Effectiveness of Vodder manual lymphatic drainage massage in adolescents with post-concussion symptoms

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Abstract

Effectiveness of Vodder manual lymphatic drainage massage in adolescents with post-concussion symptoms

Miriam Gaudelli

Fourteen to thirty-five percent of people with concussions develop post-concussion symptoms that last 30 days or more; a condition termed Post-Concussion Syndrome (PCS). Symptoms include headaches, vestibular, visual emotional and psychological changes. Rehabilitation includes physical and eye exercises, manual pharmacological therapies. We propose an additional treatment called Vodder Manual Lymphatic Drainage Massage (VMLD) that treats inflammation and lymphedema. It is hypothesized that a VMLD protocol will decrease PCS symptoms compared to a touch control treatment. Twenty-three adolescents were recruited and nineteen were randomly divided into VMLD (n=10; 16.1 ± 1.4 years) and touch control (n=9; 16.1 ± 1.3 years) groups. Time from the last concussion was 590.2± 476.7 days for the VMLD group and 468.9 ± 542.9 days for the touch control group. Participants received 15 x 1-hour interventions over 54 ± 14.8 days. On appointments 1, 7 and 15, participants were evaluated using the Rivermead Post-Concussion Syndrome Questionnaire (RPQ) and the SCAT-5 5-word and 10-word recall, Number Concentration Test, Months in Reverse and Delayed Word Recall Test. A 2x3 ANOVA (GenStat statistical software) was used to test for treatment and time effect. There was no statistical difference between the groups. Both groups showed a significant time effect ($p<0.05$) for the RPQ, SCAT5 Number Concentration, and Delayed Word Recall Tests. VMLD and touch-control treatments exhibited symptom improvements in both groups based upon questionnaire scores. These treatments may be beneficial in post-concussion syndrome rehabilitation. More research needs to be conducted to assess the effectiveness of these treatments.

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Author Contributions

Miriam Gaudelli: Design of study, recruitment, data collection, provider or VMLD and touch-control treatments, data analysis and writer of original and final draft of thesis.

Dr. Robert Kilgour: Main supervisor, design experimental study, preparation of manuscript, editing of manuscript.

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List of Abbreviations

ADHD: Attention Deficit Hyperactivity Disorder

CNS: Central Nervous System

CT: Computed Tomography

CTE: Chronic Traumatic Encephalopathy

EEG: Electro Encephalography

fMRI: Functional Magnetic Resonance Imaging

LSD: Least Significant Difference

MRI: Magnetic Resonance Imaging

PCS: Post-Concussion Syndrome

PTSD: Post-Traumatic Stress Disorder

RPQ: Rivermead Post-Concussion Syndrome Questionnaire

SCAT5: Sport Concussion Assessment Tool 5th Edition

VMLD: Vodder Manual Lymphatic Drainage Massage

CHAPTER 1

Introduction

Concussions are mild traumatic brain injuries caused by impact that can have several long-term sequelae (Jagoda et al. 2018). Post-concussion syndrome is described as the presence of ongoing concussion symptoms (Kontos et al. 2016). The length of time the symptoms must be present varies between different research projects (Kontos et al. 2016; Wood 2004). For the purpose of this study, post- concussion syndrome is identified as the presence of symptoms for one month or more after date of injury (Babcock et al. 2013) Adolescents have been found to be the most susceptible to post-concussion syndrome (Babcock et al. 2013). At least 14-35% of adolescents will report lingering concussion symptoms (Leddy et al. 2012; Yeates et al. 1999), but some studies have shown that between 30-35% (Barlow et al. 2010;) of people who have suffered from a concussion suffer from post-concussion syndrome (Perrine and Gibaldi 2016). Children who suffer from concussions are more likely to have medical psychiatric visits and inpatient psychiatric hospitalizations as adults, decreased educational and career attainment, increased disability and welfare enrollment and premature mortality later in life compared to their non-concussed siblings. Concussion outcomes worsen as the number or severity of concussions suffered increases (Goswami et al 2016; Sariaslan et al. 2016; Alosco et al. 2017; Scorza et al. 2012.)

Symptoms of post-concussion syndrome are similar to acute concussions and can vary in type and severity (Broglio et al. 2015). An indicator of post-concussion syndrome is the presence of a headache at the time of injury that persists (Schwedt et al. 2016). Symptoms can include functional deficits (Sufrinko et al. 2017), physiological changes (Quintana 2016) and psychological fluctuations (Caron et al. 2017) and can be classified into different categories; cognitive, oculomotor dysfunction, headaches, cardiovascular and vestibular (Broglio et al. 2015; Sufrinko et al. 2017; Craton et al. 2017; Furman et al. 2010). Cognitive dysfunction includes changes in memory function, attention, concentration, auditory comprehension and mental processing of information (Bialunska and Salvatore 2017). Oculomotor dysfunction symptoms will include difficulty focussing, change in field of vision, photophobia (difficulty adapting to

bright settings), blurred and unstable vision, double vision, eye strain, decreased visual tracking (Sufrinko et al. 2017; Caron et al. 2017; Craton et al. 2017 Sandel et al. 2016). Headaches are an important indicator of a concussion and can also be an indicator of how long the symptoms will persist (Babcock et al. 2013). The type of headache experienced can range from migraines to tension headaches to cervical dysfunction headaches and post-traumatic headaches (Sufrinko et al. 2017; Sandel et al. 2016). Cardiovascular dysfunction can be caused by a parasympathetic dysfunction of the trigeminal system (Mclendon et al. 2016). Cardiovascular symptoms suffered are; exercise intolerance, altered heart rate adaptation, changes in autonomic nervous system responses and tachycardia (Sufrinko et al. 2017; Sandel et al. 2016). Vestibular responses are very often linked to the oculomotor dysfunction, especially in females (Sufrinko et al. 2017). Some of the symptoms linked to the vestibular system include; disequilibrium, dizziness, vertigo, nausea, discomfort in busy or noisy environments, sensory changes and a decrease in reflexes (Sufrinko et al. 2017; Caron et al. 2017; Craton et al. 2017; Sandel et al. 2016).

Post-concussion syndrome has many long-term debilitating repercussions that can last several months to several decades (Sorza et al. 2012; Sariasian et al. 2016; Clark et al. 2017; Goswani et al. 2016; Thomsen et al. 2016). Chronic Traumatic Encephalopathy (Omalu et al 2005), Amyotrophic Lateral Sclerosis (ALS) (Thomsen et al. 2016), Punch-Drunk Syndrome (Changa et al. 2018; Gardner and Yaffe 2015) and dementia (Safinia et al. 2016; Kamins and Giza 2016) have been linked to post-concussion syndrome. Long-term or lifetime symptoms usually experienced include depression, paranoia, agitation, impaired judgement, aggressive behaviour, suicidal thoughts, inability to function nor concentrate (Scwedt et al. 2017; Henry et al. 2017). It has been found that these symptoms can start as soon as time of injury to six months post-concussion (Scwedt et al. 2017; Henry et al. 2017). The psychological and cognitive effects will increase the occurrence of disability and welfare recipience (Sariaslan et al. 2016; Alosco et al. 2017). In the past, it was wrongfully thought that in order for persistent symptoms to occur, one had to lose consciousness. It has been shown that repetitive “smaller” head trauma can also cause the long-term outcomes that will worsen with age (Henry et al. 2017; Karnguth et al. 2017).

Assessment for concussions and post-concussion syndrome

Several diagnostic tools exist for the assessment of concussions and post-concussion syndrome. Neuroimaging tests such as magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), computed tomography (CT) and electro encephalography (EEG) are effective in diagnosing concussion and abnormal brain function (Leddy et al 2012; Patterson and Holahan 2012; Useche and Bermudez 2018. Neuroimaging tests are not very cost effective and seldom are prescribed without severe symptomology or loss of consciousness (Useche and Bermudez 2018) Thus, more cost effective and reliable assessment tools must be found.

Reliable questionnaires have been developed as a subjective tool to assess concussions and severity of symptoms, especially for the acute phase. The Sport Concussion Assessment Tool 5th Edition (SCAT5) is the widely accepted assessment tool for practitioners working closely with sports teams and those who have suffered a concussion. Included in the Sport Concussion Assessment Tool 5th Edition (SCAT5) are the following: immediate or on-field assessment protocols, red flag assessment, Glasgow Coma Scale, Maddocks Memory Assessment Questions, cervical spine assessment, athlete's history and concussion history, symptom self-evaluation, cognitive screening, immediate memory test, concentration tests, neurologic screen, balance examination, delayed recall test, and a section for practitioner notes and decision on return-to play documenting. The SCAT5 is an excellent tool to assess a symptomatic concussion due to the cost effectiveness and simplicity of the assessment tools and questionnaires Sufrinko et al. 2017; Echemendia et al. 2017).

Detecting the presence of post-concussion syndrome is often done with the use of the Rivermead Post-Concussion Syndrome Questionnaire (RPQ) (King et al. 1995). Assessing a concussion using only symptoms can lead to earlier return-to-play than would be recommended using neuroimaging, indicating that a decrease in symptoms is not a sign of complete healing (Vollmer et al. 2018). Parents asked to evaluate return to play or learning capabilities for their children or themselves by evaluating if symptoms are back to normal has proven to be inaccurate when compared to more comprehensive tests. The appearance of being "back to normal" does

not necessarily represent the level of healing achieved by the brain (Vollmer et al. 2018). Studies have shown that athletes are often cleared for full return to sport when assessing symptoms, but functional magnetic resonance imaging still shows decreased brain functioning compared to before the injury (Churchill et al. 2017).

The high cost of neuroimaging, and the lack of effectiveness of using only symptom-based diagnostics has led to the search of more selective tests. Specific biological markers have been found to predict the presence of a concussion with a saliva test. MicroRNAs are small endogenous RNA molecules that can be used as biomarkers for many illnesses (Bhomia et al. 2016; Abdul-Muneer 2016). There are 18-20 miRNAs that are found in mild to severe traumatic brain injuries, 10 of which occur in mild, moderate and severe concussions (Bhomia et al. 2016; Di Pietro et al. 2017). The 10 miRNAs linked to concussions were also detected in the cerebral spinal fluid of mild to severe traumatic brain injuries (Bhomia et al. 2016). Of the 10 miRNAs that were found to be linked to the saliva and cerebral spinal fluid in people who suffered a concussion, 3 in particular were linked to specific symptoms such as miR-320c-1 for memory difficulties, miR-629 for headaches, and let-7b-5p for fatigue (Johnson et al. 2017). The levels of the salivary miRNAs may also be an effective indicator of the duration, characteristics and severity of the various symptoms (Johnson et al. 2017).

In the presence of a concussion and repeated impacts to the head, there is a disruption in the blood/brain barrier that causes neuro-inflammation (Churchill et al. 2017). The inflammation, changes in transport of fluids and substrates in the brain combined with the structural changes of the brain, including the blood brain barrier, make it difficult to effectively use a blood test to diagnose a concussion (Bhomia et al. 2016; Churchill et al. 2017; Hay et al. 2016).

