine the impact of three separate 6-week supervised and individualized exercise programs when compared to a control group on cognitive and cervical functioning in a sample of 18-35 year old healthy individuals. The four programs were composed of 40 participants who were divided equally amongst the following groups; control group, a moderate intensity aerobic group, cervical strengthening group, and a vestibulo-ocular training group. The participant's cognitive, cervical, and vestibulo-ocular functioning was assessed pre- and post-treatment. Depending on the assigned groups, participants either continued their daily living (control group) or participated in progressive aerobic cycling sessions (aerobic group), progressive cervical strengthening sessions (cervical group), or progressive vestibulo-ocular retraining sessions (vestibulo-ocular group) three times a week for 6-weeks. Analysis was conducted using a mixed MANOVA and further analyzed with a repeated measures paired t-test and two mixed factorial ANOVAs, with a rejection criteria set at a level of $p<.05$.

When looking at the main effects, the discriminant analysis revealed a statistically significant difference across time for all ImPACT® test battery scores, $F(3, 36)=2908.1$, $p=.00001$, Wilks' $\Lambda=.003$, $\eta_p^2=.997$. There was a statistically significant main effect of time Chin Tuck Head Lift Test (CTHLT) scores, $F(3, 36)=6.639$, $p=.014$, Wilks' $\Lambda=.844$, $\eta_p^2=.156$.

The findings in the current study can serve as baseline and foundational research and are clinically relevant as they may suggest that individualized exercise programs do not adversely affect healthy controls, but rather help to maintain or even improve current levels of cognitive and cervical functioning.

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Abbreviations

ANS: autonomic nervous system
ATP: adenosine triphosphate
CBF: cerebral blood flow
CCFT: craniocervical flexion test
CROM: cervical range of motion instrument
CTHLT: chin tuck head lift test
ImPACT®: immediate post-concussion assessment and cognitive testing tool
MACV: moderate intensity aerobic, cervical strengthening, and vestibulo-ocular training exercise
PCS: persistent concussion symptoms
SRC: sports related concussion
TBI: traumatic brain injury
VOMS: vestibular ocular motor screening test
VOR: vestibulo-ocular reflex

Chapter 1 – Introduction

Concussions are a multifaceted injury resulting from a variety of sources, which may lead to an intricate challenge for healthcare professionals to assess and manage. Each concussion is as unique and distinctive as the person it affects; therefore, no two concussions present in the same manner, although they may be similar. With this in mind, there has been rising healthcare, government, and media attention with regards to concussions among individuals as young as infants and up to the geriatric population. The injury can be further complicated as it does not discriminate against age, race, or gender. Although there has been an increase in the awareness directed towards this area of research, there are still noteworthy gaps in the literature in regards to prevalence, diagnosis, management, and rehabilitation. This body of literature continues to grow as new research is conducted, aiding healthcare professionals in the management of these patients.

A concussion transpires when the brain is exposed to either linear or rotational acceleration-deceleration due to impact forces, a blast injury, or to a pressure wave great enough to disrupt brain function (Riggio & Jagoda, 2016). To summarize this statement, a concussion refers to a brain injury that has briefly interrupted the brain's connectivity but may not be associated with any acute findings on imaging of the brain (Riggio & Jagoda, 2016).

Most concussions follow a predictable pattern in that they are known to resolve after 10 to 14 days while the patient participates in both cognitive and physical rest (Makdissi et al., 2017). Regrettably, not all individuals recover within the acute time frame that is often experienced by the majority of the population; rather they are exposed to a longer healing pattern, often persisting for an unknown passage of time. Approximately 10-33% of individuals who sustained a concussion experience persistent concussion symptoms (PCS) beyond the usual

10 to 14 day recovery and healing period (Kurowski et al., 2016). When this typical timeframe passes and persistent symptoms are present, the patient is diagnosed with PCS (McCrory et al., 2017). These persisting symptoms may result in deterioration in the quality of life, depression, and/or increased financial stresses as a result of diminished performance or absence from work, sport, or school (Grabowski, Wilson, Walker, Enz, & Wang, 2017). Consequently, the need for an effective rehabilitation protocol for these individuals is critical in order to avoid these negative experiences.

Although cognitive and physical rest has long been the protocol that most physicians have recommended, it is no longer appropriate for individuals who have persistent symptoms (DiFazio, Silverberg, Kirkwood, Bernier, & Iverson, 2016). Unfortunately, there has yet to be a study that effectively developed an all-encompassing treatment protocol that could be applied to all individuals affected by this disorder. The development of an effective rehabilitation protocol would benefit individuals across the life span and ideally result in a reduction and faster resolution of symptoms, allowing these individuals to return to play, school, work, and life quicker and with a greater degree of health.

More recently, there has been an increase in interest with regards to the prescription of symptom-limited aerobic exercise in this patient population, typically completed at lower intensity levels (Makdissi et al., 2017). Therefore, this highlights a significant a gap in the body of research examining the impact of higher intensity aerobic exercise and active treatment options for individuals with PCS. Results from other researchers who have completed symptom-limited aerobic exercise protocols provide promising improvements in cognitive functioning as well as vestibulo-ocular functioning (Ellis, Leddy, & Willer, 2015). Although there has been extensive research in this field, new research remains a crucial component in developing an

effective method of treatment for healthcare professionals to employ when presented with an individual with PCS.

There remains a need for a research study to be conducted on healthy controls to determine the effects of symptom specific treatments. Therefore, the purpose of this pilot research was to examine specifically the impact of three separate 6-week supervised and individualized exercise programs based off of the sub-categories of PCS when compared to a control group on healthy controls. Additionally, the outcomes of this pilot study may act as a guide for future researchers when developing protocols to specifically address the subcategories of PCS. Utilizing healthy controls will serve as a baseline for future researchers to build upon and learn from when possibly applying to a population of PCS patients.

Chapter 2 – Review of the Literature

The following will outline a detailed rationale for implementing moderate intensity aerobic exercise, cervical spine strengthening, and vestibulo-ocular training in healthy controls and ultimately the explore the future possibility of implementing it as a rehabilitation protocol for PCS patients in the future.

Concussion

Definition and prevalence. In 2011, the Canadian Community Health survey concluded that between 2009-2010 a total of 94,000 Canadians (58,000 males and 36,000 females) over the age of 12 years were affected by a concussion (Billette & Janz, 2011). Similarly, in the United States there was an estimated 1.6 to 3.8 million sport-related concussions (SRC) experienced annually (Ellis et al., 2015). It was found through a review of National Collegiate Athletic Association data for 15 sports, that concussion rates doubled from 1.7 to 3.4 concussions per 1000 athletic exposures between the 1988-1989 and 2003-2004 academic years (Graham, Rivara, Ford, & Spicer, 2014). When considering youths aged 19 years and under, the reported number of individuals treated for concussions increased from 150,000 to 250,000 between 2001 and 2009 (Graham et al., 2014). In addition to this, the rate of emergency department visits for such injuries increased over 57% during the same time period (Graham et al., 2014). These increases may be attributed to a greater awareness of concussions amongst healthcare providers, sports associations, school systems, and the general public (Graham et al., 2014). This growth in awareness has escalated the importance of developing a clear and concise definition for concussion and effective treatment programs following the injury.

A SRC was previously defined as the onset of immediate and transient symptoms of a traumatic brain injury (TBI) after participating in sport (McCrory et al., 2017). A definition such

as this is problematic, as it does not provide any insight into the portion of the brain that is impaired, nor does it detail the severity, or reflect the probability of developing persistent symptoms and/or a failed and abnormal healing response (McCrory et al., 2017). With new research being conducted every day, it still remains a relatively new area of interest and with that, there are domains that have yet to be researched. With contradictory findings in studies, varying methodologies, and numerous treatment plans proposed, confusion remains surrounding the definition and terminology used in this topic area and what the most appropriate treatment is for patients with concussion.

With the inconsistencies and frustrations of healthcare providers being heard by the research community, McCrory et al. (2017) modified the previous Concussion in Sport Group's definition of concussion. The updated definition of a SRC is that it is a TBI that is produced by biomechanical forces and has several common features that may be identified in the clinical setting in order to define the nature of the concussion (McCrory et al., 2017). The first common feature that may be identified is that there was a direct blow to the head, neck, and/or elsewhere on the body that was transmitted to the head, which caused the SRC (McCrory et al., 2017). Secondly, a SRC normally results in the quick onset of short-lived impairment of neurological function that freely resolves itself (McCrory et al., 2017). A SRC results in neuropathological changes with the acute clinical signs and symptoms mostly reflecting a functional disturbance rather than a structural injury; often no abnormality is seen on any standard structural neuroimaging device (McCrory et al., 2017). Lastly, a SRC produces a spectrum of signs and symptoms that may or may not involve the loss of consciousness. The symptoms typically follow a sequential course, but in some cases these symptoms may be prolonged (McCrory et al., 2017).

Signs and symptoms of concussion. Each concussion presents differently, regardless of patient's concussion history. Consequently, a concussion may manifest itself in a variety of ways making each person's experience with the injury and combination of symptoms unique (Sivak et al., 2016). Although the symptoms may present in a distinctive pattern for each individual, the symptoms can consist of a combination of cognitive symptoms, somatic symptoms, affective disorders, sleep disturbances, and reduced alcohol tolerance (Sivak et al., 2016). The reality that an individual's concussion may produce a combination of symptoms creates difficulty for the healthcare providers when attempting to identify, diagnose, and rehabilitate individuals with this injury.

Having the knowledge and ability to recognize and evaluate a SRC can be a perplexing task for healthcare providers. The healthcare provider must ensure that he/she provides an objective assessment in order to rule out a more serious injury at the time of impact (McCrory et al., 2017). Providing follow up assessments is crucial to the healing process as a SRC is often an evolving injury, whereby signs and symptoms may take an undetermined period of time to resolve. McCrory et al. (2017) concluded that a diagnosis of SRC requires a healthcare provider to assess a range of domains including symptoms, which may be somatic, cognitive, and/or emotional in nature. These domains may also include physical signs, balance impairment, behavioural changes, cognitive impairment, and/or sleep/wake disturbances (McCrory et al., 2017). Table 1 summarizes the clinical domains that are often reported within each subgroup.

Table 1.

Summary of clinical domains of concussions.

Domains					
Symptoms	Physical Signs	Balance Impairment	Behavioural Changes	Cognitive Impairment	Sleep/wake Disturbance
Headache	Loss of consciousness	Gait unsteadiness	Irritability	Slowed reaction times	Somnolence
Feeling in a fog	Amnesia	Dizziness			Drowsiness
Lability	Neurological Deficit				
Inability to focus					
Nausea/vomiting					

(McCrory et al., 2017; Riggio & Jaggoda, 2016).

If the assessing healthcare provider determined that any one or more of these clinical domains were present, a SRC should be suspected and the necessary management and rehabilitation should be implemented (McCrory et al., 2017). An additional difficulty for healthcare providers to consider is that the presentation of these domains may be delayed at the time of assessment; therefore, the patient may not exhibit any of the symptoms associated with the domains (McCrory et al., 2017). A re-assessment may be required for individuals who are not improving even though their primary assessment was initially clear. These signs and symptoms are not specific to concussion alone, so their presence simply implies the possible inclusion of a concussion in a differential diagnosis for a healthcare provider to consider and further evaluate (McCrory et al., 2017). With that, the presence of any one single symptom is not in itself diagnostic of a concussion (McCrory et al., 2017). Although it may seem like concussions are easily identified, the degree of the disturbance to the brain's functioning is often overlooked. The clinician must not only be aware of the symptoms present but also the physiological changes that occurred at the time of the concussion.

Neurometabolic cascade of concussion. McCrory et al. (2017) reported that a concussion is the result of biomechanical forces applied to the head, neck, and/or other part of the body that may be transmitted to this area. It has been reflected in animal models and also corroborated in human studies that a concussion is not simply a structural brain injury but rather an acute metabolic injury (Giza & Hovda, 2014). A concussion results in a neurometabolic cascade of events that consists of bioenergetic challenges, cytoskeletal and axonal alterations, impairments in neurotransmission, and vulnerability to delayed cell death and chronic dysfunction (Giza & Hovda, 2014).

The stretching of neuronal membranes and axons that occur as a result of concussion may lead to a temporary ionic disequilibrium in the brain (Giza & Hovda, 2014). After the biomechanical injury, there is a hyperacute efflux of extracellular potassium, and an influx of intracellular sodium and calcium (Giza & Hovda, 2014).

This initial ionic flux and depolarization causes an indiscriminate glutamate release (Giza & Hovda, 2014). The glutamate then activates N-methyl-D-aspartate receptors, resulting in an accumulation of intracellular calcium leading to mitochondrial respiratory dysfunction, protease activation, and apoptosis (programmed cell death (Shrey, Griesbach, & Giza, 2011)

An acute energy crisis occurs as a result of the ionic disequilibrium that is produced. As a result of the injury to the brain, the body attempts to restore ionic and cellular homeostasis by shifting the adenosine triphosphate (ATP), pushing the membrane ionic pumps into overdrive, causing hyperglycolysis, and depleting the intracellular energy reserves (Giza & Hovda, 2014). The damage caused by free radicals and the shift of metabolic pathways puts additional stress on the brain, triggering longer-lasting impairments and causing these individuals to be at an increased vulnerability for repeated injury (Giza & Hovda, 2014). It is crucial for healthcare

providers to understand this process as it provides the basic framework as to why an individual may experience lasting impairments.

   Predictors of delayed healing. Researchers and healthcare providers have slowly begun the process of determining the predictors of PCS. Until recently, they had the understanding that this was a random process and had minimal insight into the predictors of PCS. Subbian et al. (2016) developed the Kinesiological Instrument for Normal and Altered Reach Movements, a robotic assisted assessment tool, used to examine TBI patients in emergency departments and determined which patients were at a higher risk for developing PCS. The study suggested that poor visuomotor and proprioceptive performance on robot-assisted testing at the time of a TBI may be connected to the future development of PCS 3-weeks post injury (Subbian et al., 2016). This tool is essential for identifying patients who are at a higher risk for developing PCS, as it guides healthcare providers in utilizing limited clinical resources such as follow-up appointments and neurocognitive therapy for that distinct population (Subbian et al., 2016).

   This tool consisted of five robotic assisted tests. The first was the Arm-Matching Test, which required the patient to mimic the movement that a robotic handle took his/her passive hand through with the opposite active hand, thereby testing his/her proprioceptive perception processing (Subbian et al., 2016). The second test was the Visually Guided Reaching Task, which required the patient to make unassisted reaching movements towards red circular targets. This evaluated the individual's motor and visual pathways that were involved in volitional hand movement (Subbian et al., 2016). The third test was the Trail Marking Test which required the patient to connect letters and/or numbers sequentially allowing the researchers to assess completion times, dwell times, and errors (Subbian et al., 2016). The fourth test required the patient to hit virtual circular objects that fell from 10 random locations on the screen with the use

of virtual paddles in each hand (Subbian et al., 2016). This test assessed the patient's interlimb coordination and visuospacial attention (Subbian et al., 2016). The final test was the Bimanual Object Hit and Avoid Task, where six differently shaped objects randomly dropped from the top of the screen and the patient was instructed to only hit a particular shape (Subbian et al., 2016). This final test assessed the patient's rapid motor selection and attention. Each robotic-assisted test had respective normative scores that were previously collected from healthy control patients; therefore, each patient in the study was compared to the normative data (Subbian et al., 2016). If a patient scored outside of the 5th and 95th percentiles, he/she was considered abnormal for that section of the test (Subbian et al., 2016). The proportion of abnormal results each individual produced was used to determine the score of each test, with a higher proportion reflecting worse performance and a lower proportion reflecting better performance. Having this tool available in an emergency department provided the patient with the opportunity to be flagged and referred to the appropriate specialist who could then develop a rehabilitation plan that accommodated the potential of developing PCS. Clinicians who determine which patients are at an increased risk for developing PCS could utilize this tool; therefore a specialist may plan to use a rehabilitation protocol such as the one conducted in this pilot study as soon as the patient arrives as opposed to waiting until the patient sees a specialist at a separate appointment. Although this may seem like an ideal option for clinicians to employ, there are negative attributes to this protocol such as requiring a staff that is trained to use it and because of this, it is only utilized in a handle full of locations.

In addition to gaining a greater understanding of how these predictors can be identified, there are also specific symptoms and conditions that healthcare providers must be cognisant of when assessing an individual who sustained a concussion. Zuckerman et al. (2016) discovered

that an individual who had recurrent concussions, retrograde amnesia, difficulty concentrating, light sensitivity, and insomnia had a greater possibility of developing PCS. When a patient is examined on intake, a healthcare provider should be aware of these specific symptoms. This approach may be helpful in determining whether or not a patient is at an increased risk of developing PCS, and appropriate pre-emptive steps may be taken to decrease this risk. One can make inferences on whether the individual would be an optimal candidate to receive a treatment that aims to reduce the probability of developing PCS.

Broshek, De Marco, and Freeman (2015) determined that these predictors not only affected the individual's physical status but also psychological health. It was concluded that pre-morbid psychiatric and physical history (including but not limited injuries to the brain), current anxiety, life stressors, and pain were excellent predictors for developing PCS (Broshek, De Marco, & Freeman, 2015). Lastly, a patient's perceived pain levels had a positive correlation with anxiety sensitivity (Wood, McCabe, & Dawkins, 2011). When a mild head injury group and a control group were compared, it was found that both groups reported symptoms that were consistent with PCS and the symptoms were positively correlated with anxiety sensitivity (Broshek et al., 2015). When healthcare providers understand these predictive signs and symptoms, patients can then be provided with the necessary resources to best educate them about coping with the pain that is experienced. Education is one of the tools that concussion sufferers can use to understand the reason for their lingering symptoms.

Persistent Concussion Symptoms

As mentioned earlier, PCS refers to the persistent symptoms following a concussion that do not resolve within the typical 10 to 14 days period for adults and 4-weeks for children (McCrory et al., 2017). These persistent symptoms are not one single pathophysiological entity

but rather a collection of non-specific symptoms that could be related to coexisting and/or confounding factors that may not be related to the current injury in the brain (McCrory et al., 2017). The nature of PCS tends to be non-specific and, therefore, suggests global neurological dysfunction; however, if individuals present consistently with more specific symptoms, it would suggest that one specific portion of the brain may have been affected (Ellis et al., 2015). Due to the usual non-specific nature, patients are often instructed to engage in physical and cognitive rest until the symptoms spontaneously resolve (Ellis et al., 2015). Although this conservative approach has been consistently used, it does not consider the pathophysiological processes and sources of the symptoms. A further understanding is required for healthcare providers to recognize these processes and sources (Ellis et al., 2015).

This dilemma has resulted in the categorization of PCS into three neurological sub-systems within the definition of PCS. The sub-systems that have been identified include physiological PCS, cervicogenic PCS, and vestibulo-ocular PCS. Although there is often significant overlap between the sub-systems of PCS, it has been proposed that patients that fall within each category require its own specific rehabilitation protocol (Ellis et al., 2015). A healthcare provider's ability to recognize and distinguish between these forms of PCS allows for a patient to receive an individualized treatment plan that is tailored towards his/her specific symptoms, possibly promoting a successful recovery.

Physiologic Persistent Concussion Symptoms. An individual with physiologic PCS experiences persistent symptoms and impairments as a result of alterations in global cerebral metabolism (Ellis et al., 2015). These alterations include an increase in cerebral cellular energy demand that is coupled with insufficient energy delivery, which resulted in a metabolic energy crisis (Ellis et al., 2015). Physiologic PCS is characterized by decreases in all of the following

physiological processes: cell membrane permeability, ion transport regulation, neurotransmitter release, cellular metabolism, and cerebral blood flow (CBF; Ellis et al., 2015). The decrease in physiological processes is the result of suspected autonomic nervous system (ANS) dysfunction (Ellis et al., 2015). This proposed dysfunction in the ANS may also cause increased sympathetic nervous system output resulting in increased heart rate, blood pressure, and perspiration (Ellis et al., 2015). There is the potential for individuals to remedy the dysfunction occurring in the ANS with appropriate strategies.

Exercise has been utilized as a potential intervention strategy to promote ANS and concussion recovery. Although exercise has been proven to increase parasympathetic nervous system activity, decrease sympathetic nervous system activity, and increase CBF, the timing at which it is implemented in the concussed population is crucial (Ellis et al., 2015). In animal experiments, it has been found that premature exercise prescription within the first 7 days post injury resulted in impaired cognitive performance and reduced levels of peptides such as brain derived neurotrophic factor, which is responsible for mediating nervous system recovery and plasticity (Griesbach, Gomez-Pinilla, & Hovda, 2004; Griesbach, Hovda, Molteni, Wu, & Gomez-Pinilla, 2004). Conversely, when animals were exposed to aerobic exercise 14 to 21 days post injury, they were found to have improved cognitive performance and higher levels of neurotrophic peptides when compared to those treated with rest (Griesbach et al., 2004). Therefore, these studies suggested that physiologic PCS can be managed with controlled and individualized exercise treatment programmes.

Utilizing a graded aerobic treadmill test allows healthcare providers to distinguish between the PCS sub-systems (Ellis et al., 2015). The standardized Balke protocol can be used to take the patient through an incremental treadmill test to the point where symptoms occur, are

exacerbated, or until maximal exertion is achieved; this is defined as the point at which the participant reports a rating of perceived exertion (RPE) of 18-20 on the Borg scale (Ellis et al., 2015). The individual's heart rate and RPE are measured at 1-minute intervals. The test is terminated when maximal exertion, the first manifestation of symptoms, or exacerbation occurs. Individuals, who still experience symptoms at rest 3-weeks post-injury and experience a symptom-limited threshold during the graded treadmill test, are deemed to suffer from physiologic PCS (Ellis et al., 2015). Although this provides researchers useful information on the onset of symptoms with this progressive exercise assessment, the symptoms that manifest may be aggravated significantly and the patient may not be able to engage in exercises for several days or weeks until the symptoms subside. This may not be conducive to the healing process for these individuals. Individuals who continue to experience symptoms at rest 3-weeks post injury and do not have a symptom-limited threshold during a graded treadmill test should undergo further testing in order to determine the sub-system and source of the concussion symptoms. Additional testing is required for those individuals in order to determine whether those individuals have cervicogenic PCS and/or vestibulo-ocular PCS (Ellis et al., 2015).

Individuals with physiologic PCS also often have difficulties with cognitive testing tools such as the ImPACT® battery (Lovell, 2015). Concussion symptoms are not limited to physiological manifestations; however, they may also present within and be affected by the cervical spine region.

Cervicogenic Persistent Concussion Symptoms. Individuals who experience PCS and impairments that are the result of dysfunction of the cervical spine somatosensory system fall within the sub-system of cervicogenic PCS. The cervical spine plays a crucial role in maintaining balance, head orientation, and eye movement. The high density and complexity of muscle and

joint mechanoreceptors found within the cervical spine provides a high volume of proprioceptive information that is relayed to multiple levels of the central nervous system that may contribute to the symptoms experienced by the patient (Ellis et al., 2015).

There are three primary reflexes that work simultaneously throughout the cervical spine somatosensory system, including the cervicocollic reflex, the vestibulocollic reflex, and the cervico-ocular reflex (Ellis et al., 2015). When these reflexes do not work cohesively as a group, an individual may experience symptoms that are similar to vestibulo-ocular PCS (Ellis et al., 2015). These symptoms may include dizziness, gait instability, light-headedness, mental fogginess, and visual disturbances (Ellis et al., 2015). The cervicocollic reflex and vestibulo-spinal reflex work together to recruit the longus capitis and longus colli muscles, which are deep flexors of the cervical spine and stabilize the head during head and body movements (Kristjansson & Treleaven, 2016). The cervicocollic reflex is also recruited when rotation of the body occurs and the head remains still. The vestibulocollic reflex is facilitated by the vestibular system, which results in deep cervical spine muscle activation to aid in head stabilization with rapid head movements (Kristjansson & Treleaven, 2016).

The vestibular system is involved in both cervicogenic and vestibulo-ocular PCS, as it is an intricate system that works simultaneously with both the cervical spine and the vestibular and ocular systems. The vestibular system consists of the semicircular canals, cochlea, and the ampulla as depicted in Figure 1 (Goldberg, 2012). The semicircular canals contain three bony channels (anterior, posterior, and lateral) and contain receptors that are responsible for equilibrium (Tortora & Nielson, 2012). The cochlea is a winding, cone-shaped tube that forms a portion of the inner ear, which contains the spiral organ (Tortora & Nielson, 2012). The spiral organ is a sheet of epithelial cells, whose primary job is to act as the receptor organ for hearing

(Tortora & Nielson, 2012). The ampulla is the swollen enlargement found at each end of the

canal in the inner ear and functions to provide the individual with spatial orientation (Tortora &

Nielson, 2012).
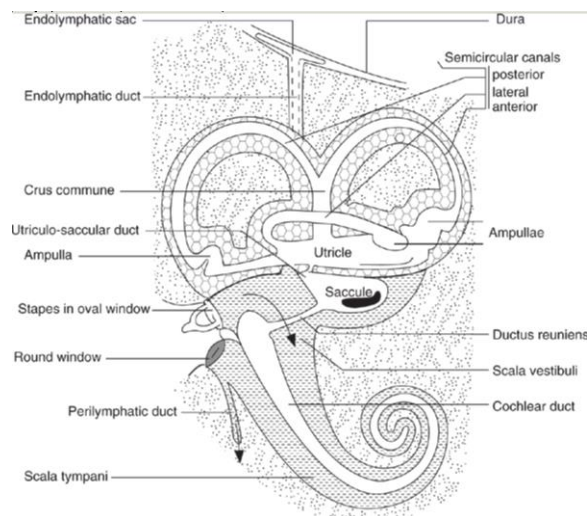
Figure 1. The anatomy of the vestibular system showing the semicircular canals, cochlea, and

the ampulla. Adapted from "Vestibular Rehabilitation," by J. M. Goldberg, 2012, The Vestibular

System: A Sixth Sense, 2, p. 24. Copyright 2012 by the Oxford University Press.

The cervico-ocular reflex is engaged when the longus capitis and longus colli muscles are

stretched. They work together with the VOR to coordinate head and eye movement while

tracking objects and are engaged while stabilizing one's gaze (Kristjansson & Treleaven, 2016).

Individuals suffering from cervicogenic PCS will often describe their injury as a result of a rapid

acceleration or deceleration force that was not only applied to the head but also the cervical spine

(Ellis et al., 2015); often a consequence of a whiplash type of injury. These individuals will

complain of cervical spine pain, stiffness, fatigue, and decreased range of motion (ROM). They

may also experience headaches that originate in the occipital region and radiate forward into the

temples, the eyes, or into other regions in the cervical spine (Ellis et al., 2015). Unlike

individuals with physiologic PCS, these headaches are not aggravated by aerobic activity but rather worsen throughout the day as the muscles fatigue over time (Ellis et al., 2015).

The trigeminocervical nucleus is a region of the upper cervical spinal cord where sensory nerve fibres running inferiorly in the trigeminal nerve are thought to interact with sensory nerve fibres from the upper cervical nerve roots in the nuclei housed in the upper cervical spine region (Biondi, 2005). This junction point of the upper cervical and trigeminal nerve pathways allows for the painful sensations to be created between the cervical spine and the trigeminal sensory nerves found in the face and head and referred to areas outside of the respective nerve (Biondi, 2005). This pathway assists in the explanation of the source of pain that one experiences with cervicogenic PCS to be found in the muscular, neurogenic, or vascular structures of the cervical region (Biondi, 2005).

With the use of ROM and strength assessments, healthcare providers can assess overall cervical spine alignment, mobility, and the strength and endurance of the deep cervical spine flexors to further determine the presence of cervicogenic PCS. Individuals with palpable tenderness, decreased strength, and decreased ROM of the cervical spine are likely to suffer from cervicogenic PCS. The ROM in these individuals can be measured using a variety of measurement techniques or equipment including the Cervical Range of Motion (CROM) instrument. The CROM has been proven to be effective in assessing cervical spine ROM in individuals with concussions and those with chronic mechanical neck pain in the upper cervical spine (Rueda et al., 2017). It is also helpful for assessing and differentiating individuals who have neck pain and healthy individuals who do not (Rueda et al., 2017). In addition to symptoms related to the cervical spine, individuals with PCS may also experience symptoms related to the vestibulo-ocular system dysfunction.

Vestibulo-ocular Persistent Concussion Symptoms. Individuals with vestibulo-ocular PCS are characterized by having symptoms that are the result of dysfunction occurring in the vestibulo-ocular system (Ellis et al., 2015). The vestibulo-ocular system is complex and consists of highly specialized neural networks that interact at the craniospinal axis to regulate gait, balance, postural control, and coordinate eye movements (Ellis et al., 2015). When a concussion occurs, various specialized sense organs such as the retina, semi-circular canals, and joint mechanoreceptors are affected.

The vestibulo-ocular reflex (VOR) controls the vestibulo-ocular system. The VOR is responsible for regulating gaze stabilization during head acceleration. A second reflex, the vestibulo-spinal reflex, is responsible for coordinating head, cervical spine, and trunk positioning during dynamic body movements (Ellis et al., 2015). When dysfunction occurs within this sub-system, individuals may experience dizziness, gait instability, fogginess, blurred vision, and difficulty focusing (Ellis et al., 2015).

The visual and oculomotor systems should be assessed through the use of visual acuity tests as well as testing for ocular alignment (Ellis et al., 2015). The assessment of the reflexes mentioned earlier is crucial in distinguishing individuals with vestibulo-ocular PCS. There are other tests that exist to assess an individual's vestibulo-ocular functional abilities. The Brain Injury Symptom Survey questionnaire is one of many tests that assesses a portion of the vestibulo-ocular system. It is a self-administered, 28-item visual symptom questionnaire, for vision symptoms related to TBI (Laukkanen, Scheiman, & Hayes, 2016). The Brain Injury Symptom Survey questionnaire is highly sensitive with 82% ability for correctly predicting a TBI and 90.4% for correctly predicting the healthy controls (Laukkenen et al., 2016). It is a useful test as individuals can complete it independently. Although it is accurate in determining

abnormal visual symptoms, the inner ear and the eyes work together to make the vestibulo-ocular system function optimally. The Brain Injury Symptom Survey questionnaire is limited to assessing the visual portion of this system and is not a useful tool in assessing the system as a whole. Therefore, an all encompassing test would be more useful in this pilot study as the vestibulo-ocular system will be assessed as a unit rather than the systems separately.

A more comprehensive test that assesses both the vestibular and ocular systems would be an ideal assessment tool in this population to rule in or out the involvement of the vestibulo-ocular system. Although there are other methods for testing the vestibulo-ocular system, the majority require specialized equipment and training, therefore, the following test was chosen as it requires little equipment and does not require specialized training to conduct. The Vestibulo-Ocular Motor Screening (VOMS) test is better suited for clinical use and for this pilot study, as it consists of five mini-tests that assesses each portion of the systems. The test will be described in greater detail in the methodology section of the manuscript. When healthcare providers have a better understanding of the three sub systems of PCS, better rehabilitation protocols can be developed to accommodate the specific needs and deficits that each patient possesses.

Rehabilitation Protocols for Persistent Concussion Symptoms

Traditional rest care for persistent concussion symptoms. Traditionally, individuals experiencing PCS have been instructed to cognitively and physically rest which involves no school or work, driving, abstaining from the use of screens related to telephone, television, and computers, and physical activity that results in perspiration (Moser, Glatts, & Schatz, 2012). The justification of this rest period is supported with the idea that this time allows the brain to resolve the metabolic disruption and energy crisis resulting from the concussion. The decrease in cognitive demands and physical activity allows ATP to be transferred and to restore intra and

extracellular ionic concentrations and metabolic homeostasis (Moser et al., 2012). During the

acute phase of the injury, cognitive tasks and physical activity may result in additional ATP

uptake (Shrey et al., 2011). The ATP, that would otherwise be utilized to resolve the metabolic

disruption, is now utilized to fuel the cognitive tasks and physical activity (Shrey et al., 2011).