Rehabilitating individuals with a concussion

Return-to-play protocols have been developed to slowly bring an athlete back to full activity levels. The protocol begins with rest, then light exercise, sport specific drills, non-contact practices, full-contact practices and finally unrestricted return-to-play. Return-to

learning protocols include time to rest, reduced workload, simplified tasks with more detailed instructions and progressive return to full time work or school (Kirkwood et al. 2006; Patel et al. 2017; Prince, Bruhns 2017).

A return-to-play and to learning protocol is most successful with multi-modal rehabilitation protocols (Gagnon et al. 2009; Adams, Moore 2017; Lal et al. 2018). Extensive research has been conducted to assess concussion symptoms and determine the most effective rehabilitation interventions. Imaging done at the end of a rehabilitation protocol in football players has identified that even with a decrease in symptomology and medical clearance, signs of decreased brain function are still present (Churchill et al 2017). Traditional rehabilitation methods focus on a combination of rest, exercise, manual therapy, and cognitive and neuropsychological interventions (Grabowski et al. 2016).

Physical therapy rehabilitation protocols from controlled studies have been found to help 24% of people with post-concussion syndrome attain a symptom free state. The physical therapy protocols include a combination of manual therapy and graded exercise (Grabowski et al. 2016). In order to treat concussion symptoms in adolescents and children, a treatment plan must be created and continuously evaluated and adapted (Grabowski et al. 2016; Gagnon et al. 2016) for optimal results. Exacerbation of symptoms such as headaches, cervicothoracic dysfunction and vestibular dysfunction are possible if the rehabilitation protocol is too ambitious (Grabowski et al. 2016).

Symptoms have been found to decrease with a combination of physical, ocular, coordination and visualization exercises, education on the importance of the rehabilitation process and motivation exercises. All children in a controlled study that followed the mentioned combination of rehabilitation tasks were able to resume normal activities (Gagnon et al. 2009) with minimal symptoms. Before returning to play and full activity, it is important to do a full medical exam with a knowledgeable professional (Kirkwood et al. 2006). Seeking a consultation with a physician in a specialized clinic is suggested as only 32% of doctors remain up to date and follow concussion guidelines (Bazarin et al. 2001). Current rehabilitation protocols are effective in helping manage concussion symptoms but haven't proven effective in

restoring full brain function and preventing long-term diseases such as chronic traumatic encephalopathy, early onset amyotrophic lateral sclerosis (Thomsen et al. 2016) and punch-drunk syndrome (Changa et al. 2018; Gardner and Yaffe 2015).

Pathophysiology of concussions

Mild traumatic brain injury causes degeneration of white matter in the brain. The mechanical breakdown of the axonal microtubules will interrupt the transport of biochemical components of the brain and fluid (Ling et al. 2017) due to a disruption of the blood-brain barrier (Churchill et al. 2017). The mechanical breakdown causes a cascade of events (Henry et al. 2017) that includes an increase of tau proteins disrupting the microtubule assembly and disassembly in the axons which is known as taupathy. Accumulation of tau proteins has been linked with the long-term effects of post-concussion syndrome (Henry et al. 2017; Schwedt et al. 2017).

The structural and metabolic changes in the brain that occur after a concussion or several sub concussive impacts have been linked to inflammation in the brain, more specifically, intracellular edema (Eierud et al. 2014). The inflammation in the brain in post-concussion syndrome and the symptoms it causes, suggests that it should be labelled a post-inflammatory syndrome (Rathbone et al. 2015; Patterson and Holahan 2012). The underlying inflammatory mechanism will result in an increase in cytokines IL-β, IL-6, TNFα, and IFN-γ (Bhomia et al. 2016; Rathbone et al. 2015). The use of anti-inflammatory medications has been suggested in order to manage neuro-inflammation, but current available anti-inflammatory drugs have been found to be ineffective (Rathbone A. et al. 2015; Patterson and Holahan 2012). The brain initiates protective measures by acutely limiting cerebral blood flow which leads to the accumulation of lactate, waste and intracellular acidosis, possibly increasing the neuro-inflammation. The accumulation of inflammation, tau proteins and other metabolic waste in the brain could be due to the permeability of the blood/brain barrier not being large enough at rest (Sharma et al. 2014; Kawata et al. 2018).

Possible connection between the lymphatic system and the central nervous system circulation

The lymphatic vascular system in the body is responsible for the return of proteins, long-chain fatty acids, fluids, debris and immune markers. Föeldi et al.(1966) observed lymphatic vessels at the base of the human skull, making the first observation of a connection between the central nervous system (CNS) and lymphatic circulation. In the murine model, there is evidence of CNS lymphatics in the dura mater. Precise mapping of the meningeal lymphatic vessels of the brain and cranium in mice was discovered in 2015 (Louveau et al. 2015). The observation of lymphatic vessels at the base of the human skull and the mapping of the lymphatic vessels in mice collectively provide neuroanatomical evidence that lymphatic channels exist and these pathways could serve as a drainage system for the brain to remove any excess cerebral fluid (edema) and concussion-induced neuro-inflammatory cytokines such as IL-β, IL-6, TNFα, and IFN-γ (Patterson and Holahan 2012). It has also been indicated that stimulation of the lymphatic flow in and around the brain could contribute to a slowing in the progression of certain illnesses such as Alzheimer's (Peng et al. 2016).

Vodder Manual Lymphatic Drainage Massage

Vodder Manual Lymphatic Drainage Massage (VMLD) was created between 1932 and 1936 by Emil and Estrid Vodder in France. The couple focussed on the study of lymphology defined as the science of lymph and tissue fluid movement. In 1936, the massage movements and protocol were finalized which included low pressure circular movements and pumps in the direction of the lymphatic terminals to promote lymphatic flow. The technique and study of lymphology only started to be popularized in the 1950s when it started to be understood that the role of the lymphatic vessels was to clean tissues and take part on the defense and protection of the body. (Wittlinger et al. 2019 pg:132-135).

The goal of VMLD is to create a state of balance and homeostasis in the body fluid levels using gentle massage techniques. VMLD creates a stretch which dilates the lymphatic vessels, resulting in a pulsation of the intrinsic pacemakers that are present in lymphatic collector

vessels. As the pulses in the system increase, there is an increase in flow (Wittlinger et al. 2019 pg:38-41). The effects of VMLD include increased lymphatic flow, decrease in sensations of pain, relaxation, decongesting of tissues and fluid build-up. The effects on the immune system are currently being studied (Wittlinger et al. 2019 pg:42-44). Lymphatic drainage is primarily used in the treatment of lymphedema in the body (Weissleder and Schuchhardt 2008 pg:403-426).

Vodder lymphatic drainage massage (VMLD) has been found to be effective in treating lymphedema or swelling of the head and neck (Smith et al 2015; Mutti-Tacani et al. 2016), in the body (Smith et al 2015; Foeldi 1994; Harris 1994) and has been found to decrease intracranial pressure in individuals in a coma (Roth et al. 2016). VMLD has also been found to be effective in the treatment of chronic venous insufficiency (Milski et al. 2013) and has been found to induce relaxation in people who suffer from psychological stress (Jung-Myo and Sung-Joong 2014). Even when using self-care lymphatic drainage techniques, a decrease in arm-circumference and decreased occurrence of breast-cancer related lymphedema has been observed (Temur and Kapuca 2019; Ridner et al 2011). As Vodder lymphatic drainage massage has been successfully used to treat swelling and lymphedema in the head and neck of cancer patients (Smith et al. 2015), it could be hypothesized that it is a viable treatment for neuro-inflammation present after a concussion and/or multiple sub-concussive events. Unpublished case studies provide preliminary evidence demonstrating that post-concussion symptoms can be reduced over a period of 4- 15 VMLD sessions (see Appendix 1a). A possible mechanism for this observation is described in Appendix 1b.

VMLD could be a promising treatment for post-concussion symptom resolution and the possible prevention of inflammatory-related long-term effects of concussion(s) on the brain.

Study Details

Study Objectives

This randomized control pilot study has three study objectives:

1) to assess the effectiveness of 15 treatments of Vodder Manual Lymphatic Drainage (VMLD) massage therapy protocol using standardized post-concussion tests (Rivermead and SCAT5) in adolescents aged 13-18 with post-concussion symptoms.
2) to assess the effectiveness of 15 treatments of touch-control massage using standardized post-concussion tests (Rivermead and SCAT5) in adolescents aged 13-18 with post-concussion symptoms.
3) To compare the VMLD findings with that of an aged-matched "touch" control group.

Research Questions

There are three research questions that are matched to the study objectives.

1) Based upon the results of the Rivermead Questionnaire and the SCAT5 tests, will the number and severity of post-concussive symptoms be significantly ($p<0.05$) reduced following 15 VMLD treatments?
2) Based upon the results of the Rivermead Questionnaire and the SCAT5 tests, will the number and severity of post-concussive symptoms be significantly ($p<0.05$) reduced following 15 "touch" treatments?
3) Based upon the results of the Rivermead Questionnaire and the SCAT5 tests, will the reduction in the number and severity of post-concussive symptoms be significantly ($p<0.05$) different between the VMLD and "touch" groups following 15 treatments?

Research Hypotheses

Based on findings from a preliminary unpublished series of case studies (N=4) (Appendix 1) where post-concussion symptoms decreased from baseline levels following 6-15 VMLD treatments, it is hypothesized that the VMLD protocol of 15 treatments will significantly decrease post-concussion symptoms compared to the "touch" control group. There is a possibility that the "touch" control group will also show improvements in treatments. It is hypothesized that any improvements in the "touch" control group will be due to a placebo effect and will not be as consistent or significant as the VLMD group.

CHAPTER 2

Effectiveness of Vodder manual drainage massage on adolescents with post-concussion symptoms

Authors: Miriam Gaudelli and Robert D. Kilgour

Abstract

Background: Post-concussion syndrome can affect 30-35% of people including adolescents who suffer from concussions. Rehabilitation includes physical exercise, pharmacological interventions, eye exercises and psychiatric interventions but little is known on the effects of selected massage techniques such as Vodder manual lymphatic drainage massage (VMLD) and touch to the head and neck regions. The purpose of this study was to compare and contrast the effects of manual lymphatic drainage versus a control touch treatment on adolescents who suffer from post-concussion syndrome. **Methods:** Twenty-three adolescents were recruited and ninetenn participated in the study (13 female, 7 male) were randomly divided into a VMLD group (n=10; 16.1±1.4 years) and touch control (n=9; 16.1 ± 1.3 years) group. Participants were evaluated at baseline and after 7 and 15 treatments using the Rivermead Post-Concussion Syndrome Questionnaire (RPQ) and performance tests from the Sport Concussion Assessment Tool 5th EditionSCAT-5. A 2x3 ANOVA was conducted to determine if differences in questionnaire and performance scores exist between groups and over time. **Results:** There were no differences between groups with respect to any of the outcome measures. However, there was a significant decrease in the VMLD and touch-control RPQ scores from baseline to treatment 15 ($p<0.05$). Similarly, there was a significant decline in VMLD and touch in Delayed Word Recall scores from baseline to treatment 7 ($p<0.05$). There was an improvement in number concentration ($p<0.05$) in the VLMD and touch groups from baseline to treatment 15. There were no differences in the SCAT 5 (5- or 10-word recall) over the treatment period. **Conclusion:** Both VMLD and touch are effective interventions in reducing the post-concussion syndrome symptoms over a 15-treatment period. Health care professionals including RMTs should consider implementing massage/touch as a complementary intervention to existing rehabilitation treatments. Future studies need to be conducted to evaluate treatment, placebo, and time effect.