Any additional metabolic demands while the brain is in this critical state may not be met with

these additional strains (Shrey et al., 2011). The clinical reasoning that supports physical and

cognitive rest is most relevant to the acute portion of a concussion, which occurs during the

critical period of 7 to 10 days post impact; however, the role of rest is not as thoroughly

supported when the injury falls outside this range and into the chronic stages.

Disadvantages of prolonged rest. The term *rest* has not been well defined across various

studies; its characteristics have varied within studies and clinical practice guidelines, making it

difficult to determine what it entails (DiFazio et al., 2016). Additionally, the ability for

healthcare providers to monitor complete withdrawal from daily activities is challenging as it

relies on the compliance of the patient (DiFazio et al., 2016). There are also negative side effects

that could be produced due to prolonged rest, such as the development of anxiety and/or the

development of a nocebo effect. The nocebo effect in regards to a concussion occurs when an

individual identifies a concussion as an injury that will produce lasting effects; therefore, this

negative connotation may create and/or exacerbate the symptoms he/she experienced post injury

(DiFazio et al., 2016).

With prolonged rest, patients tend to withdraw from daily activities where they may

experience personal satisfaction such as reading, participating in sports, working, and so on. This

withdrawal may have a negative effect on the ability to cope with the injury and is associated

with psychological complications (DiFazio et al., 2016). Prolonged rest may result in

physiological changes in a relatively short period of time such as an increase in resting heart rate and blood pressure (DiFazio et al., 2016). Deconditioning and exercise intolerance can even result after only 2-3 days of bed rest (DiFazio et al., 2016). An extended period of bed rest is contraindicated in medical conditions such as stroke, whiplash injuries, and post spinal procedural recovery (DiFazio et al., 2016). All of the previous injuries are similar to concussions, as they involve the neurological and cervical systems, it would make sense that individuals with concussions would also not respond well to extended periods of bed rest. All of the adverse effects resulting from prolonged rest should inspire healthcare providers to implement a treatment protocol that encourages the patient to continue daily routines incrementally as able.

Exercise rehabilitation for persistent concussion symptoms. It is well known that physical activity has numerous benefits on overall health and well being of all individuals (Ratey & Hagerman, 2008). The benefits can include improvements in cognitive flexibility and plasticity, learning, and the ability to retain and recall these new learnt concepts (Ratey & Hagerman, 2008). The literature is expanding on the positive effects physical activity has on the brain and cognitive functioning. Aerobic exercise has been reported to improve functional magnetic resonance imaging (fMRI) cortical connectivity and activation, be cognitively protective, and produce greater levels of brain-derived neurotrophic factor (BDNF; Leddy, Hinds, Sirica, & Willer, 2015). It has been proposed that individuals with physiologic PCS may benefit from increased levels of BDNF as it plays a part in neuronal repair at the time of injury (Leddy et al., 2015). For individuals with physiologic PCS, aerobic exercise may also encourage the improvement of the dysfunction in the ANS by specifically improving CBF, which is impaired in this population (Phillips, Baktir, Srivatsan, & Salehi, 2014). This raises the question whether aerobic activity and prescription of different exercises play a positive role or not in the

rehabilitation process of this delicate population. There is potential for healthcare providers to apply this approach to concussed populations, however there is limited research in regards to the benefits that these training programs have on individuals with PCS. This highlights a gap in the research examining the impact of moderate intensity aerobic exercise as well as cervical strengthening in healthy controls to serve as a baseline for future testing. There is a need for an exploratory study to determine the value of implementing individualized programs that are tailored towards the subcategories of PCS. Ultimately a pilot study must be performed on healthy controls before further testing on an injured population is carried out. Therefore, the benefits of testing an exercise program on healthy individuals would be valuable to ensure that it is appropriate for the general population before applying it to a PCS population who is experiencing deficits in cognitive, cervical, and/or vestibulo-ocular functioning.

Purpose of the Research

The purpose of this pilot research was to examine the impact of three different types of 6-week supervised and individualized exercise programs when compared to a control group on cognitive and cervical functioning in a sample of 18-35 year old healthy individuals. The four programs were composed of a control group, a moderate intensity aerobic exercise group, cervical strengthening group, and a vestibulo-ocular training group.

Research Questions

The following research questions were used to guide the purpose of this pilot study:

1. What was the effect of the exercise based programs compared to the control on cognitive measures of verbal memory, visual memory, visual motor speed, reaction time, and impulse control composite scores?

2. What was the effect of the exercise based programs compared to the control on strength measures of the cervical spine flexor muscles?

3. What was the effect of the exercise based programs compared to the control on cervical spine flexibility for forward flexion, extension, side flexion, and rotational movements?

Chapter 3: Methods

The following outlines the characteristics of the participants, instrumentation and outcome measures, procedures, data collection, and data analysis.

Participants

After obtaining ethical approval from the Thunder Bay Regional Health Sciences Centre Research Ethics Board, a one group pre-test post-test design was implemented. Through the use of an a priori analysis with the G*Power 3.1 Software®, it was determined that approximately 40 participants were sufficient to detect a medium to large effect size with 80% power at α=.05 (two-tailed) in the ImPACT® battery cognitive tasks. As a result, 40 participants, both male and female, between the ages of 18-35 years were recruited to participate in the supervised and individualized moderate intensity aerobic, cervical strengthening, and vestibulo-ocular retraining (MACV) exercise based program. Both male and female participants were included as the effect of sex was not a variable that was investigated in this pilot study. Additionally due to a smaller population to sample from, both males and females were included as to ensure enrolement was at the highest it could be.

Recruitment. The participants were recruited through the use of posters that were displayed on community bulletin boards found throughout the Lakehead University campus. An electronic copy of the poster, found in Appendix A, was also distributed through social media (e.g., Facebook, Twitter, and Instagram) and was put on public pages that potential participants may have frequented. The lower limit of the age range was chosen to be 18 years of age as there is adolescent-specific paradigms within the concussion population such as puberty found in individuals less than 18 years of age (McCrory et al., 2017). The management of SRC in

children, for example, may require special consideration and different parameters and time lines that are more suitable for the developing child and the intent of this pilot study was geared towards the adult population (McCrory et al., 2017). The upper limit of 35 years was chosen as this is often the time at which women begin to experience the starting symptoms of perimenopause (Martin et al., 2016). It has been reported that individuals in the perimenopause state are at a higher frequency for developing headaches than those who are not in this state (Martin et al., 2016). Although concussed individuals were not included in this pilot study, healthy individuals beyond this age range may contribute to irrelevant variance due to perimenopause, which may affect the use of the findings on future PCS research populations (Martin et al., 2016). These individuals may have also experienced declines in energy and not have had the capacity to complete the aerobic portion of this pilot study (Martin et al., 2016). Therefore, including indidviduals above this age range may have caused the data to be skewed due to body changes that were the result of perimenopause, which led to the decision of excluding this aged population.

Once potential participants identified that they wished to participate in the pilot study, they were asked to contact the student researcher with the given email and/or phone number displayed on the poster. If the participant chose to participate, an information letter detailing the requirements and procedures of the pilot study was provided. The participant was provided with a prospective meeting time to allow him/her to ask any questions regarding the pilot study, prior to committing.

Upon completion of the recruitment phase of the pilot study, the 40 participants were randomly and equally divided into four treatment groups; 1) no treatment group, 2) moderate intensity aerobic group, 3) cervical strengthening group, and 4) vestibulo-ocular retraining group.

Participants were randomly assigned based on time of sign up, there was a pre-set order in which the groups were set up where the groups were in order and repeated themselves. When participants began to sign up they were put into the group in sequential order. There was no incentive for participants to engage in this study, other than the perosonal satisfaction of adding to the research community.

Inclusion Criteria. Participants for the pilot study were included if they met the following criteria:

1. Males or females between the ages of 18-35 years.

2. Were physically active for a minimum of 150-minutes per week.

3. Were cleared to begin exercising by completing a Physical Activity Readiness Questionnaire.

Exclusion Criteria. Participants were excluded from the pilot study if they:

1. Suffered from a concussion or persistent symptoms in the past 5 years.

2. Suffered from a musculoskeletal or spinal injury that inhibited his/her participation in daily exercise such as a sprain, strain, and/or fracture within the past 6 months.

Instrumentation and Outcome Measures

The following instruments and outcome measures were used:

Immediate post-concussion assessment and cognitive testing. The ImPACT® test battery is a neuropsychological test measure that is used by researchers, healthcare providers, and countless university and professional sports teams (Lovell, 2015). Healthcare providers implement the ImPACT® test battery when attempting to measure components of cognitive functioning including attention, concentration, reaction time, memory, processing speed,

decision making, executive functioning, problem solving, and response variability (Nakayama, Covassin, Schatz, Nogle, & Kovan, 2014). Nakayama et al. (2014) reported that the ImPACT® test battery was highly sensitive at 81.9% in it's ability to identify individuals with cognitive deficits; and highly specific at 89.4% in determining individuals without cognitive impairments. Maerlender et al., (2016) evaluated the test-retest reliability of the ImPACT® composite scores in division one level athletes over a span of four years. It was found that the test-retest reliability of all four composite scores was significant at $p<.001$ with visual motor speed having the best score (intra-class correlation [ICC]=.89), followed by visual memory (ICC=.78), then reaction time (ICC=.77), and, lastly, verbal memory (ICC=.74; Maerlender et al., 2016).

The ImPACT® test battery is a three stage evaluation consisting of a demographic and background information questionnaire, followed by an assessment of 22 concussion symptoms graded on a 7-point Likert scale, and concludes with a neuropsychological test completed on a computer consisting of six modules (Nakayama et al., 2014). For the purpose of this pilot study, the ImPACT® test battery was administered to healthy participants to measure cognitive functioning utilizing the composite scores of verbal memory, visual memory, visual motor speed, reaction time, and impulse control.

Cervical range of motion instrument. The CROM device was used to assess the participant's cervical spine forward flexion, extension, side flexion, and rotation ROM (degrees). The device was placed on the head with the front portion positioned on the bridge of the nose and the side portions parallel with the external acoustic meatus on either side of the head (Youdas, Carey, & Garret, 1991). After the device was positioned on the participant's head, a magnetic necklace was placed comfortably around the cervical spine; this was utilized to counteract any magnetic fields within the room that may have affected the inclinometer's ROM

readings. This device offered a hands free approach to assessing cervical spine ROM, allowing the participant to move freely and independently from the researcher. The CROM device has been reported to be highly reliable when measuring cervical spine flexion (inter-class correlation=.86) and extension (inter-class correlation=.83; Youdas et al., 1991).

Chin tuck head lift test. The participant's deep cervical spine flexor muscle strength was assessed via the CTHLT that measures the duration of time (seconds) in which the participant could hold his/her head in position without breaking form. The CTHLT has a reported moderate inter-rater reliability of ICC=.66 (Domenech, Sizer, Dedrick, McGalliard, & Brismee, 2010).

Stabilizer™ pressure bio-feedback unit. The Stabilizer™ Pressure Bio-Feedback unit was utilized throughout the intervention for the individuals assigned to the cervical spine strengthening treatment group and can be seen in Figure 2. It was utilized in providing feedback to the individual on determining the level of muscle contraction and pressure at which the participant must hold throughout the cervical spine exercises. The Stabilizer™ Pressure Bio-Feedback unit was designed by physical therapists and registers changing pressure in an air filled pressure cell (Chattanooga, 2009). This unique system allows body movement, and more specifically, cervical spine movement, to be detected during exercise (Chattanooga, 2009). The Stabilizer™ Pressure Bio-Feedback unit may be used to monitor and provide feedback on the quality of body movement during cervical and lumbar spine exercises and ability to generate small, incremental changes in force by increasing the amount of muscular contraction during stabilizer retraining (Chattanooga, 2009). A greater muscular contraction resulted in an increase in the pressure within the unit that was reflected on the dial, showing a greater amount of mmHg.

Therefore, it was chosen as an instrument to employ during the exercises completed by

participants in the cervical spine strengthening treatment group.

Figure 2. The Stabilizer™ Pressure Bio-Feedback unit. Adapted from, "Stabilizer™ Pressure

Bio-Feedback Unit," by Chattanooga 2009, Stabilizer™ Pressure Bio-Feedback Operating

Instructions, p. 1. Copyright 2009 by the DJO, LLC Vista.

Measures of vestibulo-ocular functioning. The VOMS Test was used to assess the

participant's vestibulo-ocular functional abilities. The VOMS Test consists of five separate

assessments to examine various components of this intricate system. The first is the Smooth

Pursuit Test which assessed one's ability to follow a moving target; second, is the Horizontal and

Vertical Saccade Test which assessed one's ability to follow a target between two points as fast

as possible; third, is the Convergence Test which assessed one's ability to view a near target

without double vision occurring; the fourth test examined the Horizontal VOR, which is one's

ability to stabilize the vision as the head is moving; and the final component assessed the

participant's visual motor sensitivity and the participant's ability to inhibit vestibular induced eye

movements (Mucha et al., 2014).

For the Smooth Pursuit Test, the examiner had the participant sit at a distance of 1-meter from the researcher. The participant was instructed to follow a moving pen that was held in the researcher's hand both horizontally and then vertically without moving his/her head for a total of two repetitions per direction; his/her symptom severity was then recorded (Mucha et al., 2014). The symptom severity was scored on a 10-point Likert scale from 0-10. Zero indicated that the individual experienced no symptoms of headache, dizziness, nausea, and fogginess, and 10 indicated that the participant was experiencing the worst case of his/her symptoms ever.

The Horizontal and Vertical Saccade Test required the participant to keep his/her head still while looking between two targets that were 1-meter apart (Mucha et al., 2014). The first part required the participant to look from left to right 10 times and then up and down 10 times; upon completion of the task, his/her symptom severity was recorded on the 10-point Likert scale.

For the Convergence Test, the participant was positioned in a seated position and with a piece of paper with 14-point font writing held by the participant with an outstretched arm (Mucha et al., 2014). The participant was asked to bring the paper in towards his/her face while focusing on the writing; the point at which the participant experienced double vision was where the forward progression of the piece of paper was stopped and the distance to the participant's eyes was measured. This indicated to the researcher how well the participant's eyes could focus and at what distance the participant lost focus. The symptom severity was recorded once again on the 10-point Likert scale.

The VOR Test was also completed in a sitting position whereby the same 14-point font target was held by the participant at eye level at a distance of 1-meter away. The participant was then instructed to rotate his/her head horizontally while keeping his/her gaze on the paper for a total of 10 repetitions. The participant was then instructed to keep his/her gaze on the paper for a

total of 10 repetitions, however, this time the participant nodded his/her head up and down

(Mucha et al., 2014). The final portion of the test assessed the participant's visual motor

sensitivity by having him/her stand with his/her feet shoulder width apart and one arm

outstretched while focusing with his/her eyes on his/her thumb (Mucha et al., 2014). The

participant was instructed to rotate his/her head, eyes, and trunk to 80-degrees to the left and 80-

degrees to the right for a total of five repetitions; the symptoms experienced were scored by the

participant on a Likert scale from 0-10.

A scoring sheet was used throughout the assessment to record the nature of the symptoms

that the participants experienced within each subtest and can be found in Appendix B. The

symptoms that were assessed included the presence of headache, nausea, dizziness, or fogginess

and were scored on a Likert scale ranging from 0-10 with 0 meaning there were no symptoms

and 10 being the worst symptoms ever experienced (Mucha et al., 2014). Generally speaking,

healthy individuals would likely experience little to no symptoms as they do not have any

injuries to their vestibulo-ocular system. However, there is a small possibility that symptoms

may be reproduced as participants may have vertigo or another balance issue that does not affect

their ability to participate in this pilot study.

Procedures

Once informed consent was obtained, the data collection process consisted of three

components: 1) Pre-treatment assessment; 2) Completion of the 6-week MACV program, and 3)

Post-treatment assessment.

The participants were randomly assigned to four respective treatment groups with the

first being the no treatment (control) group, the second was the aerobic exercise treatment group,

the third was the cervical strengthening exercise group, and the fourth was the vestibulo-ocular

retraining exercise group. All of the groups were instructed to maintain their daily exercise

routines and not to increase/decrease their typical daily exercise and this was tracked through a

weekly exercise tracker, as seen in Appendix C, provided at the commencement of the pilot

study. They were asked to report to the student researcher each week how many hours they spent

exercising as to remain consistent throughout the pilot study, and all participants adhered to their

daily routines remaining consistent throughout the 6-weeks.