Introduction

Post-concussion syndrome occurs when concussion symptoms are persistent for more than one month after injury (Kontos et al. 2016). Reports of the incidence of post-concussion syndrome vary from 30-35% of people who have suffered from concussions (Adams and Moore 2017; Lal et al 2018). If symptoms persist, they can be quite debilitating which may have an additional psychological effect (Caron et al. 2017). Symptoms can generally be classified as physical, cognitive, and emotional (Sufrinko et al. 2017; Caron et al 2017; Craton et al. 2017). Cognitive deficiencies can involve forgetfulness, difficulty concentrating, and changes in long-term or short-term memory (Caron et al. 2017). Emotional symptoms include anxiety, feelings of depression, and tearfulness (Craton et al. 2017). Physical symptoms include muscle pain, changes in eyesight and balance, changes in sleep patterns, nausea, changes in hunger patterns and headaches (Quintana 2016). Headaches have been identified as a predicting symptom for post-concussion syndrome (Babcock. et al. 2013). Diagnosing concussions and post-concussion syndrome can be done using imaging techniques such as computed tomography (CT) (Useche and Bermudez 2018) scans and functional magnetic resonance imaging (fMRI)s (Churchill et al. 2017; Rosenthal et al. 2018), or with the use of questionnaires and functional tests (Echemendia et al. 2017). Many rehabilitation practitioners prefer the use of questionnaires such as the Sport Concussion Assessment Tool 5th Edition (SCAT5) (Davis et al. 2017; Echemendia 2017) and the Rivermead Post-Concussion Syndrome Questionnaire (RPQ) (King et al. 1995) due to cost effectiveness, ease of use, and to avoid potential negative side-effects from imagery radiation (Useche and Bermudez 2018). The RPQ has been shown to identify post-concussion syndrome (Thomas et al. 2017), but it does not meet today's psychometric standards (Eyres et al. 2004). Evidence has shown that the use of multi-modal assessment tools will help to better identify concussion sequelae and allow for better rehabilitation program design (Schneider 2019). The SCAT5 is a standardized multi-modal tool that includes a questionnaire, short- and long-term memory test, and concentration test. This screening tool has been used to assess athletes of all ages (13 years and older) in terms of their symptoms following head injury (Davis et al. 2017; Echemendia 2017).

Currently, rehabilitation interventions for concussions and post-concussion syndrome are quite similar. Rehabilitation programs include physical exercise, eye exercises, visualization exercises, vestibular rehabilitation, psychological evaluation and pharmacological interventions (Broglio et al 2015; Gagon et al. 2016). Despite the use of multi-modal rehabilitation protocols, imaging of the brain after terminating rehabilitation programs still indicates changes in the brain, calling for further improvement in the rehabilitation process (Churchill et al. 2017).

Recent studies have found the presence of inflammatory markers and an abnormal amount of proteins in the brain after a concussion and some researchers have referred to post-concussion syndrome as post-inflammatory syndrome due to the possibility of many symptoms being caused by the presence of inflammation (Rathbone et al. 2015; Patterson and Holahan 2012). At present, available rehabilitation tools including pharmacological interventions are not completely effective in treating the neuro-inflammation and excess proteins in and around the brain (Patterson and Holahan 2012).

Chronic swelling and lymphedema in the rest of the body have an excess of inflammatory markers and proteins similar to those found in the brain after injury (Wittlinger et al. 2019 pg29-60; Weissleder and Schuchhardt 2008 pg45; Rathbone et al. 2015) VMLD was created to treat problems with lymphatic flow, including chronic swelling and lymphedema (Mutti Tacani et al. 2013; Weissleder and Schuchhardt C. 2008 pg45). Studies have shown that VMLD is an effective tool in the treatment of lymphedema of the face, head and neck (Smith et al. 2015; Mutti Takani et al. 2016), and in the treatment of upper and lower limb lymphedema (Foeldi 1994; Harris 1994). Evidence suggests that lymphedema self-care along with maneuvers taught to patients will also help to decrease the incidence of lymphedema (Temur and Kapuca 2019; Ridner et al. 2011). Oncology massages have also been found to decrease pain, anxiety, fatigue and improve well-being and sleep patterns (Lopez et al. 2017). Research has also shown that the health and functioning of the lymphatic system in the brain is directly linked to the onset and progression of neurophysiological diseases. It has been shown that if the lymphatic flow around the brain is optimized to promote homeostasis, the progression of Alzheimer's may be delayed (Weller 2009). Evidence exists that VMLD may decrease intracranial pressure in coma patients with high intracranial pressure (Roth et al. 2016). To date, there is no information concerning the

influence or effectiveness of VMLD of the face, head, and neck regions on improving post-concussion symptoms following head injury.

Evidence for the need for better or more effective rehabilitation protocols that includes VMLD has led to the hypothesis of this pilot study. When compared to a touch control group, it is hypothesized that applying the VMLD protocol to a group of post-concussion syndrome adolescents will demonstrate greater decreases in post-concussion symptom scores on the RPQ as well as show significantly improved scores on the short- and long-term memory tests and concentration tests from the SCAT5 concussion assessment protocol.

Methods

Ethics approval was received from the Concordia University Ethics Committee (Project #: 30009665) on August 31, 2018 and renewed in August 2019. All massages were done in a clinical setting either at Clinique Santé et Physique Montreal Inc. in Dollard des Ormeaux Quebec or the Active Care Medical Group clinic in Kanata, Ontario. Treatments in Kanata were done in on Wednesdays and Fridays. Treatments in Dollard des Ormeaux were done on Tuesdays, Thursdays or Saturdays. The frequency most participants were able to schedule the research sessions was twice a week whether in Kanata or Dollard des Ormeaux. Many participants had to schedule around school, summer school, work, extracurricular activities and parents' schedules in order to get to the treatment sessions.

Recruitment was done using different media. Social media advertising was used to recruit participants in Dollard des Ormeaux and was done through the use of posts on the main researcher's Facebook and LinkedIn account, on Clinique Santé et Physique's Facebook business page and by posting in various groups such as West Island Community and West Island Community Advertisers and Sellers. Recruitment through the business networking groups BNI Fusion, BNI VIP and BNI Embassy was done through weekly announcements and discussions with members of the groups. Recruitment in Kanata was done through the Active Care Medical Group through direct contact between the potential participants and their pediatrician and pediatric nurse. In total, 5 participants were recruited through social media efforts and 18

participants were recruited through the medical clinic in Kanata, with the exception of one participant recruited in Kanata who travelled to Montreal for 3 research sessions.

Inclusion Criteria

i) Ages 13-18 years of age
ii) Diagnosed with a concussion within the last 12 months
iii) Presence of post-concussion symptoms
iv) Ability to communicate in French and/or English
v) Ability to attend all treatment appointments
vi) Ability to communicate with parent or guardian
vii) Need to be symptomatic at time of study

Exclusion Criteria

i) Loss of motor function
ii) Severe loss of cognitive function (unable to communicate, or total loss of memory)
iii) Loss of speech
iv) Need for hospitalization
v) Underlying neurologic, psychiatric and developmental conditions
vi) Use of neuro-modulating drugs (recreational)
vii) Contra-indications to VMLD (cardiac insufficiency, active infection, diagnosed and untreated blood clots, cold or flu)
viii) Removal of sections of the lymphatic system in upper body or presence of lymphedema

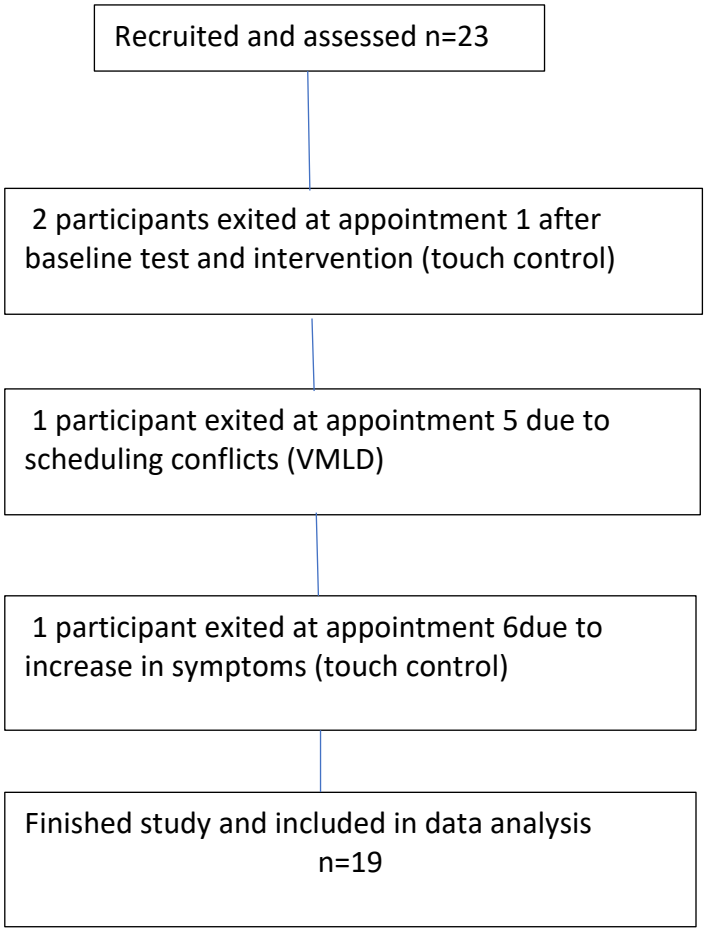


Figure 1: CONSORT diagram of the study.

Study Design

The pilot study was designed to include 20 participants being randomly assigned to either the VMLD test group or the touch control group. A total of 23 adolescents were recruited. After taking into account the dropouts, a total of 10 participants were assigned to the VMLD group and 9 participants to the touch control group (see CONSORT diagram). Each participant in both groups received a total of 15 treatment sessions. Each session was scheduled as a 60-minute session but lasted only 40 minutes except for sessions 1, 7 and 15. At appointments 1, 7 and 15, each participant completed the RPQ form and had the Immediate Memory 5-Word and 10-Word Memory test, Reverse Number Concentration test, Months in Reverse test and Delayed Word Recall test from the SCAT5 test sequence.

Interventions

All interventions were performed by the researcher (M.G.) who has been a registered massage therapist for 15 years and certified by the Vodder School in VMLD. All participants were given the same treatment as the others in their group. Traditionally, massage maneuvers are adapted and repeated in order to perform a proper VMLD treatment. For the purpose of the study, all maneuvers were performed based on the basic and advanced VMLD protocol of the head, neck and face consisting of 3 sets of 5 repetitions in each treatment position for each maneuver (Table 1)

General Location	Specific Location and Action
Back of head and neck	• Effleurage: Parallel rotary technique from centre of thoracic spine to cervical vertebrae. • Profundus/Middle/Terminal: Stationary circles with 4 fingers at base of cranium on neck, middle and terminal technique. • Occiput/Middle/Terminal: Stationary circles with 4 fingers at base of occiput, middle and terminal technique.
Standing at the head	• Horizontal Stationary Circles: Stationary circles in three locations from centre of head to base of ears, 3 different lines. • Vertical Stationary Circles: Stationary circles in three positions from top of head towards occiput. • Alternating pump and push movement from the occiput down the neck.
Shoulders and Deltoids	• Pump movement from the insertion of the deltoids to the terminus.
Upper Back	• Flat thumb circles; parallel along the spine and alternating towards right and left terminal

	• Soldiers: 4-point vertical pressure in three positions • Vibrating effleurage to terminate
Neck	• Cervical nodes: Stationary circles from angle of mandible to base of neck in 3 positions ending in terminal. • Occiput: Stationary circles in 3 positions from occiput to base of neck, ending in terminal.
Face	• Effleurage • Mandible: Stationary circles in 3 positions along mandible. • Upper Lip: Stationary circles in 3 positions (middle of upper lip, corner of lip, angle of mandible) • Repeat cervical movement • Nose: Stationary circles with 2 fingers from center of nose to base in 3 positions and along base from eyes to tip. • Long Voyage: Stationary circles on cheeks, corner of mouth, and mandible followed by spirals under chin. • Eyes: Stationary circles in 3 positions under eyes. • Pulling from the root of the nose towards the eyebrows. • Stationary circles in 3 positions over eyebrows. • Forehead: Stationary circles in 3 positions from center of forehead to hairline. • Side of head: Vertical stationary circles in 3 positions. • Repeat cervical movement • Effleurage

Table 1: Vodder Manual Lymphatic Drainage Massage basic and advanced maneuvers (Wittlinger et al. 201.9 pg:50-100)

Participants in the touch control group were given a treatment similar to the VMLD treatment. Where a lymphatic drainage maneuver would traditionally be performed by creating a stretch and minor twist in the skin by creating a pump and push, the area was gently touched.

Instead of performing 3 sets of 5 maneuvers in each position, the hands or fingers were placed on the area for 3 sets of 10 seconds in each position. Ten seconds was chosen because each VMLD maneuver takes 2 seconds to perform with 5 repetitions in each position.

Measures

Rivermead Post Concussion Questionnaire: All questionnaires were available in both French and English having been professionally translated for the purpose of the study. The RPQ is an accepted questionnaire for the detection of post-concussion syndrome in research. The questionnaire consists of 16 different symptoms and asks the participants to rate on a scale of 0-4 (e.g., 0: Not experienced at all; 1: Was a problem but no more; 2: A mild problem; 3: A moderate problem; and 4: A severe problem) how limiting each symptom is compared to before the concussion or concussions. If the participant indicated that the symptoms were greater than the lower number, but not quite severe enough to be at the higher number, the symptom score was rounded up. Participants were also asked to indicate if they suffered from any of the symptoms before their concussions (Appendix 4). The maximum score that could be achieved is 64.

SCAT5 Tests: The Immediate Memory tests from the SCAT5 include the 5-word recall test and the 10-word recall test. Each participant was given 5 words and asked to repeat them in any order. Each participant was given three tries to remember the words, with them being repeated each time. The number of words remembered was documented and totalled with a maximum total score being 15. The 10-word immediate memory recall test consisted of the participants being given 10 words to remember and repeat in any order. The words were repeated to each participant 3 times. The words remembered were marked down and added up at the end totalling a maximum score of 30.

The Concentration Number Test: This test consisted of giving the participants number sets and were asked to repeat the numbers in the reverse order given to them. The number sets consisted of 2 sets 3,4,5 and 6 numbers. Each set was repeated to the participants only once. Each number

set correctly recited in reverse order was given a score of 0.5. At the end, the scores were totalled with a maximum potential score being 4.

Months in Reverse test: This test consists of having the participant recite the months of the year in reverse order. If the participants were able to recite the months, they received a score of 1, if they were unable to recite the months, they received a score of 0.

Delayed Memory Recall test: This test was conducted 5 minutes after the Immediate Memory Recall test. The participants were asked to recite any words they recalled from the 5 Word test and 10 Word tests from the Immediate Memory Test. The maximum score that could be obtained was 15.

Statistical analyses

For the RPQ, SCAT5 5-word recall, 10-word recall, Number Concentration and delayed recall test a 2x3 ANOVA was fitted to the data, to compare the efficacy of the VLMD treatment and touch control groups (two fixed factors) over time (Appointments 1, 7 and 15). Model assumptions of normal distribution and a homogenous variance were graphed and checked visually. A square-root transformation needed to be used for the 5-word recall and the delayed word recall in order to obtain robust models. The Least Significant Difference (LSD) and 5% Type I error rate was used to do a pairwise comparison of means to check for a significant effect of time. In order to conduct these ANOVAs, the post-hoc LSD testing, the degrees of freedom used in the calculation of the *F*-ratio probabilities were Box-adjusted based on Box's test for symmetry (of the covariance matrix) and the Green-House Geisser epsilon value.

The measurement for the months in reverse only had a 0 or 1 score resulting in the inability to use an ANOVA measurement. The data was divided into three separate 2 x 2 contingency tables. Each contingency table was created for each of the visits and the frequency of either 0 or 1 reported was analyzed using a chi-square test.

One participant in the touch-control group dropped out of the study making the total number of participants used in statistical analysis n=19. All analyses were done in GenStat v.14 software (VSN International, Hemel Hempstead, UK).

Results

Participant Demographic

At the time of recruitment, participants were between the ages of 14 and 18 years of age. Seven of the participants suffered from four concussions or more (4 in the test group and 3 in the touch-control group.) In total, 23 participants were recruited but 19 completed the full study (see CONSORT diagram).

Table 2. Participant's characteristics

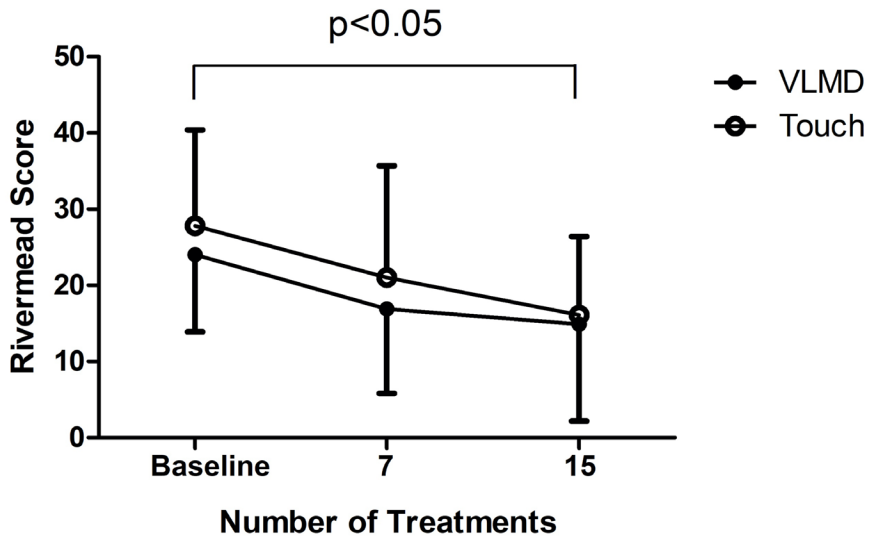
Variables	**Groups**		**P-value**
	VMLD n=10	Touch n=9	
Age	16.1 ± 1.4	16.1 ± 1.3	1.00
Sex	4M / 6F	3M / 6F	1.00
# of concussions	3.8 ± 2.5	2.4 ± 2.5	0.23
# of days from last concussion to treatment	590.2 ± 476.7	468.9 ± 542.9	0.60

There are three participants who were referred to the study by their pediatrician from the Active Care Medical Group who may have underlying conditions that were not reported until the end of the study. Participant 5 was diagnosed with ADHD and was being evaluated for anxiety. Participant 7 was diagnosed with PTSD and participant 10 was found to be on the spectrum.

Rivermead Post-Concussion Questionnaire

There were no differences between groups following the 15 treatment sessions. However, both groups experienced a significant ($p<0.05$) decline in RPQ scores from baseline to treatment 15 (Figure 2).

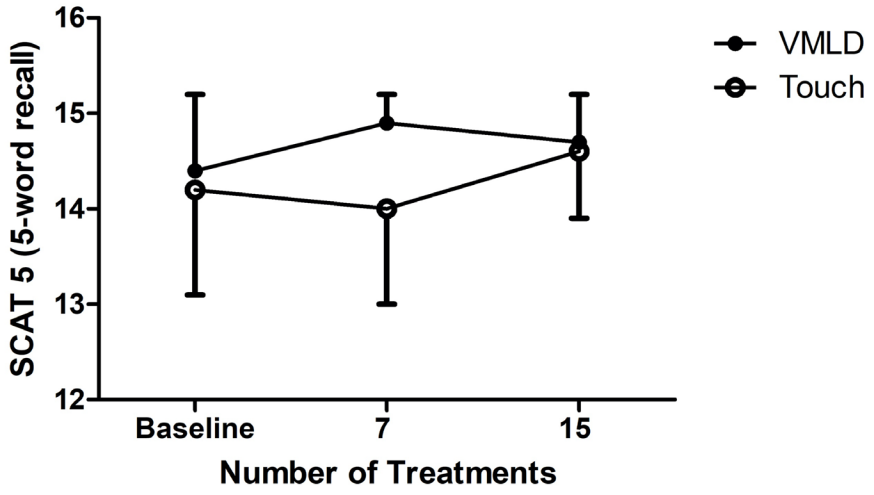
Figure 2. A comparison of the RPQ scores between the VMLD and touch control groups throughout 15 treatments



SCAT5 5-Word Recall

With respect to the SCAT 5 (5-word recall), there were no between-group differences nor was there any significant change over the 15-treatment period (Figure 3).