Pre-Assessment. The pilot study involved a pre-treatment assessment that took

approximately 40-60-minutes of the participant's time in the multi-purpose lab (SB-1028) in the

Lakehead University Sanders Building. Once consent was obtained from prospective

participants, the height (cm), weight (kg), resting heart rate (beats per minute), and blood

pressure (millimeters of mercury; mmHg) was measured as part of the pre-treatment assessment

test battery. To ensure for accurate resting blood pressure and heart rate readings, participants

were instructed to not engage in physical activity up to two hours prior to the assessment.

Cognitive testing. The participant then completed a 25-minute computerized assessment

of his/her demographic and background information, concussion symptoms, and cognition that

measured attention span, verbal/visual memory, working memory, response variability, reaction

time, and non-verbal problem solving abilities with the use of the ImPACT® test battery.

Although the participants in this pilot study are healthy and free from a concussion with

symptoms, the ImPACT® test battery is a highly reliable test for cognition testing for individuals

with concussions and PCS. This pilot study is meant to be exploratory in nature and to serve as a

stepping stone for future researchers to apply to participants with PCS; therefore, having a test

that is sensitive to this population is valuable in this initial phase. These components of cognition

were assessed through the use of the following six modules: word memory, design memory, X's and O's, symbol match, colour match, and three letters. The scores of these six modules were then combined to produce verbal memory composite scores, visual memory composite scores, visual motor speed composite scores, reaction time composite scores, and impulse control composite scores. The verbal and visual memory composite scores are out of 100 and indicate the percentage of correct answers given during the test; therefore, a higher composite score suggests a greater number of correct answers. A higher visual motor speed composite score indicates to the researcher that the participant produced a higher number of correct answers two of the tasks; therefore, a higher score is a better score. The reaction time composite score is measured in seconds and a lower score indicates that the participant had a faster reaction time in the various tests, which suggests that functioning is within the normal limits. Lastly, the impulse control composite score is indicative of how many incorrect answers the participant produces on particular tasks; therefore, it is better to have a lower score as it suggests there were fewer errors made. This computer-based test was completed on a laptop, in an area free from noise and other distractions.

Cervical spine flexibility. Cervical spine flexibility was then tested using a CROM device that measured the degrees of motion for forward flexion, extension, side flexion (left and right), and rotation (left and right). The participant was seated in a chair where the feet were hip width apart and feet were planted on the ground with the toes facing forward. Shoulders were then set back to achieve a neutral spine position and the head was also positioned so that the CROM device read 0 degrees in all directions. After the CROM device was positioned on the participant's head, the magnetic necklace was placed comfortably around the participant's neck.

The degrees of movement for each direction were then recorded for two trials in each direction, with the maximum ROM of the two being recorded.

      Cervical spine flexor muscle strength. Cervical spine flexor muscle strength was assessed next with the use of the CTHLT. The CTHLT measured the endurance of the longus capitus and longus colli muscles. The participant was instructed to lie in supine lying with his/her knees bent at a 90-degree angle. The participant was then instructed to flex the cervical spine by tucking his/her chin towards the chest and lifting the back of the head off the ground. Once the participant was in position with his/her knees bent at a 90-degree angle, the researcher began measuring the time, stopping the timer when the participant could no longer hold the required position. The researcher was also looking for compensation from muscles surrounding the cervical spine region that would result in the time being stopped. The length of time (seconds) and the ability to hold his/her head off of the table when the chin was tucked and the head was held in 45º of cervical spine flexion was recorded for one trial during the assessment.

      Vestibulo-ocular functioning testing. Vestibulo-ocular functioning of the participant was tested through the VOMS Test, which included five mini tests within the assessment.

      VOMS smooth pursuit test. The first of the five tests tested the participant's ability to follow a moving target with his/her eyes when the participant was seated as depicted in Figure 3. As indicated previously, the participant was asked to complete a total of two repetitions per direction (horizontal and vertical) for this test and the symptom severity was measured after both directions on a Likert scale of 0-10.

Figure 3. Smooth pursuits test. Adapted from "Vestibular Rehabilitation," by Physiotherapy Alberta, 2017, Vestibular/Ocular-Motor Screening (VOMS) for Concussion. Copyright 2017 by the Physiotherapy Alberta College and Association.

VOMS horizontal and vertical saccades test. For the second test, the participant was asked to follow a target between two predetermined points as quickly as the partcipant could up and down and then from side to side as illustrated in Figure 4. As indicated earlier, the participant completed a total of 10 repetitions per direction and upon completion, the symptom severity was measured on a Likert scale of 0-10.
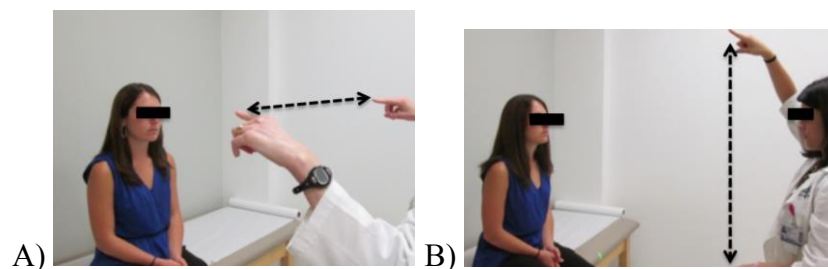

A)   B)

Figure 4. Horizontal saccades (A) and vertical saccades (B) test. Adapted from "Vestibular Rehabilitation," by Physiotherapy Alberta, 2017, Vestibular/Ocular-Motor Screening (VOMS) for Concussion. Copyright 2017 by the Physiotherapy Alberta College and Association.

VOMS near point of convergence test. For the third test, the participant was asked to focus on a small target as the researcher slowly brought it in towards his/her nose; the test was stopped when the participant experienced double vision and the distance from the target to the eyes of the participant was measured in centimetres as shown in Figure 5.
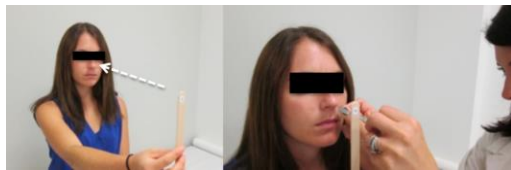
Figure 5. Horizontal convergence test. Adapted from "Vestibular Rehabilitation," by Physiotherapy Alberta, 2017, Vestibular/Ocular-Motor Screening (VOMS) for Concussion. Copyright 2017 by the Physiotherapy Alberta College and Association.

VOMS horizontal and vertical VOR test. The fourth test examined the participant's ability to keep his/her vision stable while the head moved from left to right as illustrated in Figure 6. The participant was then asked to complete a total of 10 repetitions per direction (horizontal and vertical) and symptom severity was measured on a Likert scale of 0-10.

Figure 6. Horizontal VOR test. Adapted from "Vestibular Rehabilitation," by Physiotherapy Alberta, 2017, Vestibular/Ocular-Motor Screening (VOMS) for Concussion. Copyright 2017 by the Physiotherapy Alberta College and Association.

VOMS visual motion sensitivity test. The last test examined the participant's visual motor sensitivity and the body's ability to stop eye movements that are caused by the vestibular system as shown in Figure 7. As explained earlier, the participant was asked to complete a total of five repetitions and the symptom severity was measured on a Likert scale of 0-10.

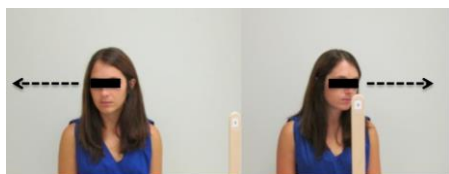*Figure 7.* Visual motion sensitivity test. Adapted from "Vestibular Rehabilitation," by

Physiotherapy Alberta, 2017, Vestibular/Ocular-Motor Screening (VOMS) for Concussion.

Copyright 2017 by the Physiotherapy Alberta College and Association.

The participant's ability to complete these tasks was noted and whether or not any

difficulty or symptoms were elicited or reported was documented.

Then based off of the participant's group assignment, the first exercise session followed

the pre-assessment. It should be noted that those who were assigned to the control group were

then instructed to leave and come back after the 6-weeks.

No treatment (control) group. The no treatment (control) group of participants that

received no training took part in the pre- and post-treatment assessments but received no

treatment within the 6-weeks of the pilot study. The participants were asked to report weekly

exercise to the researcher through the use of an exercise tracker as seen in Appendix C.

Supervised and progressive aerobic training program group. Once the pre-treatment

baseline measures were completed, the participants in this group were asked to attend 18, 30-

minute aerobic training sessions, over the course of 6-weeks (three sessions per week). All

sessions were completed within the Lakehead University Sanders Building in the Exercise

Physiology lab in room SB-1025. The session began with a warm-up on a stationary bicycle for

5-minutes at a self-selected rate that was set by the participant; the session then progressed to 20-

minutes of stationary cycling as per the stage of the exercise protocol under the supervision and

guidance of the student researcher. The student researcher was a graduate of the Lakehead University Honours Bachelors of Kinesiology program, was CPR-Health Care Provider certified, Kinesio taping Level One certified, and also certified in wrapping and taping. For the warm-up, the participant was then asked to cycle on the stationary bicycle for a total of 5-minutes at his/her own choice of intensity. By the end of the 5-minutes, the participant should have been able to transition into the intensity level that was required during that week of the protocol. The intensity for the aerobic exercise component on the stationary bike was individualized for each participant based on his/her resting heart rate. The Karvonen formula was used to calculate each participant's exercise intensity, based on his/her resting heart rate and age. The Karvonen formula was helpful as it considered the heart rate reserve (HRR) of each individual and was a relatively simple formula to calculate.

The Karvonen formula calculates exercise intensity as follows:

Target Exercise Heart Rate = [(220 – Age - Resting Heart Rate) x % Intensity] + Resting Heart Rate (Karvonen Method, 2007).

The resting heart rate used in the calculation was the resting heart rate that the participant presented with at the beginning of each session as indicated on the Polar FT2© heart rate monitor. Refer to Table 2 for the aerobic exercise intensities and progressions for each week.

Table 2.

Weekly Aerobic Exercise Protocol

Week	Cycling
1	First 10-Minutes: 40% of Max HR Second 10-Minutes: 45% of Max HR
2	First 10-Minutes: 45% of Max HR Second 10-Minutes: 50% of Max HR
3 and 4	First 10-Minutes: 50% of Max HR Second 10-Minutes: 55% of Max HR
5 and 6	First 10-Minutes: 55% of Max HR Second 10-Minutes: 60% of Max HR

During week one, the participant was asked to complete 10-minutes of cycling at 40% of his/her maximum target exercise heart rate and the remaining 10-minutes at 45% of the maximum target exercise heart rate. During week two, the participant was asked to complete the first 10-minutes of cycling at 45% of his/her maximum target exercise heart rate and then increased to 50% for the last 10-minutes. During weeks three and four, the participant was asked to complete the first 10-minutes at 50% of the maximum target exercise heart rate and the last 10-minutes at 55% of the maximum target exercise heart rate. During weeks five and six, the participant was asked to complete the first 10-minutes at 55% of the maximum target exercise heart rate and the remaining time at 60%. If an individual was not able to progress to the next intensity level, the participant remained at the level that the session began at, although none of the participants needed to resort to this during the pilot study. The reasoning behind having the aerobic session split into two intensity levels was to accommodate those individuals who could

not progress to the next level. Therefore, the individual would still be able to participate in the aerobic session and maintain his/her aerobic capacity, however, the participant would simply not be at the appropriate intensity level for that week or ready to progress to the higher intensity, again none of the participants needed to resort to this and were able to progress normally. This option to not progress is helpful with a concussed population as it allows the participant to continue exercise, without the worry of exacerbating the symptoms, therefore it is a built in safety measure.

The Canadian Society of Exercise Physiology (2012) suggests that adults between the ages of 18-64 years participate in at least 150-minutes of moderate to vigorous aerobic activity each week. Therefore, participation in this pilot study provided the participant with at least half of the required minutes each week, as well as the intensity level required. The given intensity levels were also chosen based off of past literature with participants with PCS which determined that lower intensity levels such as 20% of one's maximum heart rate was too low for any significant changes to occur (McGeown, Zerpa, Lees, Niccoli, & Sanzo, 2018). This protocol had been adapted and progressed from the recommendations made from previous studies with individuals with PCS and to determine whether it would be appropriate with healthy controls before being later being applied to the atypical population. Additionally, concussed participants subjectively reported that the intensity level of 20% of one's maximum heart rate was too easy and did not stress their cardiovascular system enough (McGeown, 2017). Therefore, moderate intensity levels were chosen as they provided a progression to higher intensity levels as to continuously and progressively stress the cardiovascular system for individuals with PCS.

Cervical strengthening exercise group. The participants who were randomly assigned to participate in the cervical strengthening portion of the pilot study completed 18, 15-minute

sessions throughout the 6-weeks of the MACV exercise program. The cervical spine strengthening exercises required the participant to engage in exercises that strengthened the deep flexor muscles of the cervical spine, however, they progressively became more difficult in nature with each passing week of the pilot study. Jull, O'Leary, and Falla (2008) developed the protocol for the Craniocervical Flexion Test that is used clinically to assess, treat, and retrain the longus capitis and longus colli muscles (Jull et al., 2008).

In addition to assessing the anatomical action of the deep cervical spine flexors, the Craniocervical Flexion Test (CCFT) is useful in differentiating cervical spine pain patients from controls and is sensitive to change as a result of a training program (Jull, Sterling, Falla, Treleaven, & O'Leary, 2008). The CCFT has been deemed useful in retraining the deep cervical spine flexors within a motor relearning program for individuals with cervical spine pain (Jull et al., 2008). Jull et al. (2008) also utilized a pressure biofeedback unit in their protocol; therefore, this supports the use of this protocol and device in the protocol used this pilot study.

During the first week and for the first cervical spine strengthening exercise, the participant was in position, with a Stabilizer™ Pressure Biofeedback Unit positioned under the lordotic curve of the cervical spine (Chattanooga, 2009). The participant was instructed to nod by contracting the deep flexor muscles of the cervical spine and slightly lifting their head off the bed. As the participant performed this movement, the back of his/her head made contact with the pressure biofeedback unit, which in turn produced a pressure value change that was displayed in mmHg. During the first week, the participant was asked to maintain 22 mmHg for 10 repetitions and for 5 seconds each.

During week two, the participant was asked to increase the contraction of the cervical spine flexor muscles producing a pressure to 24 mmHg. Participants completed 10 repetitions,

holding each for 10 seconds. During weeks three and four, the participant was asked to again increase the strength of the contraction of the cervical spine flexor muscles producing 26 mmHg for 10 repetitions and for 15 second holds. Finally, during weeks five and six, the participant was asked to maintain 28 mmHg for 10 repetitions and for 15 second holds each. The participants were asked to complete three sets at the appropriate pressure for each session during all 6-weeks.

The second exercise required the participant to retract the cervical spine pushing his/her chin back for a predetermined amount of time. These exercises were based off of the McKenzie method, which is considered to be a highly effective exercise program for patients with nonspecific spinal pain and also for strengthening the extensors of the cervical spine (Busanich & Verscheure, 2006). The McKenzie classification attempts to categorize neck pain into three syndromes (posture, dysfunction, and/or derangement) in response to the repetition of movement in the preferred direction (Lee et al., 2017). It provides an individualized self-care exercise program dependent on the clinical presentation of symptoms in the patient (Lee et al., 2017). Often individuals with cervicogenic PCS have weakness in the extensor muscles of the cervical spine; therefore, utilizing one of the proposed exercises of the McKenzie method allows the researcher to integrate this into the individualized program. This integration of the exercise from the McKenzie method supports the exercise plan and its roots being laid in the McKenzie method.

In weeks one and two, the participant was asked to complete 10 repetitions of this exercise in position holding for each repetition for 5 seconds and for a total of three sets. In weeks three and four, this exercise was progressed to a sitting position. The participant was asked to complete the same exercise for 10 repetitions but for 10 second holds. Finally, in weeks five and six, the participant was positioned in prone lying. The participant was asked to complete

10 repetitions of the retraction exercise holding the position for 10 seconds. The participant was asked to complete three sets for each exercise during each of the weeks. Refer to Figure 8 for an illustration of the cervical spine strengthening exercises.
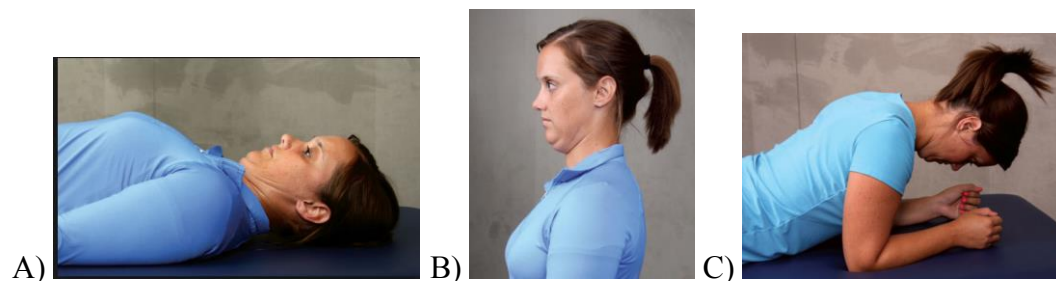

Figure 8. Supine lying retraction (A); Sitting Retraction (B); and Prone lying retraction exercises. Adapted from "Cervical Exercise: The Backbone of Spine Treatment," by Exercise Committee, 2012, Know Your Back. Copyright 2017 by the North American Spine Society.

Vestibulo-ocular retraining exercise group. The vestibulo-ocular exercises followed similar progressions to the other treatment groups, in that the exercises became more difficult with each week. During weeks one and two, participants were asked to contract the cervical spine flexor muscles and slowly look from the left to right side and then the participant looked up and down while holding this position for a total of three sets for 10 repetitions each. During weeks three and four, while in a seated position participants were asked to contract the cervical spine flexor muscles and turn his/her head from side to side while keeping the eyes staring straight ahead for a total of three sets of 10 repetitions. The last progression was completed in four-point kneeling during weeks five and six. The participant was asked to contract the short cervical spine flexor muscles and rotate the head from side to side while not moving the eyes, again for a total of three sets of 10 repetitions. The eyes remained still and staring straight ahead focused on a pen that was held by the researcher in the distance as the head moved; the participant was asked to keep his/her line of vision motionless while performing the task. If the

participant was unable to progress to the harder variation of the exercises, the participant was allowed to stop the exercises, or revert back to the easier exercises from the previous week. In the case of this pilot study, none of the participants were in need of reverting back to the easier exercises and were able to progress with each step.

The protocol for the stationary cycling, cervical spine strengthening, and vestibulo-ocular training was supervised, progressed, and controlled by the student researcher. The intensity of cycling and difficulty of the cervical spine and vestibulo-ocular exercises was slightly increased by the student researcher each week to ensure that the participants were appropriately and progressively challenged.

Post-Assessment. Once the 18 exercise sessions were completed, a post-treatment assessment was conducted and included all of the tests that were completed in the pre-treatment assessment and described previously.

Data Analysis

Statistical analysis was completed using IBM SPSS 25®. Descriptive statistics for demographic information such as age, height, weight, and sex were conducted to determine the means and standard deviations.

Descriptive statistics were conducted to examine the means and standard deviations for verbal memory, visual memory, visual motor speed, reaction time, and impulse control from the ImPACT® test battery. A two way mixed factorial MANOVA, four groups (control, aerobic conditioning, cervical strengthening, and vestibulo-ocular retraining) and time (pre-post) with repeated measures on the second factor was conducted to examine the interaction effect between these two independent variables on ImPACT® test battery scores (verbal memory, visual memory, visual motor speed, reaction time, and impulse control). Since an interaction effect was

not found between these two independent variables, discriminant analyses were conducted separately across time and across groups to examine the main effect of each independent variable on all dependent variables. Subsequently, univariate analyses using paired t-test for repeated measures were conducted to examine the main effect of time for each dependent variable separately.

Descriptive statistics were conducted to examine the means and standard deviations for CTHLT scores to examine cervical strength. A two way mixed factorial ANOVA, four groups (control, aerobic conditioning, cervical strengthening, and vestibulo-ocular retraining) and time (pre-post) with repeated measures on the second factor was conducted to examine the interaction effect between these two independent variables on CTHLT scores. Since an interaction effect was not found between these two independent variables, a one-way ANOVA was conducted across groups to examine the main effect on the dependent variable.

Descriptive statistics were conducted to examine the means and standard deviations for ROM scores to examine any change in cervical flexibility. A three way mixed factorial ANOVA, four groups (control, aerobic conditioning, cervical strengthening, and vestibulo-ocular retraining), six movements (flexion, extension, left side flexion, right side flexion, left rotation, and right rotation), and time (pre-post) with repeated measures on the third factor was conducted to examine the interaction effect between these three independent variables on degrees of movement. Since an interaction effect was not found between these three independent variables, main effects were analyzed across time and across groups to examine the main effect of each independent variable on the dependent variable. The main effect for movement type was not analyzed, as it is not clinically significant, as it would be expected that the different movement directions would have differing degrees of motion.

Chapter 4 – Results

The results of this pilot study provided evidence that supervised and individualized exercise programs are suitable and even provide some improvements for healthy individuals, which is to be expected as these individuals did not possess deficits in the areas tested that one may expect to see in a PCS population. There were improvements found in regards to ImPACT® battery test scores for neurocognitive function and reaction time as well as cervical spine strength when looking at pre- and post-treatment differences.

Demographics

Forty-one healthy participants were recruited into the pilot study, however, one participant had to withdraw due to an injury sustained outside of the pilot study. Therefore, 40 participants: control (n=10), aerobic (n=10), cervical (n=10), and vestibulo-ocular (n=10) exercise groups completed the pilot study and were included in the data analysis. The participants' anthropometric characteristics are summarized in Table 3.

Table 3.

Anthropometric characteristics of participants (Mean ± SD)

	Sex	Age (years)	Weight (kg)	Height (cm)
	Females 25	23.2 (2.2)	76.7 (19.9)	168.6 (9.5)
	Males 16	23.5 (2.9)	79.0 (13.2)	177.9 (6.7)
Total	40	24.5 (8.1)	78.2 (17.5)	172 (9.8)

Question 1: What is the effect of the exercise based programs compared to the control on cognitive measures of verbal memory, visual memory, visual motor speed, reaction time, and impulse control composite scores?

There was no statistically significant two way interaction effect between group assignment and time on ImPACT® test battery scores, $F(3, 36) = .488$, $p=.917$, Wilks' $\Lambda=.843$. When looking at the main effects, the discriminant analysis revealed a statistically significant difference across time for all dependent variables, $F(3, 36)=2908.1$, $p=.000$, Wilks' $\Lambda=.003$, $\eta_p^2=. 997$.The discriminant analysis, however, revealed no main effect among group assignment on ImPACT® test battery scores. The paired t-test univariate analysis for each dependent variable in relation to time revealed the following results:

Verbal memory. The paired t-test analysis revealed that there was no statistically significant difference between pre-treatment (M=91.8, SD=7.26) and post-treatment (M=93.2. SD=6.68) on verbal memory composite scores, $t(39),-1.485$, $p=.146$. Figure 9 illustrates the differences in verbal memory composite scores amongst the groups separately.

Figure 9. Group results pre- and post-treatment in ImPACT® verbal memory composite scores.

Visual memory. The paired t-test analysis revealed that there was a statistically significant difference between pre-treatment (M=78.2, SD=11.38) and post-treatment (M=84.2, SD=10.83) on visual memory composite scores, $t(39)$- 3.496, p=.001, d =-0.55. Figure 10 illustrates the changes in visual memory composite scores amongst the groups separately.
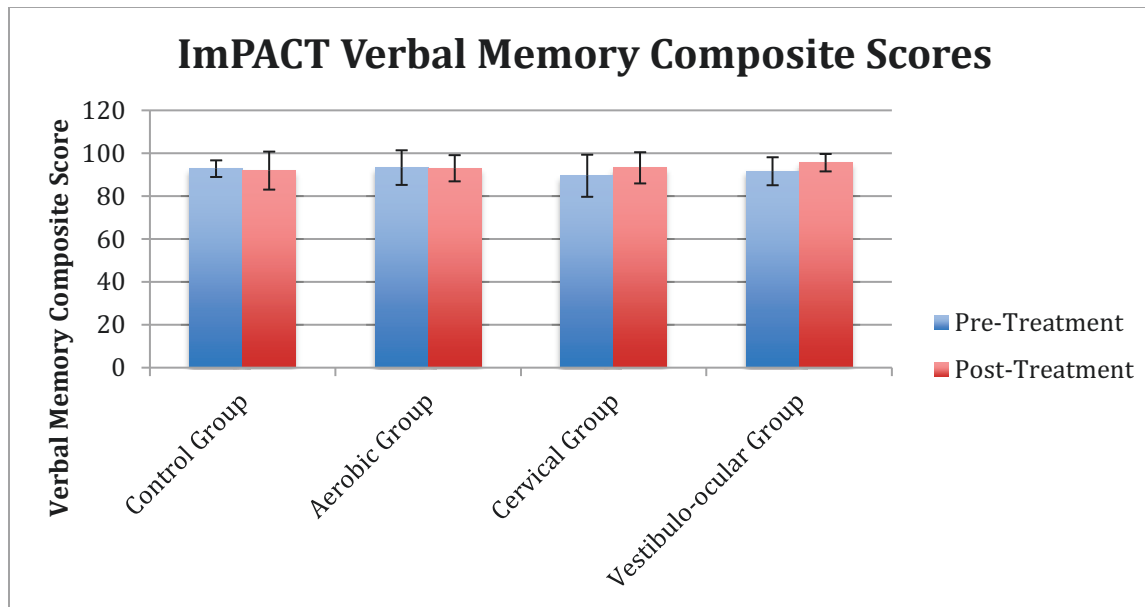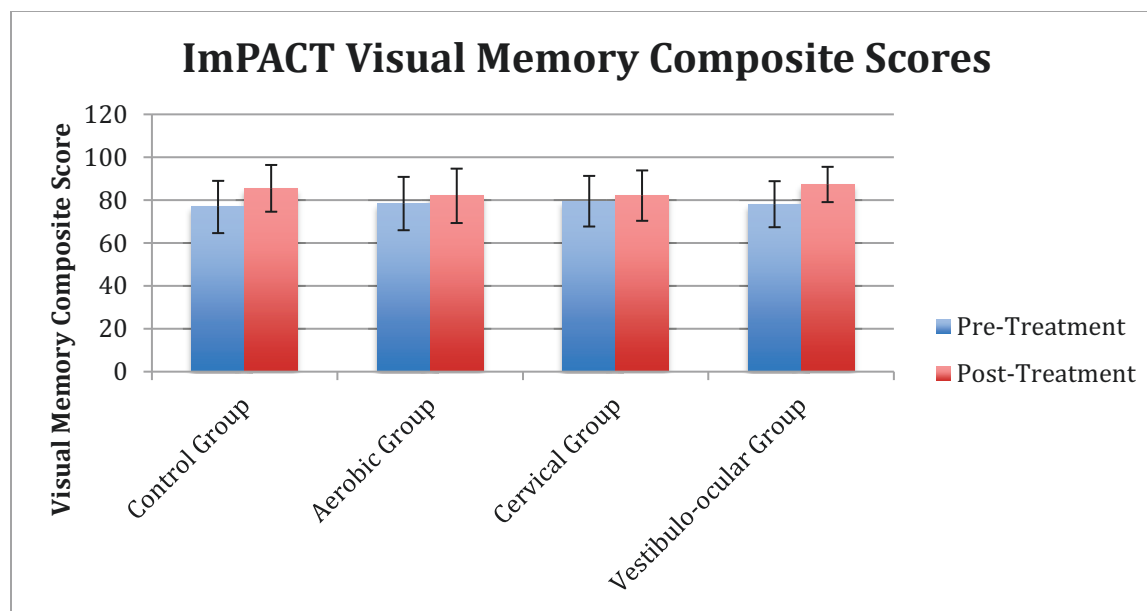
Figure 10. Group results pre- and post-treatment in ImPACT® visual memory composite scores.

Visual motor speed. The paired t-test analysis revealed that there was a statistically significant difference between pre-treatment (M=40.0, SD=5.85) and post-treatment (M=41.3, SD=5.54) on visual motor speed composite scores, $t(39)$,-2.712, p=.010, d=-.643. Figure 11 illustrates the changes in visual motor speed composite scores amongst the groups separately.
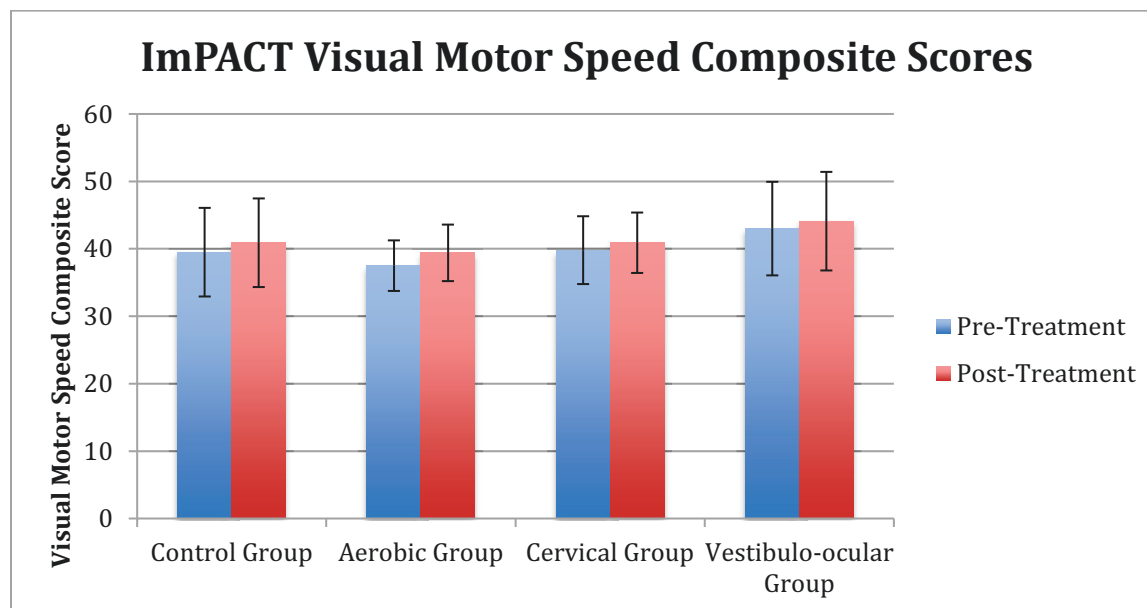
Figure 11. Group results pre- and post-treatment in ImPACT® visual motor speed composite scores.