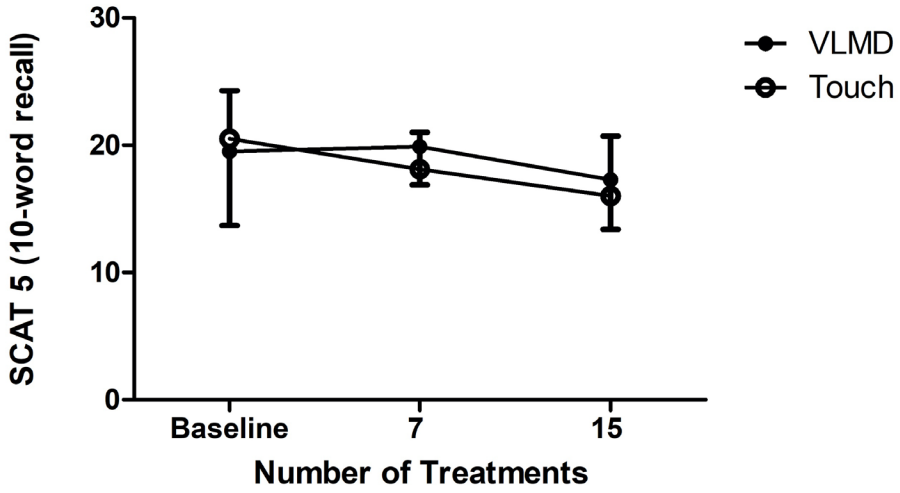
Figure 3. A comparison of the SCAT5 5-word recall scores between the VMLD and touch control groups throughout 15 treatments



SCAT5 10-Word Recall

There were no differences between groups nor was there any significant change in the SCAT5 (10-word recall) following 15 treatments (Figure 4).

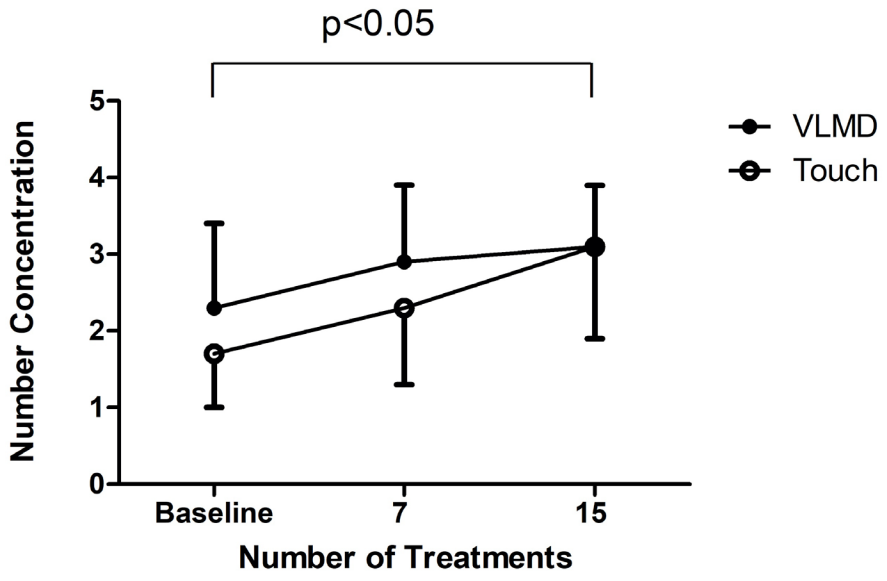
Figure 4. A comparison of the SCAT5 10-word recall scores between the VMLD and touch control groups throughout 15 treatments



Number Concentration Test

There were no differences between groups. However, the scores of the number concentration test in both groups improved significantly ($p<0.05$) following 15 treatment periods (Figure 5).

Figure 5. A comparison of the SCAT5 number concentration scores between the VMLD and touch control groups throughout 15 treatments



Months in Reverse Order

Using the Chi squared test to determine if the groups were able to recall the months in reverse order, neither group displayed any differences.

2 x 2 Contingency Table for Time 1

Pearson chi-square value is 0.00 with 1 d.f.

Probability level (under null hypothesis) p = 1.000

2 x 2 Contingency Table for Time 3

Pearson chi-square value is 0.69 with 1 d.f.

Probability level (under null hypothesis) p = 0.405

2 x 2 Contingency Table for Time 3

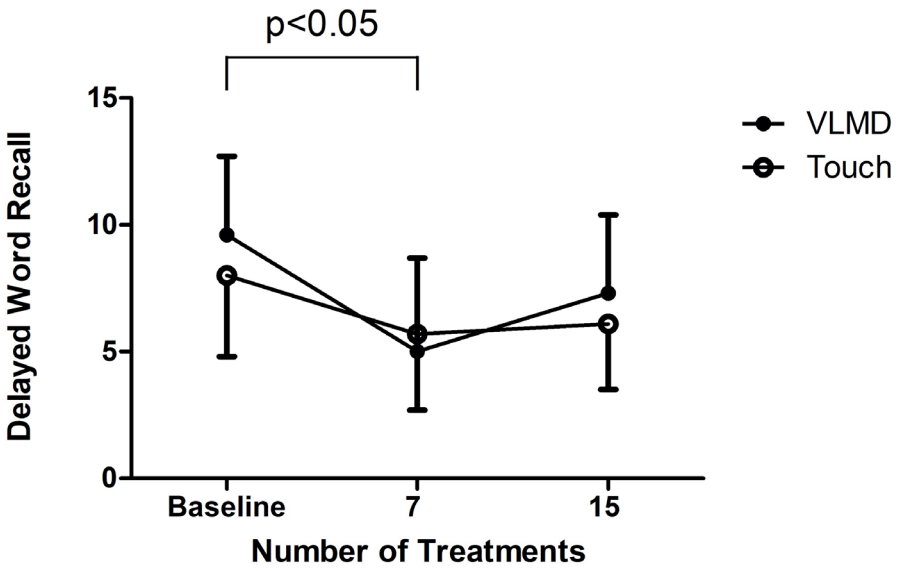
Pearson chi-square value is 0.15 with 1 d.f.

Probability level (under null hypothesis) p = 0.701

SCAT5 Delayed Word Recall

There were no differences between groups. Following a square-root transformation of the data, a significant change over time was detected with a "U" pattern because of the response at baseline and treatment 15. Thus, there was a significant decrease in the delayed word recall from baseline to treatment 7. However, from treatment 7 to 15, there was a significant increase in the delayed word recall (Figure 6).

Figure 6. A comparison of the SCAT5 delayed recall scores between the VMLD and touch control groups throughout 15 treatments



Discussion

This study tested the hypothesis that there would be a significant improvement in questionnaire scores in the VMLD group when compared to the touch-control group. This was based upon evidence that lymphatic channels existed in and around the brain and the base of the head (Louveau et al; 2015; Foeldi et al., 1966). With this evidence, we postulated that movement of the lymph around the face head and neck could possibly cause or facilitate drainage of the lymph from the brain. Lymph drainage from the brain may contain active cellular biomarkers that elevate whenever the brain is concussed (Bhomia et al. 2016; Eierud et al 2014; Rathbone et al. 2015). Although we find that this is still an attractive hypothesis, we did not observe any significant change in questionnaire scores that would reflect changes in post-concussion symptoms or performance. To the extent that the RPQ and SCAT 5 questionnaires are sensitive to changes in PCS, both the VMLD and touch interventions showed similar improvements over 15 treatment sessions. We uncovered a significant time-effect in both groups; over the 15-treatment time period, VMLD and touch control showed improved RPQ scores and SCAT 5 (5-word recall) and Number Concentration test. This finding reflects an overall improvement in the post-concussion symptoms.

There is a possibility that using a multi-modal evaluation protocol would have better identified if the participants were in fact showing improvement in their post-concussion symptoms (Adams and Moore 2017). Multi-modal evaluation methods incorporate symptom scores, eye tests, exercise and physical assessments along with vestibular and psychological assessments (Fuller et al. 2015; Howell et al. 2018; Ketcham et al. 2014; Kelly et al. 2014). Self-reported scores for concussions and post-concussion syndrome may not always detect all the symptoms that are present (Galea et al. 2019). The RPQ is widely used to identify post-concussion syndrome (King et al. 1995). The RPQ has come under scrutiny as it hasn't been shown to be valid for both concussion subtypes (Eyres et al. 2004; Thomas et al. 2017). Post-concussion syndrome symptoms can be divided into two different subtypes; dynamic (usually acute symptoms) and enduring (long-term or acute symptoms) (Prince and Bruhns 2017; Carroll et al. 2004) The RPQ has been shown to be accurate in assessing the enduring symptoms of PCS

which is why this questionnaire was selected to be used in this population of adolescents with PCS, but invalid for the dynamic symptoms (Vos et al. 2019; Thomas et al. 2017; Prince Bruhns 2017). Many dynamic symptoms are also grossly experienced by the general population such as nausea, headache, dizziness and fatigue on a daily basis (Prince and Bruhns 2017). Studies concentrating on the use of the RPQ assessment in post-concussion syndrome rehabilitation in adolescents only aren't readily available.

When comparing the SCAT5 symptoms questionnaire and the RPQ, there are several differences that can be noted, potentially affecting the precisionof the data collected. The RPQ consists of 16 symptoms that need to be scored from 0-4 and has a maximum score of 64. People are asked to rate 0 - as no symptoms, 1- was a problem but no more, 2 – A mild problem, 3 – a moderate problem, 4 – a severe problem. In the instructions, it is stated that the participants must analyze how they feel today compared to before their concussion (King et al. 1995). The SCAT5 symptom questionnaire has 22 symptoms that must be scored on a scale of 0-6 with a maximum total score of 132. Visually, the score columns are identified as 0 – no symptoms, 1, 2 – mild, 3,4 – moderate, 5, 6 – severe giving participants filling out the questionnaire more choices and visual cues (Echemendia et al. 2017). In non-concussed individuals, it was found that the average RPQ score was 12.7 ± 9.6 (Zakzanis et al). 2011). In one controlled study of symptomatic patients with chronic pain, it was found that the average RPQ scores reported were 27.3 (Stalnacke 2012). Interestingly, in another study, it was found that the mean RPQ score in both complicated and uncomplicated mild-traumatic brain injuries 3- and 6-months post injury was as low as 7 (Voormolen et al. 2019). The RPQ scores in this present study (VMLD 24 ±10.1; touch control 27.8 ± 12.57) are similar to the mean RPQ score of 27.3 in participants with chronic pain (Stalnacke 2012). Even at the end of the study, RPQ scores were still slightly more elevated than in a non-concussed sample size (Zakzanis et al 2011).

Physicians in emergency departments often use 22-symptom scale tests to identify the presence of concussion symptoms (Howell et al. 2018). The Sports Concussion Assessment Tool Third Edition (SCAT 3) was found to be an excellent tool to identify post-traumatic headaches (Begasse de Dhaem et al. 2017). It was found that in adults, the symptom scores and the test scores didn't always correlate with each other in identifying a concussion in adults (Sargeant et al.2018). The SCAT 5 was created to be a more inclusive and thorough tool to

identify a concussion by comparing test scores to baseline. A SCAT5 tool was created for children (up to 12 years old) and a separate one for adults (13 years old and over) to increase validity (Davis et al. 2017). The evaluation includes date of injury, time of injury, on field evaluation (red flags, observable signs, Maddocks Questions memory assessment, Glasgow Coma Scale and cervical spine assessment). The office or on-field portion of the assessment includes the athlete's background and history, symptom evaluation, cognitive screening (immediate memory, digits backwards, months of the year in reverse. The physical portion includes a neurological screen, balance examination followed by the delayed word recall test (Davis et al. 2017; Echemendia et al. 2017). Being a fairly new assessment tool, research studies are currently being conducted to test validity. It was found in collegiate athletes in the NCAA (17/18 years old and older) in the United States of America that international athletes tended to score higher on the SCAT 5 and ImPACT questionnaires putting into question if a cultural difference in response methods may exist (Norheim et al. 2019). A loss of insight after a concussion may also affect the ability to precisely answer the symptom scale questionnaires (Sargeant. et al. 2018). The SCAT 5 summary score has been found to be a reliable tool in the detection of a concussion and in creating a reliable baseline value for athletes. Research has not yet been done to test the reliability over a longer timeline such as in post-concussion syndrome rehabilitation (DaCosta et al. 2019). Studies focussing only on adolescents 13-18 years of age are not readily available.

Touch in and of itself is also being researched as a potential tool for communication and healing (Kraus 2010; Hertenstein et al. 2006; Rodrigues et al. 2009). NBA players who had more physical contact by touching each other more often at the beginning of the season, showed improved performance on an individual and team level as the season progressed (Kraus 2010). Touch has also been shown to be a way to communicate emotions and feelings (Hertenstein et al. 2006). In a study conducted, it was also found that holding hands with a familiar person or stranger was able to decrease feelings of being threatened in a fMRI model (Musial and Weiss 2014). It has been shown that with Healing Touch Treatments, oncology treatments can be more effective however the mechanism by which this happens is unknown (Hart et al. 2011). In the touch-control treatment, the participants were touched for the same amount of time that the

VMLD group was touched and could have therefore benefitted from the human contact experienced during the treatment.

In stroke patients, it was found that gentle massage therapy strokes of 2.5 Newtons decreased feelings of anxiety and pain. By the end of the study protocol, stroke patients who had received gentle massage strokes experienced an increase in health-related quality of life and an improvement in sensorimotor functions as well as an increase in brain activities in areas that process pleasure (Lamas et al. 2016). C-fibres that are associated with hair in the skin are part of the somatosensory system as they are sensitive to touch and form a second touch system can be affected by touch. Stimulus such as a light touch or breeze is all that is needed to create a response. The CT system is likely what induced the autonomic responses with pleasant touch such as relaxation (Musial and Weiss 2014). Many enduring symptoms in post-concussion syndrome are related to psychological symptoms such as feelings of anxiety, depression and restlessness, (Craton et al. 2010) some of the same symptoms shown to have improved in the touch massage studies.

The treatment used in the touch-control group was created for the purpose of the study to mimic the VMLD treatment as closely as possible. It has been found that in lymphedema treatment and prevention, even when self-administered, VMLD can help to decrease the onset or severity of lymphedema (Temur and Kapuca S. 2019; Ridner et al. 2011). It is possible that both groups experienced positive outcomes during the study because the touch-control treatment so closely mimics VMLD.

It has been shown that diabetes patients who are more closely followed by physicians have more positive outcomes in diabetes patients (McAlister et al. 2007). Fifteen of the twenty participants, 7 in the control group and 8 in the test group were referred by their treating physician who is a concussion specialized pediatrician. The fifteen participants had weekly or bi-weekly check-ins with their physician allowing for regular adaptations to medications and treatment protocols. Patients who are regularly followed by medical professionals have a decreased chance of being misdiagnosed and improves the chances of being diagnosed of co-morbidities (Prince and Bruhns 2017; Kaye et al. 2010). In pediatric concussion management,

pediatricians tend to be the primary physician; however, updated concussion research and protocols are not readily available to them (Kaye et al. 2010). Improvements can be seen when patients are followed up with appropriate care (Kaye et al. 2010). There is the possibility that the regular physician follow-ups compared to medical appointments every several weeks to several months can improve patient outcomes.

CHAPTER 3

Limitations

Several limitations were identified in numerous different areas including participant selection, other forms of rehabilitation, use of questionnaires for concussion rehabilitation tracking, and scheduling times.

The age, activity levels, and education of the participants varied greatly and may have influenced our findings. Some participants had a full activity level (e.g., work/school and leisure) while other participants were still unable to return to school, work or physical activity. Any changes in physical activity or intellectual activities were not formally tracked. Since the sample size was relatively small, we were unable to stratify according to activity levels. In order to properly compare groups and participants, it would be favourable to match participants in both groups.

Since the sample size of the study was also quite small, we cannot generalize our findings to the population of post-concussion syndrome patients. A high participant dropout rate in the touch control group versus the VMLD group (3 vs 1) also limited the ability to properly test the progression throughout the fifteen treatments of all participants. A questionnaire for participants exiting the study may have been useful to understand why they were leaving the study. Having been symptomatic for an average of 16 months, may decrease the effectiveness of VMLD.

Rehabilitation protocols between participants varied greatly. Some participants were seeing several rehabilitation experts such as chiropractors, neurotracking experts, massage therapists, physiotherapists, osteopaths, acupuncturists while others weren't following any formal rehabilitation protocols. Several participants also changed their medications or medication dosages throughout the study. Some participants (n=15; 7 touch and 8 VMLD) were able to communicate with their doctor on a weekly or bi-weekly basis allowing for more regular adaptations to medications and treatments. Pharmacological adaptations could affect

concentration, sleep, memory, depression, anxiety and various other symptoms. The increased medical interventions may have influenced the outcome (Ballenger 2000).

Scheduling of participants was irregular due to school, vacations and other medical appointments. Many participants signed up for the study towards the end of their school year and ended the research project the week before going back to school. Stress due to exams, beginning of school, and personal factors could cause a spike in symptomology.

The RPQ posed some issues for some of the participants. The questionnaire asks that participants compare their symptoms before their concussion to their current state (King et al. 1995). Certain participants having had several concussions could not remember their health before concussions, and in other cases, memory or cognition was affected making filling out the questionnaire difficult. Two participants suffered anxiety attacks at their last appointment affecting their symptoms score. The SCAT5 word recall has the 5 initial words repeated during the 10-word recall test at appointment 1 and 7, but not at appointment 15 potentially affecting the number of words recalled (Echemendia et al. 2017). The questionnaire and tests used tracked cognition, symptom scores and memory function but did not take into account any changes in participant activity levels or their ability to return to school or part-time work. Evidence exists that the RPQ may not meet the modern psychometric standards for concussion rehabilitation and identification and should therefore be divided into separate scales RPQ-3 and RPQ-13 to accommodate measurement for dynamic or enduring symptoms. (Eyres et al. 2004). The success of rehabilitation and identification tools such as the Children's Exertional Effects Rating Scale (Sady et al. 2018), multi-modal assessments (Schneider K. J. 2019), pharmacological interventions (Begasse de Dhaem et al. 2017) and Vergence Endurance Test (Yaramothu et al. 2019) prove that a multi-faceted evaluation and rehabilitation would be more precise in tracking the progress of participants in addition to the RPQ and SCAT5.

Conclusion

We employed the use of two valid and reliable questionnaires to test the effectiveness of 2 interventions (VMLD and Touch) on improving post-concussion symptoms. There were no differences in questionnaire scores between groups; however, there was a statistically significant 15-treatment period effect. We conclude that the VMLD and Touch interventions produced the same questionnaire scores in the Rivermead, the SCAT5-5-word recall, the 10-word recall, and Number Concentration. We originally hypothesized that the VMLD group would demonstrate greater improvement in questionnaires scores when compared to the Touch group. This would have reflected a greater influence of VMLD on the post-concussion symptoms. However, this was not the case. What we can conclude is the observation that both the VMLD and Touch interventions showed improved questionnaire scores over the 15-treatment period.

Recommendations for Future Studies

A future project should include a larger number of participants. Future studies should include a true control group (a group that does not receive the treatment), a treatment group and a touch control group. Greater care in future studies should also be given to matching participants to ensure that the two groups have a similar number of concussions and symptom type (dynamic vs enduring symptoms). It is suggested that the evaluation tools should use a multi-modal model.