Reaction time. The paired t-test analysis revealed that there was a statistically significant difference between pre-treatment (M=.63, SD=.08) and post-treatment (M=60, SD=.08) on reaction time composite scores, *t*(39), 2.658, *p*=.011, *d*=0.42. Figure 12 illustrates the changes in reaction time composite scores amongst the groups separately.
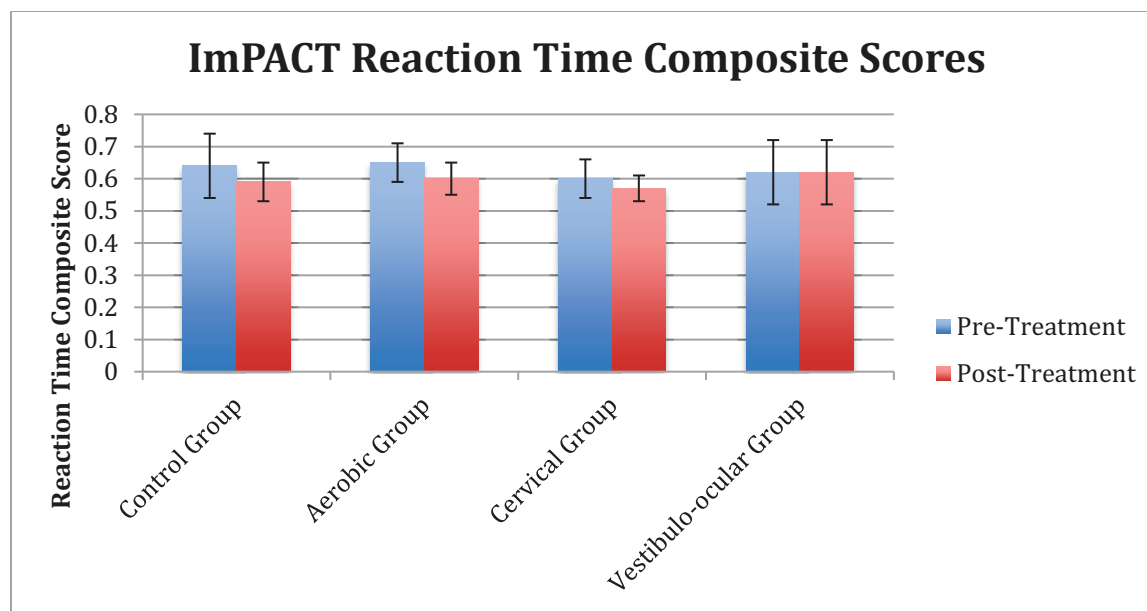
Figure 12. Group results pre- and post-treatment in ImPACT® reaction time composite scores.

Impulse control. The paired t-test analysis revealed that there was no statistically significant difference between pre-treatment (M=4.68, SD=2.91) and post-treatment (M=5.53, SD=4.70) on impulse control composite scores, $t(39)$, -1.395, $p=.171$. Figure 13 illustrates no significant changes in impact impulse control composite scores amongst the groups separately.

ImPACT Impulse Control Composite Scores
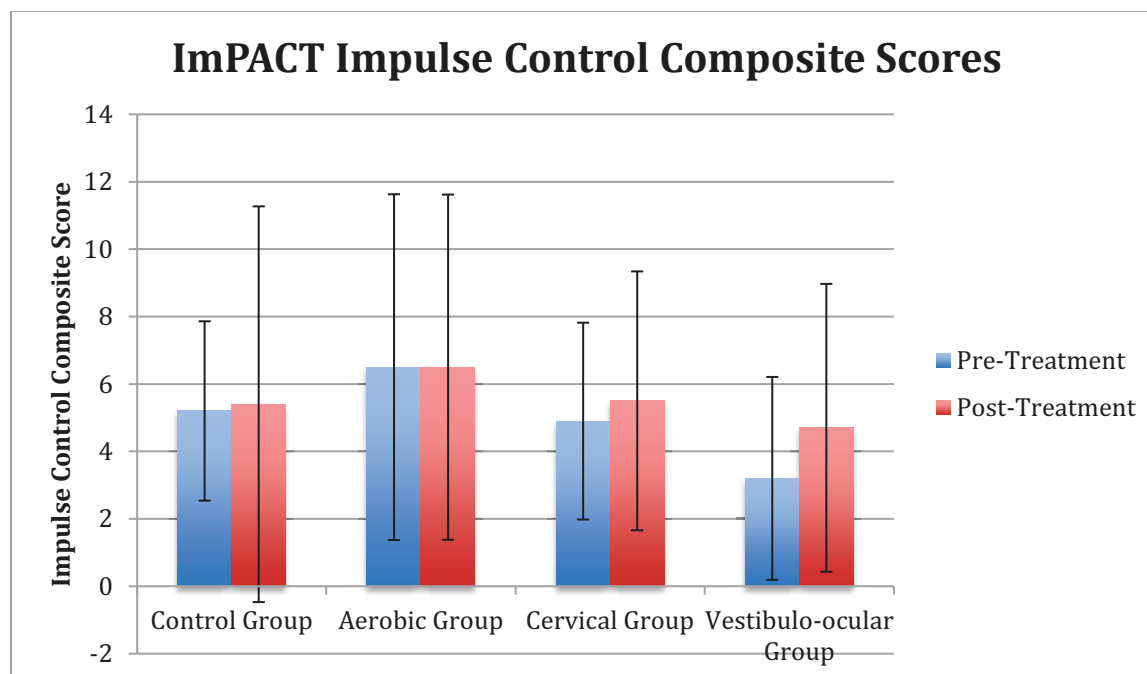
Figure 13. Group results pre- and post-treatment in ImPACT® impulse control composite scores.

Question 2: What is the effect of the exercise based programs compared to the control on strength measures of the cervical spine flexor muscles?

There was no statistically significant interaction effect between group assignment and time on the CTHLT scores, $F(3, 36)=2.070$, $p=.121$. There was no significant main effect on group, $F(3, 36)=2.070$, $p=.121$. There was, however, a statistically significant main effect of time on CTHLT scores, $F(3, 36)=6.639$, $p=.014$, $\eta_p^2=.156$. Figure 14 illustrates the changes in CTHLT scores amongst the four groups separately.
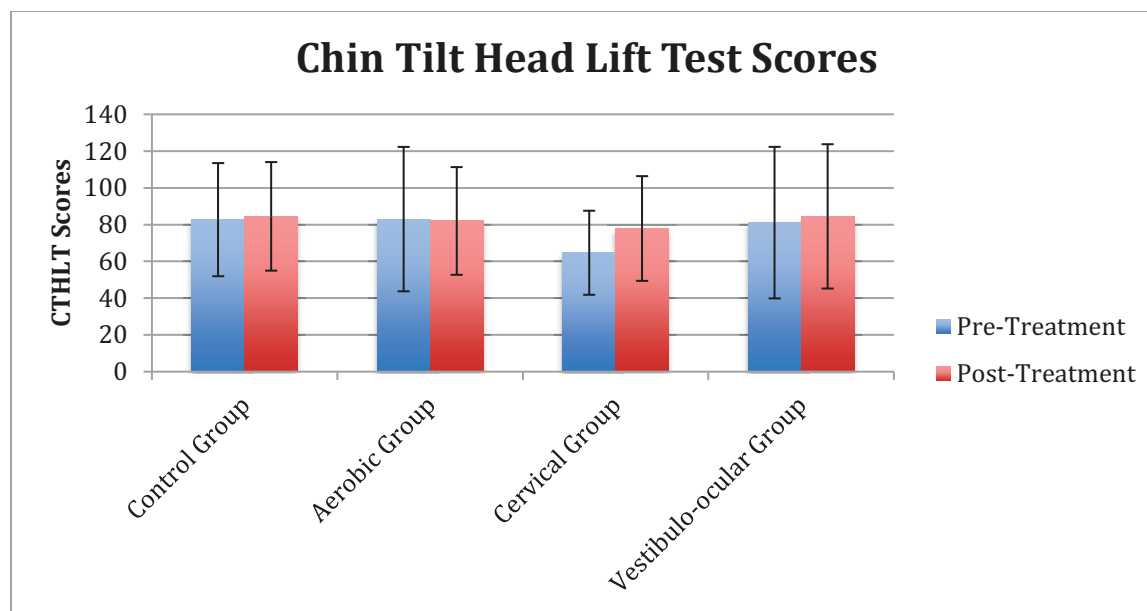
Figure 14. Group changes in CTHLT scores (seconds).

Although there were not significant differences between groups on CTHLT scores, some groups appeared to change more than others due to the intervention. Figure 15 illustrates the change from the pre-test to the post-test on CTHLT scores for each group. The difference in time (seconds) between the pre- and post-treatment scores is what produces mean change scores. This outcome seems to highlight whether there was an increase or decrease in the participant's ability to maintain one's position in the CTHLT. In more details, Figure 15 illustrates increases in the control, cervical, and vestibulo-ocular exercise groups' mean scores; the cervical and vestibulo-ocular exercise groups demonstrated the greatest increase in positional hold times with scores of 13.2 seconds and 15.3 seconds. The aerobic exercise group had a decrease in positional hold times of 1.0 second between the pre- and post-treatment.
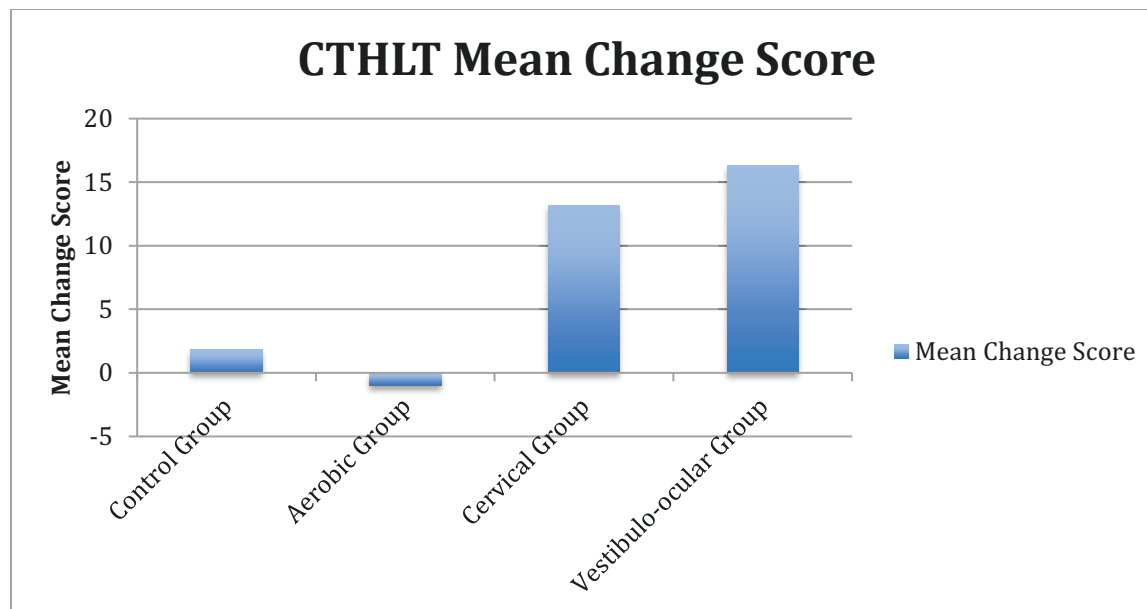
Figure 15. Group changes in CTHLT mean change scores (seconds).

Question 3: What is the effect of the exercise based programs compared to the control on cervical spine flexibility for forward flexion, extension, side flexion, and rotational movements?

There was no statistically significant three-way interaction effect between group assignment, time, and movement type on the degrees of motion in the cervical spine, $F(3, 36)=.683$, $p=.373$, Wilks' $\Lambda=.740$. There were, however, significant main effects for movement type, $F(3, 36) = 175.277$, $p = .00001$; but not for time, $F(3, 36)=1.607$, $p=.213$ on degrees of motion in the cervical spine. The descriptive statistics for cervical spinal flexibility are summarized in Table 4.

There was no statistically significant two-way interaction effect between group assignment and movement type on the degrees of motion in the cervical spine, $F(3, 36)=.679$, $p=.799$. There was no statistically significant two-way interaction effect between group assignment and time on the degrees of motion in the cervical spine, $F(3, 36)=1.672$, $p=.190$.

There was no statistically significant two-way interaction effect between movement type and time on degrees of motion in the cervical spine, $F(3, 36)=1.565$, $p=.198$.

Table 4.

Descriptive statistics of degrees of motion for cervical spinal flexibility.

Group	Normative Values (Swinkels & Swinkels-Meewisse, 2014).	Control		Aerobic		Cervical		Vestibulo-ocular	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Flexion	M=60, SD =10.9	M=48.5, SD=7.26	M=48.6, SD=5.42	M=48.6, SD=9.29	M=48.6, SD=6.26	M=49.8, SD=8.87	M=46.2, SD=8.13	M=57.2, SD=10.55	M=54.6, SD=8.99
Extension	M=75, SD =10.3	M=66.4, SD=12.6	M=67.6, SD=11.7	M=73.2, SD=7.79	M=70.2, SD=8.19	M=66.2, SD=11.0	M=64.0, SD=9.52	M=79.4, SD=17.6	M=72.2, SD=12.3
Rotation (Left)	M=78, SD =8.0	M=60.4, SD=13.4	M=62.2, SD=9.01	M=62.4, SD=8.26	M=62.0, SD=10.5	M=60.3, SD=7.42	M=60.0, SD=8.27	M=69.9, SD=12.56	M=67.4, SD=7.24
Rotation (Right)	M=79, SD =6.6	M=63.2, SD=13.67	M=63.4, SD=10.54	M=68.4, SD=6.98	M=66.4, SD=13.91	M=64.2, SD=7.45	M=57.8, SD=9.26	M=70.2, SD=10.81	M=69.0, SD=9.85
Side Flexion (Left)	M=46, SD =7.5	M=38.7, SD=7.21	M=41.4, SD=5.82	M=39.2, SD=5.67	M=41.6, SD=5.95	M=37.4, SD=5.97	M=38.4, SD=4.30	M=43.2, SD=9.58	M=40.6, SD=8.38
Side Flexion (Right)	M=45, SD =7.5	M=36.0, SD=8.26	M=37.4, SD=5.34	M=37.4, SD=5.17	M=39.4, SD=6.11	M=33.2, SD=6.05	M=34.2, SD=3.58	M=41.0, SD=9.20	M=40.5, SD=7.82

Chapter 5 - Discussion

The purpose of this research was to investigate the impact of three different types of 6-week supervised and individualized exercise programs when compared to a control group on cognitive and cervical functioning in a sample of 18-35 year old healthy individuals. Additionally, this pilot study was also conducted to determine the possibility for future researchers to utilize these protocols when applying to patients with PCS, therefore a baseline was required to determine the effect on healthy controls. The four programs were composed of a control group, a moderate intensity aerobic exercise group, cervical strengthening group, and a vestibulo-ocular training exercise group. There were no statistically significant differences amongst the four exercise programs when assessing cognitive functioning and cervical range of motion. Again, there were no statistically significant results produced for the cervical spine strengthening, however, there were positive trends found in cervical strength for the participants who engaged in the cervical and vestibulo-ocular training exercise. The following chapter discusses in greater detail the results observed in the present pilot study to address the research questions.

Question 1: What is the effect of the exercise based programs compared to the control on cognitive measures of verbal memory, visual memory, visual motor speed, reaction time, and impulse control composite scores?

There was a statistically significant main effect of time on ImPACT® composite scores. After much debate, researchers have concluded that a concussion is a brain injury that results in a complex and abnormal pathophysiological process, which in turn, causes impairment in neurological functioning (Leddy, Baker, Haider, Hinds, & Willer, 2017). In addition to the impairment in neurological functioning, it causes a functional disturbance in brain processing

(Leddy et al., 2017). Structurally speaking, concussions are referred to as diffuse axonal injuries, which result in some degree of functional impairment (Clark & Guskiewicz, 2016). The diffuse axonal injury is a product of the overstretching and sometimes shearing of the axons that comprises the brain's deep white matter (Su & Bell, 2016). White and grey matter cells are responsible for creating a connective network within the central nervous system, which allows for the transportation of sensory and motor information and responses throughout the body's nervous system (Dean, Sato, Vieira, McNamara, & Sterr, 2015). Individuals with PCS who reported greater and more severe PCS symptoms were observed to have reduced grey and white matter integrity (Dean et al., 2015). A diffuse axonal injury often causes a disruption to a portion of the brain responsible for breathing, heart rate, and consciousness, which are often experienced at the time of injury and associated with individuals with physiological PCS (Clark & Guskiewicz, 2016). Individuals may also experience memory loss, cognitive deficits, and balance disturbances, which are all tested using the ImPACT® battery. Therefore, this pilot study utilized the ImPACT® battery to assess cognitive functioning as this protocol may be adapted by future researchers when applying to a PCS population. There is still limited research in regards to the effects of exercise based programs as rehabilitation tools for individuals with PCS. McCrory et al., (2017) concluded that individuals with physiological PCS should be prescribed individualized, symptom-limited aerobic exercises in order to improve the deficits experienced in autonomic instability and physical deconditioning. The current pilot study involved healthy controls as to determine whether the protocol would be suitable for future application to PCS patients. Therefore, these individuals should not have possessed physical deconditioning or cognitive deficits that one may expect to see in an individual with physiological PCS. This pilot study did not consider aerobic conditioning as a dependent variable

as it would be expected that these individuals could meet the physical demands of the aerobic conditioning group. Therefore, the ability of the healthy participants to progress seamlessly throughout the 6-weeks without difficulty is promising for future researchers who wish to employ this protocol for individuals with physiological PCS.

There is still a vast gap in the literature regarding the clinical utility and implementation of exercise based programs for individuals with PCS in an attempt to improve cognition. Leddy et al. (2013) equally divided eight participants with PCS into either an aerobic exercise group or a placebo stretching group, and four healthy non-concussed participants to act as a control group. All participants completed a math-processing task during an fMRI at the commencement of the study. Depending on their group assignment, the PCS patients then either participated in a 12-week aerobic exercise, or a 12-week low-intensity stretching program (Leddy et al., 2013). The healthy controls did not participate in any intervention. The participants in the exercise group, engaged in aerobic exercise at 80% of their maximum heart rate for 20-minutes per day, for six days a week (Leddy et al., 2013). This intensity level is drastically different from the current pilot study in that it utilized high intensity levels and gave a greater risk for symptom reproduction, thus creating a longer time back to activity. Therefore, lower intensity levels were chosen as to avoid set backs due to symptom reproduction. Upon completion of the study by Leddy et al. (2013), participants completed a second math-processing task during an fMRI. Prior to the start of the study, all of the PCS participants experienced abnormal brain functioning and possessed deficits in cognition, when compared to the healthy controls (Leddy et al., 2013). The second fMRI revealed that the PCS participants who engaged in aerobic activity did not differ from the healthy controls in regards to brain functioning, whereas the stretching PCS group still possessed abnormal brain functioning as evident on the scans (Leddy et al., 2013). Additionally,

at the time of the second assessment, participants who completed the aerobic exercise program as opposed to stretching program experienced greater exercise heart rate and possessed fewer symptoms (Leddy et al., 2013). The results from Leddy et al., (2013) suggested that aerobic exercise might be an effective rehabilitation protocol to consider and prescribe for individuals with PCS. The protocol from this pilot study is supported by the research conducted by Leddy et al., (2013) as it highlights the importance of participating in aerobic exercise post injury to improve cognition. Since the healthy controls in this pilot study did not experience adverse effects from participating in the aerobic group it is possible that it may be beneficial for participants with PCS. When comparing to Leddy et al. (2013), the intensity level was much higher and could have resulted in symptom reproduction and result in a set back in the rehabilitation process. If this pilot study was conducted with physiological PCS patients, it may provide a smoother transition from sedentary to active rehabilitation, as healthy controls did not experience difficulty with the increasing intensity levels.

Two randomized control trials involving 116 individuals revealed a statistically significant decrease in reaction time on the ImPACT® battery, when exposed to aerobic exercise for 20 minute intervals at a moderate intensity level in comparison to the control counter parts (Maerlender, Rieman, Lichtenstein, Condiracci, 2015; Thomas, Apps, Hoffmann, Hammeke, 2015). The results from the current pilot study support and mimic those of the studies described previously as there were statistically significant improvements found in reaction time scores. Thomas et al. (2015) examined 88 patients with acute concussion and found that an active exercise program produced statistically significant improvements in visual memory and reaction time ImPACT® scores with an exercise rehabilitation protocol when compared to their control counterparts. Similarly, participants in the current pilot study also improved in regards to visual

memory and reaction time, which supports the importance of aerobic exercise as it assists in cognitive rehabilitation. This suggested that exercise may be beneficial for individuals with physiological PCS who are experiencing cognitive deficits.

The ImPACT® battery was used in this pilot study to evaluate changes in verbal memory, visual memory, visual motor speed, reaction time, and impulse control in a group of healthy participants. Statistically significant differences were not detected for any of the composite scores when assessing the four groups separately. Although when further analyzed, it was found that time had a significant main effect on the five composite scores of the ImPACT®. Despite the random group assignment, all groups demonstrated improvements in visual attention and scanning, learning, memory, visual processing, visual motor response speed, and reaction time speed during the ImPACT® battery. These results concur with the findings of Maerlender et al. (2015), and Thomas et al. (2015), which is promising as only healthy controls were included in this pilot study and they all improved regardless of group assignment. The descriptive information suggests that there were greater improvements in visual memory, visual motor speed, and reaction time scores in the exercise groups when compared to the controls. Based off of the descriptive statistics it could be suggested that the aerobic exercise group produced the greatest differences amongst the treatment groups, although it was not statistically significant. This may be something to consider with a concussed population as they already possess deficits in the areas that the ImPACT® battery assesses, therefore, significant changes may become evident as compared to the healthy controls used in this pilot study.

The lack of differences amongst the groups in the present pilot study may be explained by a number of factors including the fact that the participants were healthy and free from cognitive impairments due to a concussion or PCS. Whereas a portion of the 116 participants

from the two studies described previously were suffering from concussion symptoms including deficits in cognitive function as noted on ImPACT® testing, therefore it would be expected that there would be a significant difference amongst the treatment groups (Maerlender et al., 2015; Thomas et al., 2015). The 40 participants involved in the current pilot study were healthy individuals who had not suffered a concussion or symptoms of one up to five years prior to engaging in the pilot study. Generally speaking, these individuals should not have possessed any deficits in this area; therefore, would not be expected to make significant improvements in cognition when an exercise protocol was implemented as it can be assumed based on their concussion history that there were none to begin with. There were some changes and improvements noted in the descriptive data, which is promising as these individuals are healthy and if the protocol were applied to PCS population with cognitive deficits, it may provide positive outcomes and improvements in symptoms as seen in the studies conducted by Maerlender et al., (2015) and Thomas et al., (2015).

Similar findings were reported by Miller, Adamson, Pink, and Sweet (2007) who completed preseason, midseason, and postseason assessments using the ImPACT® battery on 58 collegiate football players. These were healthy, currently enrolled, collegiate football players who had no known concussion history and were engaging in aerobic exercise and training. No statistically significant changes were found in the ImPACT® battery scores, which were expected, as these were healthy individuals who had not sustained a concussion or had PCS (Miller et al., 2007). Although, there were only improvements observed in three of the five composite scores in this pilot study, the lack of negative outcomes is not unexpected and the fact that there were not any negative effects and it was feasible to complete is promising. This is

foundational for future researchers as they may be able to apply a similar protocol to individuals with PCS to examine the effects of a similar rehabilitation strategy to determine its true utility.

Question 2: What is the effect of the exercise based programs compared to the control on strength measures of the cervical spine flexor muscles?

There were no statistically significant differences amongst the four groups when assessing changes in cervical spine flexor muscle strength. When viewing the descriptive data it should be noted that the cervical strengthening and vestibulo-ocular retraining groups had the greatest increases in CTHLT times.

The upper cervical spine is particularly vulnerable as it is the most mobile part of the vertebral column and is comprised of a complex neurovascular and proprioceptive system that has connections to the vestibular and visual systems in the higher centres of the brain (Leddy, Baker, & Willer, 2016). This highly complex system puts the cervical spine at risk for injury, as there are many nerves and the trigeminocervical nucleus that traverses the area and may be damaged during trauma. A concussion does not always require direct trauma to the brain but rather can be elicited from an injury to the cervical region. When symptoms extend beyond the normal healing timeframes, these individuals are often diagnosed with cervicogenic PCS; the symptoms experienced are generated from the structures in the cervical region and individuals do not respond to aerobic exercise in a similar manner to individuals with physiologic PCS (present with a limited aerobic exercise threshold in which symptoms are generated). The management of cervicogenic PCS may be treated with physical therapies including manual therapy (Kennedy, Quinn, Tumilty, & Chapple, 2017). The current pilot study utilized this information and provided exercises to the cervical strengthening group in hopes of improving CTHLT scores and overall cervical health. It is interesting to note that the participants assigned to the cervical strengthening

group, which involved physiotherapy based exercises, were the ones with the greatest improvement in cervical strength as seen in the CTHLT. Having the six weeks to progressively strengthen the deep cervical flexors could contribute to the increase in CTHLT scores in the cervical strengthening group. The vestibulo-ocular retraining group may have improved as a result of the exercises requiring some deep cervical spine flexor recruitment.

In their study, Kennedy et al. (2017) examined 46 patients, 32 of which had cervicogenic PCS. Of the individuals with cervicogenic PCS, 21 received physiotherapy treatment, specifically manual therapy to address the pain, weakness, and ROM restrictions in the cervical spine region compared to the 11 who were either not considered to require follow-up, referred on for cervical spine treatment, or did not return (Kennedy et al., 2017). The cervical spine treatment involved anyone or a combination of the following services; manual therapy, acupuncture, and stability exercises. The 14 who did not have cervicogenic PCS were referred back to the concussion service provider and did not receive physiotherapy cervical spine treatment (Kennedy et al., 2017). It was reported that the patients with cervicogenic PCS benefited the most from the specific manual therapy treatment to the cervical spine (Kennedy et al., 2017). The study described previously, highlights the importance of prescribing individualized treatment plans for the specific sub-categories of PCS, and in this case, the inclusion and importance of manual therapy and exercise directed to the cervical spine flexor muscles for patients with cervicogenic PCS (Kennedy et al., 2017).

Therefore, the current pilot study mimicked this in that there were treatment groups with interventions that would be specific to the subcategories of PCS. Individuals with cervicogenic PCS can be prescribed exercises to stretch and strengthen the deep flexor muscles of the cervical spine, in order to eliminate or ease the symptoms that are being experienced (Leddy et al., 2016).

The individuals in the cervical strengthening group even reflected the importance of prescribing cervical spine exercises, as they were the group with the greatest improvements in CTHLT scores. Individuals in the vestibulo-ocular retraining group were second in improvements, which could be attributed to their exercises involving the cervical spine and some strength to conduct.

The CTHLT was utilized to assess strength changes in participant's deep cervical spine flexors pre- and post-treatment. It should be noted that a longer CTHLT time is associated with stronger cervical spine flexor muscles as the participants could hold the position for longer periods of time. There were no statistically significant interaction effect between the group assignment and time on the CTHLT hold times. Change scores were calculated for the CTHLT with the change scores reflecting the difference between the pre- and post-treatment hold times for each group, with a positive change score indicating that there was an improvement in the length of time that the participants could hold the position. There was little to no difference observed between the control and aerobic groups, which is to be expected, as the rehabilitation protocol for these individuals did not involve, any exercises specifically involving the strengthening of the cervical spine musculature. Although they were not statistically significant, there were improvements observed with the cervical and vestibulo-ocular groups. This may be a result of both programs involving the cervical spine. The cervical group directly addressed cervical strengthening, whereas the vestibulo-ocular group completed exercises that indirectly involved the cervical spine. This is interesting to note, as the participants were healthy individuals who did not have any reported cervical spine injuries and/or deficits, yet still demonstrated some improvements. If this pilot study were to be strategically prescribed and applied to a cervicogenic PCS population, it may produce positive results, as these individuals may benefit from an exercise protocol that specifically addresses the deficits in this region.

Future researchers may be able to apply and utilize this protocol for individuals classified with cervicogenic PCS as it did not produce any adverse effects in this healthy group and even generated some improvement to some degree.

Question 3: What is the effect of the exercise based programs compared to the control on cervical spine flexibility for forward flexion, extension, side flexion, and rotational movements?

Individuals suffering from cervicogenic PCS often experience a combination of weakness in the cervical spine as well as limited cervical ROM. The cervical spine is a highly mobile area of the vertebral column, allowing it to move in multiple planes. Therefore, when injury occurs, these movements can become limited, prolonging the healing period for individuals with cervicogenic PCS.

Schneider et al. (2014) examined 31 participants with PCS who were equally and randomly divided into either a control or intervention group. Under the supervision of a physiotherapist and over an 8-week period, both groups were prescribed ROM exercises and encouraged to engage in cognitive and physical rest. The intervention group also received cervical spine and vestibular rehabilitation (Schneider et al., 2014). The intervention involved manual therapy of the cervical and thoracic spine regions, cervical neuromotor retraining exercises, sensorimotor retraining exercises, gaze stabilization, and standing and dynamic balance exercises. After 8-weeks, 73% of the participants in the treatment group were medically cleared to return to sport and did not possess any symptoms or symptom reproduction, as compared to the 7% in the control group (Schneider et al., 2014). This study provides further support that the combination of cervical spine ROM exercises and vestibular retraining may be beneficial in the treatment of individuals with cervicogenic and vestibulo-ocular PCS (Schneider

et al., 2014). The interventions completed in the present pilot study produced descriptive statistics that suggests there were positive improvements in cervical strength, with the greatest improvements found in the cervical strengthening and vestibulo-ocular retraining groups. Therefore, if these protocols were applied to individuals with strength deficits in these areas, it may produce positive results and assist these individuals in returning to normal daily living.

In the current pilot study, there were no statistically significant changes in the participant's cervical spine ROM. It is not unexpected as none of the four programs directly addressed ROM or provided stretching and flexibility exercises for the cervical spine. Generally speaking, the participants in this pilot study had relatively normal ROM for most movements of the cervical spine as seen in Table 4. It would not be unexpected for healthy controls to have no changes in regards to cervical ROM as their range was already within the normal limits. Additionally, none of the four protocols addressed cervical stretching directly, therefore, it would be expected that the ROM should remain consistent over the 6-weeks without any significant improvements.

Limitations

The pilot study was limited to a relatively small sample size in which prospective healthy participants were randomly assigned to one of four treatment groups. The small sample size may have contributed to the lack of statistically significant findings in the dependent measures. The small sample size also created a cohort that was close in age range, rather than being distributed to a wider age range and more representative of the general population impacting on the external validity. Additionally, with a larger sample size, ideally there would be an equal number of male and female participants, which can affect the outcomes on cognitive and cervical functioning as sex plays a role in both of these categories especially if applied to a concussed population

(Iverson et al., 2017). This pilot study had a greater number of females (n=25) than males (n=16), which can affect the response to the interventions.

Lastly, the lack of cervical stretching exercises limited the results of the ROM variables taken. Had there been cervical stretching exercises included in the prescription, there could have been a greater chance for positive results in regards to ROM in the cervical strengthening exercise group. Future researchers should expand upon this if increased cervical ROM is a desired result.

Future Directions and Recommendations

Future research should expand on the results found in this preliminary work to further explore the possible outcomes that these different exercise protocols may have on individuals who experience deficits in cognitive and cervical functioning related to PCS or other neurocognitive disorders. Future researchers should attempt to recruit more and an equal number of female and male participants spanning different ages across the lifespan in order to determine how individualized exercise protocols may impact on patients suffering from PCS. Future researchers may want to explore studies that are longer in duration as to ensure that aerobic conditioning and strengthening occurs. Researching the differences amongst a 6-week, 8-week, or up to a 12-week protocol may be beneficial in determining the ideal treatment time for changes to occur. It may also be beneficial for researchers to identify specific individuals who are suffering from physiological, cervical, and/or vestibulo-ocular PCS and assign them to one of the four groups based off of their symptoms and presentation rather than being randomly assigned but more prescriptive in nature. Having a symptom specific rehabilitation protocol that is prescribed based on the assessment findings and diagnosis may be more representative of how

this can be applied in a clinical environment and truly demonstrate the clinical utility of the exercise protocol.

Chapter 6 - Conclusion

The purpose of this pilot study was to investigate the impact of three different types of 6-week supervised and individualized exercise programs when compared to a control group on cognitive and cervical functioning in a sample of 18-35 year old healthy individuals. The findings of this pilot study concluded that there were no statistically significant differences between the four exercise programs when assessing cognitive functioning (visual memory, visual motor speed, and reaction time) during the ImPACT® battery and no statistically significant difference in cervical spine ranges of motion. Although, there were statistically significant main effects when assessing time for visual memory, visual motor speed, and reaction time. While they were not statistically significant, there were positive trends found in the strength of the cervical spine flexor muscles when participants engaged in the cervical and vestibulo-ocular training exercises. The findings in the current pilot study can serve as baseline and foundational research and are clinically relevant as they may suggest that individualized exercise programs do not adversely affect healthy controls, but rather help to maintain or even improve current levels of cognitive and cervical functioning. This provides promise to future researchers as they may expand these protocols when conducting larger studies applied to individuals suffering from PCS.