CHAPTER 4

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CHAPTER 5

Appendix

Appendix 1a: Unpublished Case Study

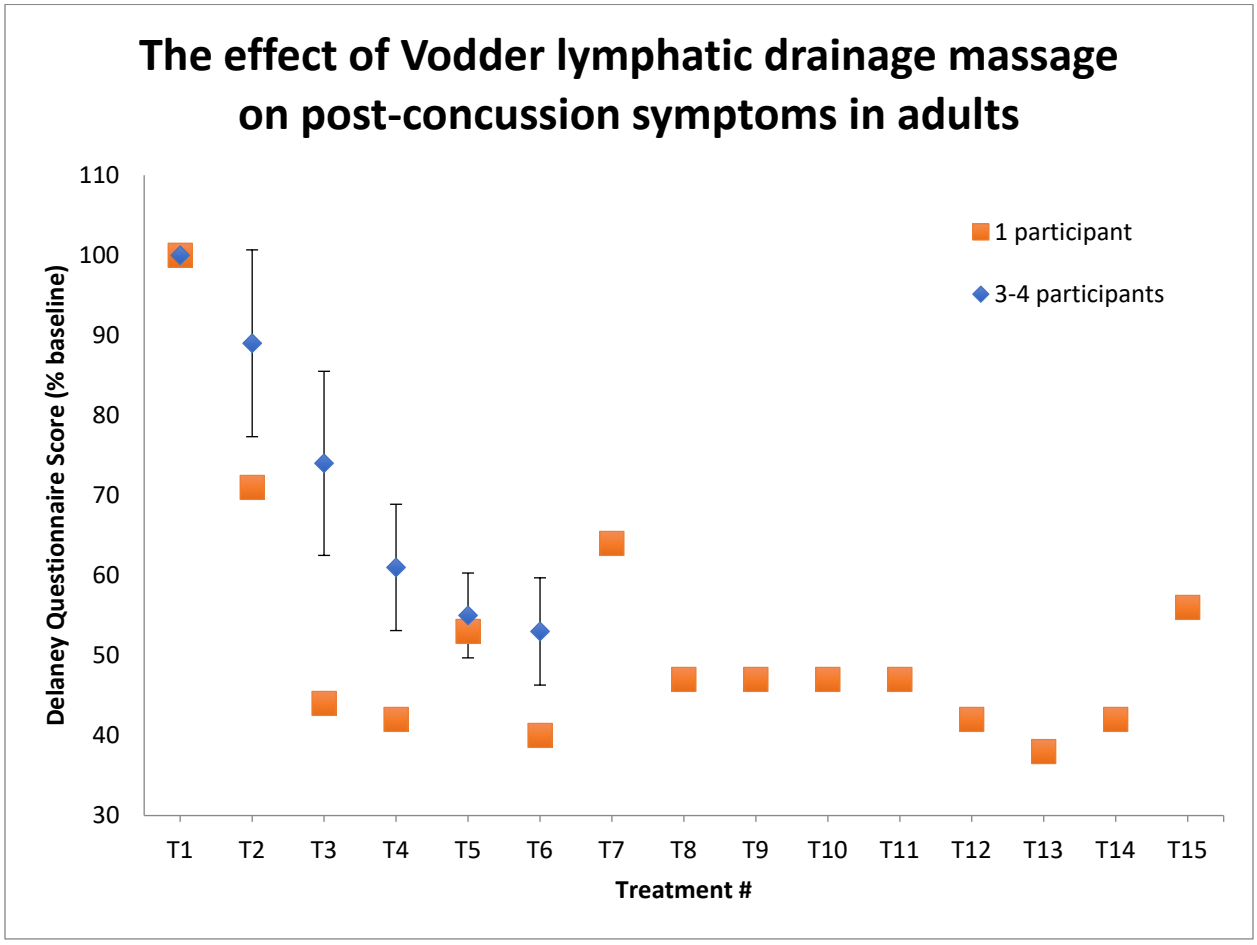
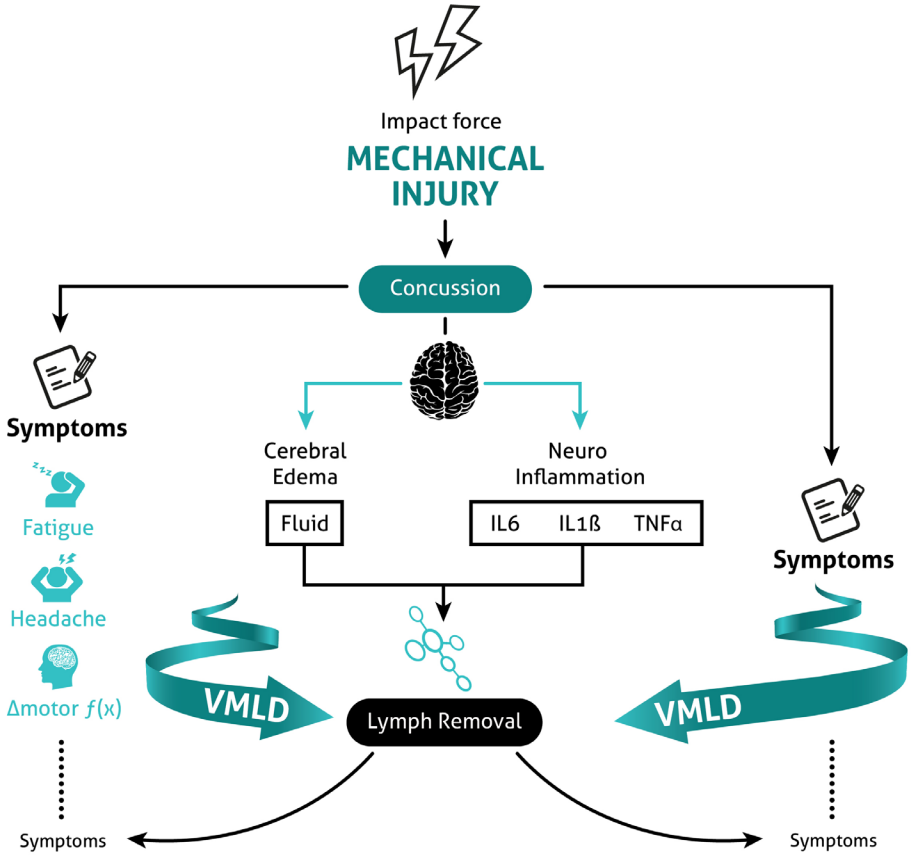


Figure 1. The effect of lymphatic drainage using the Vodder massage technique to reduce post-concussion symptoms in adults.

This graph shows a relationship between the Delaney Questionnaire Score in percent of baseline and the number of Vodder lymphatic drainage massage treatments. It is interesting to note that the most dramatic decline in symptoms occurred from baseline to treatment 6 and that scores remained lower at the last treatment than at baseline.

Appendix 1b: Proposed Mechanism



Appendix 1 b. Schematic diagram highlighting the possible mechanistic action of manual lymphatic drainage massage.
As a result of impact force, the brain receives a mechanical injury that is defined as a concussion. The two major consequences are; the accumulation of fluid and swelling followed by neuro-inflammatory processes that produce toxic agents such as pro-inflammatory cytokines (eg interleukin 6, interleukin 1beta and tumor necrosis factor alpha). Collectively, the accumulation of interstitial fluid in the cerebral compartments along with neuro-inflammation negatively affects a number of brain regions and could lead to secondary tissue damage. The brain regions that are affected are typically responsible for many sensory, cognitive and motor functions. The concussed individual begins to experience a number of post-concussion symptoms such as headache, fatigue and changes in motor and cognitive functions. It is hypothesized that manual lymphatic drainage massage of the head and neck will be an effective and viable treatment to mobilize and remove excess fluid and inflammatory cytokines via the central nervous system

lymphatic channels. As the fluid and by-products are removed, the severity and number of symptoms may decrease.

Appendix 2: Sport Concussion Assessment Tool 5th Edition

BJSM Online First, published on April 26, 2017 as 10.1136/bjsports-2017-097506SCAT5

SCAT5©

SPORT CONCUSSION ASSESSMENT TOOL —5TH EDITION

DEVELOPED BY THE CONCUSSION IN SPORT GROUP

FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

Patient details

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date of Injury: _____ Time: _____

WHAT IS THE SCAT5?

The SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1]. The SCAT5 cannot be performed correctly in less than 10 minutes.

If you are not a physician or licensed healthcare professional, please use the Concussion Recognition Tool 5 (CRT5). The SCAT5 is to be used for evaluating athletes aged 13 years and older. For children aged 12 years or younger, please use the Child SCAT5.

Preseason SCAT5 baseline testing can be useful for interpreting post-injury test scores, but is not required for that purpose. Detailed instructions for use of the SCAT5 are provided on page 7. Please read through these instructions carefully before testing the athlete. Brief verbal instructions for each test are given in italics. The only equipment required for the tester is a watch or timer.

Recognise and Remove

A head impact by either a direct blow or indirect transmission of force can be associated with a serious and potentially fatal brain injury. If there are significant concerns, including any of the red flags listed in Box 1, then activation of emergency procedures and urgent transport to the nearest hospital should be arranged.

Key points

- Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. No athlete diagnosed with concussion should be returned to play on the day of injury.
- If an athlete is suspected of having a concussion and medical personnel are not immediately available, the athlete should be referred to a medical facility for urgent assessment.
- Athletes with suspected concussion should not drink alcohol, use recreational drugs and should not drive a motor vehicle until cleared to do so by a medical professional.
- Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
- The diagnosis of a concussion is a clinical judgment, made by a medical professional. The SCAT5 should NOT be used by itself to make, or exclude, the diagnosis of concussion. An athlete may have a concussion even if their SCAT5 is "normal".

Remember:

- The basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the athlete (other than that required for airway management) unless trained to do so.
- Assessment for a spinal cord injury is a critical part of the initial on-field assessment.
- Do not remove a helmet or any other equipment unless trained to do so safely.

IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The Maddocks questions and cervical spine exam are critical steps of the immediate assessment; however, these do not need to be done serially.

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

STEP 1: RED FLAGS

RED FLAGS:

- **Neck pain or tenderness**
- **Double vision**
- **Weakness or tingling/ burning in arms or legs**
- **Severe or increasing headache**
- **Seizure or convulsion**
- **Loss of consciousness**
- **Deteriorating conscious state**
- **Vomiting**
- **Increasingly restless, agitated or combative**

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"

Mark Y for correct answer / N for incorrect

What venue are we at today?	Y	N
Which half is it now?	Y	N
Who scored last in this match?	Y	N
What team did you play last week / game?	Y	N
Did your team win the last game?	Y	N

Note: Appropriate sport-specific questions may be substituted.

STEP 4: EXAMINATION GLASGOW COMA SCALE (GCS)[3]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

OFFICE OR OFF-FIELD ASSESSMENT

Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.

STEP 1: ATHLETE BACKGROUND

Sport / team / school: _____

Date / time of injury: _____

Years of education completed: _____

Age: _____

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: _____

When was the most recent concussion?: _____

How long was the recovery (time to being cleared to play) from the most recent concussion?: _____ (days)

Has the athlete ever been:

Hospitalized for a head injury?	Yes	No
Diagnosed / treated for headache disorder or migraines?	Yes	No
Diagnosed with a learning disability / dyslexia?	Yes	No
Diagnosed with ADD / ADHD?	Yes	No
Diagnosed with depression, anxiety or other psychiatric disorder?	Yes	No

Current medications? If yes, please list:

_____

_____

_____

_____

_____

_____

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

2

STEP 2: SYMPTOM EVALUATION

The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.

Please Check: ☐ **Baseline** ☐ **Post-Injury**

Please hand the form to the athlete

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
Total number of symptoms:							of 22
Symptom severity score:							of 132
Do your symptoms get worse with physical activity?						Y	N
Do your symptoms get worse with mental activity?						Y	N
If 100% is feeling perfectly normal, what percent of normal do you feel?							

If not 100%, why?

_____

_____

_____

Please hand form back to examiner

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

ORIENTATION

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation score		of 5

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5) Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 15
					Time that last trial was completed			

List	Alternate 10 word lists					Score (of 10) Trial 1	Trial 2	Trial 3
G	Finger Candle	Penny Paper	Blanket Sugar	Lemon Sandwich	Insect Wagon			
H	Baby Elbow	Monkey Apple	Perfume Carpet	Sunset Saddle	Iron Bubble			
I	Jacket Dollar	Arrow Honey	Pepper Mirror	Cotton Saddle	Movie Anchor			
					Immediate Memory Score			of 30
					Time that last trial was completed			

CONCENTRATION

DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one)					
List A	List B	List C			
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9	3-9-2-4	Y	N	1
1-7-9-2-6	4-1-8-6-9	2-4-7-5-8	Y	N	0
4-1-7-5-2	9-4-1-7-5	8-3-9-6-4	Y	N	1
2-6-4-8-1-7	6-9-7-3-8-2	5-8-6-2-4-9	Y	N	0
8-4-1-9-3-5	4-2-7-9-3-8	3-1-7-8-2-6	Y	N	1
		Digits Score:			of 4

MONTHS IN REVERSE ORDER

Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November. Go ahead.