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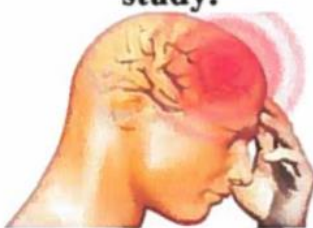*Neurosurgical Focus, 40*(4). doi: 10.3171/2016.1.FOCUS15593

Appendix A

Recruitment Poster

Lakehead UNIVERSITY

PARTICIPANTS WANTED FOR STUDY

The effects of moderate exercise on cognitive, cervical, and vestibulo-ocular functioning in healthy individuals: A pilot study.

Conducted by Amy Werden
School of Kinesiology
Lakehead University

Participants:

Healthy males and females aged 18-35 years, no musculoskeletal injury or condition that prevents you from exercising. Must be able to be physically active for ~ 150 minutes per week.

You will be asked to complete a PAR-Q form and answer a few questions prior to the study to ensure you are eligible. An initial assessment will be required; you may then participate in either 16 free exercise sessions (3 times per week) or serve as a control participant. A second assessment after the 6 weeks will be completed. Each session will be supervised by the student researcher and will require 5-30 minutes of your time. All sessions will take place in the multi-purpose laboratory (SB-1028) in the Sanders Building at Lakehead University.

This study has been approved by Thunder Bay Regional Health Sciences Centre Research Ethics Board
For additional information on the study or to participate, please contact:

Student Researcher: Amy Werden- alwerden@lakeheadu.ca, 807-709-0744

Version #1-December, 2017

Appendix B

VOMS Scoring Sheet

VOMS SCORING SHEET

Symptoms on a 0-10 point scale

Vestibular/ Oculomotor	Type	Not Tested	Headache	Dizziness	Nausea	Fogginess	Comments
Baseline Symptoms							
Smooth Pursuit							
Saccades (Horizontal)							
Saccades (Vertical)							
Convergence (Near Point)							Score#1_____cm Score#2_____cm Score#3_____cm
VOR Horizontal							
VOR Vertical							
Visual Motion Sensitivity							

Appendix C

Exercise Tracker

Exercise	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Type							
Duration							

Appendix D

Information Letter

![Lakehead University logo]

Lakehead
U N I V E R S I T Y

School of Kinesiology
t: (807) 343-8544
f: (807) 343-8944

Recruitment Letter For Participants

Dear Potential Participant,

My name is Amy Werden and I am a Masters Student in the School of Kinesiology at Lakehead University. I would like to invite you to participate in a research pilot study, titled "The effects of moderate exercise on cognitive, cervical, and vestibulo-ocular functioning in healthy individuals: A pilot study." The purpose of this research is to examine the difficulty level of implementing a supervised and individualized moderate intensity aerobic, cervical spine strengthening, and vestibulo-ocular training exercise plan in healthy individuals. Once this protocol is examined in this pilot study, this approach has the potential to be applied to concussed populations; currently only limited research exists regarding how, if at all, training programs may benefit individuals with persistent post concussion symptoms.

You are eligible to participate in this pilot study if you are between 18 and 35 years of age. You must not have suffered from any concussions or persistent symptoms in the past 5 years prior to the start of this study. You may take this letter home with you to review with anyone who you feel comfortable reading and consenting with, for example your family or family physician. Prior to the start of the pilot study, you will be asked to complete a consent form as well as an additional Physical Activity Readiness Questionnaire which is an assessment tool used to determine whether or not you can safely participate in the study. The form is attached in the information package and I will ask you to bring it to the first session, if you are interested in participating. However, it is entirely up to you as to whether you would like to participate in this study or not. You may refuse to take part in this research or stop at any point during the study without fear of consequences.

You will not be reimbursed for parking as the sessions will be short in length and located on the Lakehead University campus, where there is guest parking available.

The pilot study will involve a pre-treatment assessment that will take approximately 40-60 minutes of your time in the multi-purpose lab (SB-1028) in the School of Kinesiology at Lakehead University in the Sanders Building. Once you have completed the consenting process, your resting heart rate and blood pressure will be measured. You will then be asked to complete a 25 minute computerized assessment of your cognition that measures your attention span, memory, reaction time, impulse control, and problem solving abilities with the use of the Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. This computer-based test will be completed on a laptop within SB-1028. Your neck strength will then be tested with the use of the Chin Tuck Head Lift Test (CTHLT). Your neck flexibility will then be tested using a Cervical Range of Motion (CROM) device that measures in degrees how much you are able to rotate your neck and bend forward, backward, and side to side. Lastly, your vestibulo-ocular functioning is essentially your body's ability to coordinate your eyes and ears to allow you to navigate your way through your own environment. Your vestibulo-ocular functioning will be tested through the Vestibulo-ocular Motor Screening Assessment (VOMS), which will include 5

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mini tests within the assessment. The researcher will be observing and noting your ability to complete the tasks and whether or not any difficulty or symptoms have been reported.

Once the pre-treatment assessment is completed, you will be randomly assigned to 1 of 4 treatment groups. The first of which is a control group where you will not change your daily routine and simply be tested again after 6 weeks has past without any intervention. The second will be the aerobic group where you will complete 3, 25 minute aerobic exercise sessions each week for the entire 6 weeks. If you are assigned to the control group you will simply be asked to attend the pre and post assessments, as well as report weekly to the student researcher the number of minutes you participate in physical activity. If you are assigned to the moderate intensity aerobic group you will be supervised and guided by the student researcher a 5 minute warm-up, followed by 20 minutes of cycling on a stationary bike, which will remain consistent for each week. The exercise intensity on the stationary bike will be individualized based on your resting heart rate that was taken at the start of the study. The student researcher will utilize the Karvonen formula to determine your own individual exercise intensity. The Karvonen formula considers your resting heart rate, age, and the exercise intensity at which the researcher would like you to exercise at to determine the target exercise heart rate for that session. During week 1, you will be asked to complete 10 minutes of cycling at 40% of your maximum heart rate and the remaining 10 minutes at 45% of your maximum heart rate. During week 2, you will be asked to complete the first 10 minutes of the cycling at 45% of your maximum heart rate and then increase it to 50% for the last 10 minutes. During weeks 3 and 4, you will be asked to complete the first 10 minutes at 50% of your maximum heart rate and the last 10 minutes at 55% of your maximum heart rate. During weeks 5 and 6, you will be asked to complete the first 10 minutes at 55% of your maximum heart rate and the remaining time at 60%.

If you are assigned to the neck strengthening group you will engage in exercises that strengthen the deep muscles of the cervical spine, however, they will progressively become more difficult in nature with each passing week of the study. The first neck strengthening exercise will require you to lay on your back, with a pressure biofeedback unit positioned behind your neck. You will be required to nod and slightly lift your head off the bed as to maintain a predetermined unit of pressure. As you are completing the exercises, the back of your head makes contact with the pressure biofeedback unit which in turn produces a pressure value that is displayed in mmHg when you move your neck. During the first week, you will be instructed to maintain 22 mmHg for 10 repetitions and for 5 seconds each. During week 2, you will be asked to increase to 24 mmHg with 10 repetitions and holding for 10 seconds. During weeks 3 and 4, you will be asked to increase to 26 mmHg for 10 repetitions for 15 seconds each. Finally during weeks 5 and 6, you will be asked to maintain 28 mmHg for 10 repetitions for 15 seconds each. You will be asked to try to complete 3 sets of the exercises at the appropriate pressure for each session during all 6 weeks. The second exercise will require you to push your chin back as if you were to create a double chin for a predetermined amount of time. In weeks 1 and 2, you will be asked to complete this exercise while laying on your back and completing 10 repetitions for 5 seconds each. This will then be progressed to a sitting position in weeks 3 and 4 and you will be asked to

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complete 10 repetitions for 10 seconds each. Finally while lying on your stomach for the last progression in weeks 5 and 6, you will be asked to complete 10 repetitions for 10 seconds each. Similar to the first exercise, you will complete 3 sets each session for this exercise.

If you are randomly assigned to the vestibulo-ocular retraining group you will participate in vestibulo-ocular exercises, which will follow similar progressions and become more challenging as the study progresses. During weeks 1 and 2, you will be asked to contract the short neck flexor muscles and slowly look with your eyes from left to right and then up and down while holding this position for a total of 3 sets of 10 repetitions each. During weeks 3 and 4, while in a seated position you will be asked to contract the short neck flexors and turn your head from side to side while keeping the eyes staring straight ahead focused on an object in the distance for a total of 3 sets of 10 repetitions. The last progression during weeks 5 and 6 will be completed in 4-point kneeling. You will be asked to contract the short neck flexors and rotate your head from side to side while not moving your eyes, again for a total of 3 sets of 10 repetitions. Your eyes must remain still and staring forward as the head moves; you will be asked to try to keep your line of vision motionless while performing the tasks. If you are unable to progress to the harder variation of the exercises, you may stop the exercises, or revert back to the easier exercises from the previous week. Throughout these exercise sessions, the student researcher who is a Health Care Provider Level C and First Aid certified master's student will supervise you during the pilot study. The protocol for the stationary cycling, neck strengthening, and vestibulo-ocular training will be controlled by the student researcher; the intensity of cycling and difficulty of the neck and vestibulo-ocular exercises will be slightly increased by the student researcher each week to ensure that you are appropriately and progressively challenged. Once the 16 exercise sessions have been completed, a post-treatment assessment will include all of the tests that were completed in the pre-treatment assessment.

There are some potential benefits to participating in this study, first of which is if you are assigned to the aerobic training group you will be completing a total of 40-60 minutes of the recommended 150 minutes of moderate intensity exercise per session as per the Canadian Society for Exercise Physiology guidelines each week and may have improved cardiovascular conditioning and neck strength and range of motion. Also. the information obtained from this study may be used in the development of future studies involving patients who have sustained a concussion. The information gathered may guide future research and assist in the introduction of a new and effective rehabilitation protocol that may be applied to individuals with concussion.

There are minimal risks that are present if you choose to participate in the study. The student researcher has taken precautionary steps to minimize these associated risks. There is the potential to sustain a soft tissue strain or sprain during the exercise portion of the study and have some muscle soreness from exercising. In order to minimize this risk, you will be asked to complete a 5 minute warm up prior to the start of every exercise session and the student researcher will supervise all exercise sessions and guide you to ensure that the exercises are performed correctly and no injury occurs. Although, if you are experiencing any soreness you can excuse yourself

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from any one session or the study entirely without any repercussions. There is also a small social risk as some personal information is being collected and there is always a chance of loss of privacy. Therefore all the information that you provide will be strictly confidential and you have the right to decline answering any questions. Your name will not be used throughout the study but rather you will be assigned a number that will be used to identify you. Only the student researcher, Amy Werden, and her supervisor, Dr. Paolo Sanzo, will have access to the recorded data and personal information. All information will be securely stored in Dr. Paolo Sanzo's office at Lakehead University for 5 years. If you choose to do this please contact Amy Werden at 807-709-0744 as to give some notice. At this time, whatever data has been collected from your participation will remain with the student researcher; you may not withdraw this collected data. The time at which you quit the study may be useful in determining whether this program is feasible for future patients. Participation in this study is completely voluntary and you have the right to withdraw at any time without penalty.

The results from this study may be presented in a paper, oral presentation, and/or poster presentation as part of the course requirements for completing the Masters of Science in Kinesiology program. The abstract from this study may also be submitted for consideration for conference presentations and/or publication in an academic journal. Full anonymity and confidentiality will be maintained during the course of the study and the following research and presentations. You will not be named in any way and you may be provided with a copy of the results of the study, if you so choose.

This research has been approved by the Thunder Bay Regional Health Sciences Centre Research Ethics Board. If you have any concerns regarding your rights as a research participant, or wish to speak to someone other than a research team member about this research project, you are welcome to contact the:

Chair, Research Ethics Board
Thunder Bay Regional Health Sciences Centre
980 Oliver Road, Thunder Bay, Ontario, P7B 6V4
Phone: 807-684-6422 Fax: 807- 684-5904
Email: ResearchEthics_Chair@tbh.net

Also, please do not hesitate to contact me if you have any additional questions or concerns that you would like to discuss prior to your decision at 807-709-0744 or alwerden@lakeheadu.ca.

Thank you for your time and considering your participation in my research project.

Sincerely,

Amy Werden
Masters of Science in Kinesiology Student
School of Kinesiology, Lakehead University

JAN 1 0 2018
Research Ethics Board

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School of Kinesiology
t: (807) 343-8544
f: (807) 343-8944

Dr. Paolo Sanzo
Associate Professor
School of Kinesiology, Lakehead University

JAN 1 0 2018

Appendix E

Consent Form

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I, _____, agree to participate in a study entitled "The effects of moderate exercise on cognitive, cervical, and vestibulo-ocular functioning in healthy individuals: A pilot study". The purpose of this research is to examine the effect of a supervised and individualized moderate intensity aerobic, cervical spine strengthening, and vestibulo-ocular training exercise plan in healthy individuals. The pilot study will be conducted by Amy Werden, a Master's of Science in Kinesiology student at Lakehead University, and supervised by Dr. Paolo Sanzo, Associate Professor in the School of Kinesiology at Lakehead University.

I have read and understand the recruitment letter. I understand that participation in this study requires healthy individuals who have been cleared through the use of the PAR-Q screening questionnaire and who have also been concussion and symptom free in the past 5 years since the start of the study. I am between the ages of 18-35 years, and I am free from any musculoskeletal or spinal injury that prevents me from exercising. I understand that as part of the study I will be asked to complete a pre-treatment initial assessment, which will require about 60 minutes of my time. I will then be asked to participate in one of four supervised and individualized exercise programs. If assigned to the exercise groups, this will require me to attend 16 exercise sessions that will be approximately 5-25 minutes long, and will be completed over a six week period. If assigned to the control group, I will only be asked to attend the pre and post assessments at the beginning and end of the six week period. After the six week exercise program has been completed, I understand that the pilot study will conclude with a post-treatment assessment similar to the tests that I completed prior to the pilot study. I understand that the vestibulo-ocular system is the system where my eyes and ears work together to maintain my balance and spatial orientation when completing tasks. I understand that the assessments and exercise sessions will be held within the multi-purpose lab (SB-1028) at the Lakehead University in the Sanders Building.

I understand that there are minimal risks to participating in this pilot study, and the researcher has taken precautionary steps to minimize these associated risks. I understand an unlikely risk could be sustaining a soft tissue strain or sprain during the exercise portion of the study. "I understand that if I am assigned to the aerobic group that there are minimal risks associated with everyday aerobic activity". I understand that I will complete a warm-up prior to cycling to minimize this risk, and all exercises will be progressed and supervised by the student researcher. This student researcher has obtained her Health Care Provider CPR and First Aid and has graduated from the undergraduate Kinesiology program at Lakehead University. Working as a trainer, she has provided supervision, first aid, and rehabilitation to varsity athletes at Lakehead University in the past.

I understand that there are potential benefits to participating in this study. I understand that my participation in this study, if assigned to the aerobic training group, will allow me to complete 40-60 minutes per session of my recommended 150 minutes of moderate intensity exercise as per the weekly guidelines. I understand that my participation in this study and the

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information obtained regarding the feasibility of the exercise protocol may be developed into future research studies and subsequently beneficial to patients with concussion

I understand that my participation in this pilot study is completely voluntary and that I may withdraw at any time without penalty. I understand that my identity will remain anonymous and all of the data gathered will be kept confidential. Only Amy Werden and Dr. Paolo Sanzo will have access to this data and it will be securely stored in the office of Dr. Paolo Sanzo for a period of five years following the completion of the study. Lastly, I understand that I will be assigned a participant number to ensure that I remain anonymous throughout the entirety of this research.

I understand the requirements of participating in this pilot study and that I have read each page of this form. I confirm that this research study has been fully explained to me and all of my questions have been answered to my satisfaction. I have also been informed of the rights of a research participant and that I have the right to withdraw.

I understand that I will be provided with a copy of my results and the final study results after completion of the pilot study, if I so choose.

_____   _____

Participant's Signature   Date

_____   _____

E-mail Address   Phone #

If you wish to receive a copy of the results upon completion of the pilot study, please check the box below and provide a mailing address.

☐ _____