Dec - Nov - Oct - Sept - Aug - Jul - Jun - May - Apr - Mar - Feb - Jan	0 1
Months Score	of 1
Concentration Total Score (Digits + Months)	of 5

4

STEP 4: NEUROLOGICAL SCREEN

See the instruction sheet (page 7) for details of test administration and scoring of the tests.

Can the patient read aloud (e.g. symptom check-list) and follow instructions without difficulty?	Y	N
Does the patient have a full range of pain-free PASSIVE cervical spine movement?	Y	N
Without moving their head or neck, can the patient look side-to-side and up-and-down without double vision?	Y	N
Can the patient perform the finger nose coordination test normally?	Y	N
Can the patient perform tandem gait normally?	Y	N

BALANCE EXAMINATION

Modified Balance Error Scoring System (mBESS) testing[5]

Which foot was tested (i.e. which is the non-dominant foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) _____

Footwear (shoes, barefoot, braces, tape, etc.) _____

Condition	Errors
Double leg stance	of 10
Single leg stance (non-dominant foot)	of 10
Tandem stance (non-dominant foot at the back)	of 10
Total Errors	of 30

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

5

STEP 5: DELAYED RECALL:

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section. Score 1 pt. for each correct response.

Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order.

Time Started _____

Please record each word correctly recalled. Total score equals number of words recalled.

_____

_____

_____

Total number of words recalled accurately: of 5 or of 10

6

STEP 6: DECISION

	Date & time of assessment:		
Domain			
Symptom number (of 22)			
Symptom severity score (of 132)			
Orientation (of 5)			
Immediate memory	of 15 of 30	of 15 of 30	of 15 of 30
Concentration (of 5)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 of 10

Date and time of injury: _____

If the athlete is known to you prior to their injury, are they different from their usual self?
☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**
(If different, describe why in the clinical notes section)

Concussion Diagnosed?
☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

If re-testing, has the athlete improved?
☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

I am a physician or licensed healthcare professional and I have personally administered or supervised the administration of this SCAT5.

Signature: _____

Name: _____

Title: _____

Registration number (if applicable): _____

Date: _____

SCORING ON THE SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.

SCAT5 © Concussion in Sport Group 2017

CLINICAL NOTES:

Name: _____
DOB: _____
Address: _____
ID number: _____
Examiner: _____
Date: _____

CONCUSSION INJURY ADVICE

(To be given to the person monitoring the concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. Recovery time is variable across individuals and the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, worsening headache, double vision or excessive drowsiness, please telephone your doctor or the nearest hospital emergency department immediately.

Other important points:

Initial rest: Limit physical activity to routine daily activities (avoid exercise, training, sports) and limit activities such as school, work, and screen time to a level that does not worsen symptoms.

1) Avoid alcohol

2) Avoid prescription or non-prescription drugs without medical supervision. Specifically:

   a) Avoid sleeping tablets

   b) Do not use aspirin, anti-inflammatory medication or stronger pain medications such as narcotics

3) Do not drive until cleared by a healthcare professional.

4) Return to play/sport requires clearance by a healthcare professional.

Clinic phone number: _____

Patient's name: _____

Date / time of injury: _____

Date / time of medical review: _____

Healthcare Provider: _____

Contact details or stamp

INSTRUCTIONS

Words in *Italics* throughout the SCAT5 are the instructions given to the athlete by the clinician

Symptom Scale

The time frame for symptoms should be based on the type of test being administered. At baseline it is advantageous to assess how an athlete "typically" feels whereas during the acute/post-acute stage it is best to ask how the athlete feels at the time of testing.

The symptom scale should be completed by the athlete, not by the examiner. In situations where the symptom scale is being completed after exercise, it should be done in a resting state, generally by approximating his/her resting heart rate.

For total number of symptoms, maximum possible is 22 except immediately post injury, if sleep item is omitted, which then creates a maximum of 21.

For Symptom severity score, add all scores in table, maximum possible is 22 x 6 = 132, except immediately post injury if sleep item is omitted, which then creates a maximum of 21x6=126.

Immediate Memory

The Immediate Memory component can be completed using the traditional 5-word per trial list or, optionally, using 10-words per trial. The literature suggests that the Immediate Memory has a notable ceiling effect when a 5-word list is used. In settings where this ceiling is prominent, the examiner may wish to make the task more difficult by incorporating two 5–word groups for a total of 10 words per trial. In this case, the maximum score per trial is 10 with a total trial maximum of 30.

Choose one of the word lists (either 5 or 10). Then perform 3 trials of immediate memory using this list.

Complete all 3 trials regardless of score on previous trials.

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order." The words must be read at a rate of one word per second.

Trials 2 & 3 MUST be completed regardless of score on trial 1 & 2.

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do NOT inform the athlete that delayed recall will be tested.

Concentration

Digits backward

Choose one column of digits from lists A, B, C, D, E or F and administer those digits as follows:

Say: *"I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."*

Begin with first 3 digit string.

If correct, circle "Y" for correct and go to next string length. If incorrect, circle "N" for the first string length and read trial 2 in the same string length. One point possible for each string length. Stop after incorrect on both trials (2 N's) in a string length. The digits should be read at the rate of one per second.

Months in reverse order

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November ... Go ahead"

1 pt. for entire sequence correct

Delayed Recall

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section.

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Score 1 pt. for each correct response

Modified Balance Error Scoring System (mBESS)[5] testing

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5]. A timing device is required for this testing.

Each of 20-second trial/stance is scored by counting the number of errors. The examiner will begin counting errors only after the athlete has assumed the proper start position. The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum number of errors for any single condition is 10. If the athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once the athlete is set. Athletes that are unable to maintain the testing procedure for a minimum of five seconds at the start are assigned the highest possible score, ten, for that testing condition.

OPTION: For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50cm x 40cm x 6cm).

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

"I am now going to test your balance. Please take your shoes off (if applicable), roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] *Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

(c) Tandem stance:

"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Tandem Gait

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 metre line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object.

Finger to Nose

"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended), pointing in front of you. When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose, and then return to the starting position, as quickly and as accurately as possible."

References

1. McCrory et al. Consensus Statement On Concussion In Sport – The 5th International Conference On Concussion In Sport Held In Berlin, October 2016. British Journal of Sports Medicine 2017 (available at www.bjsm.bmj.com)
2. Maddocks, DL; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clinical Journal of Sport Medicine 1995; 5: 32-33
3. Jennett, B., Bond, M. Assessment of outcome after severe brain damage: a practical scale. Lancet 1975; i: 480-484
4. McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sport Medicine. 2001; 11: 176-181
5. Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30

7

CONCUSSION INFORMATION

Any athlete suspected of having a concussion should be removed from play and seek medical evaluation.

Signs to watch for

Problems could arise over the first 24-48 hours. The athlete should not be left alone and must go to a hospital at once if they experience:

- Worsening headache
- Drowsiness or inability to be awakened
- Inability to recognize people or places
- Repeated vomiting
- Unusual behaviour or confusion or irritable
- Seizures (arms and legs jerk uncontrollably)
- Weakness or numbness in arms or legs
- Unsteadiness on their feet.
- Slurred speech

Consult your physician or licensed healthcare professional after a suspected concussion. Remember, it is better to be safe.

Rest & Rehabilitation

After a concussion, the athlete should have physical rest and relative cognitive rest for a few days to allow their symptoms to improve. In most cases, after no more than a few days of rest, the athlete should gradually increase their daily activity level as long as their symptoms do not worsen. Once the athlete is able to complete their usual daily activities without concussion-related symptoms, the second step of the return to play/sport progression can be started. The athlete should not return to play/sport until their concussion-related symptoms have resolved and the athlete has successfully returned to full school/learning activities.

When returning to play/sport, the athlete should follow a stepwise, **medically managed exercise progression, with increasing amounts of exercise.** For example:

Graduated Return to Sport Strategy

Exercise step	Functional exercise at each step	Goal of each step
1. Symptom-limited activity	Daily activities that do not provoke symptoms.	Gradual reintroduction of work/school activities.
2. Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training.	Increase heart rate.
3. Sport-specific exercise	Running or skating drills. No head impact activities.	Add movement.
4. Non-contact training drills	Harder training drills, e.g., passing drills. May start progressive resistance training.	Exercise, coordination, and increased thinking.
5. Full contact practice	Following medical clearance, participate in normal training activities.	Restore confidence and assess functional skills by coaching staff.
6. Return to play/sport	Normal game play.	

In this example, it would be typical to have 24 hours (or longer) for each step of the progression. If any symptoms worsen while exercising, the athlete should go back to the previous step. Resistance training should be added only in the later stages (Stage 3 or 4 at the earliest).

Written clearance should be provided by a healthcare professional before return to play/sport as directed by local laws and regulations.

Graduated Return to School Strategy

Concussion may affect the ability to learn at school. The athlete may need to miss a few days of school after a concussion. When going back to school, some athletes may need to go back gradually and may need to have some changes made to their schedule so that concussion symptoms do not get worse. If a particular activity makes symptoms worse, then the athlete should stop that activity and rest until symptoms get better. To make sure that the athlete can get back to school without problems, it is important that the healthcare provider, parents, caregivers and teachers talk to each other so that everyone knows what the plan is for the athlete to go back to school.

Note: If mental activity does not cause any symptoms, the athlete may be able to skip step 2 and return to school part-time before doing school activities at home first.

Mental Activity	Activity at each step	Goal of each step
1. Daily activities that do not give the athlete symptoms	Typical activities that the athlete does during the day as long as they do not increase symptoms (e.g. reading, texting, screen time). Start with 5-15 minutes at a time and gradually build up.	Gradual return to typical activities.
2. School activities	Homework, reading or other cognitive activities outside of the classroom.	Increase tolerance to cognitive work.
3. Return to school part-time	Gradual introduction of school-work. May need to start with a partial school day or with increased breaks during the day.	Increase academic activities.
4. Return to school full-time	Gradually progress school activities until a full day can be tolerated.	Return to full academic activities and catch up on missed work.

If the athlete continues to have symptoms with mental activity, some other accomodations that can help with return to school may include:

- Starting school later, only going for half days, or going only to certain classes
- More time to finish assignments/tests
- Quiet room to finish assignments/tests
- Not going to noisy areas like the cafeteria, assembly halls, sporting events, music class, shop class, etc.
- Taking lots of breaks during class, homework, tests
- No more than one exam/day
- Shorter assignments
- Repetition/memory cues
- Use of a student helper/tutor
- Reassurance from teachers that the child will be supported while getting better

The athlete should not go back to sports until they are back to school/learning, without symptoms getting significantly worse and no longer needing any changes to their schedule.

Sport concussion assessment tool - 5th edition

Br J Sports Med published online April 26, 2017

Notes

Appendix 3: Rivermead Symptom Checklist

RIVERMEAD SYMPTOM CHECKLIST

Name: **Date:**

We would like to know whether, at the present, you suffer from any of the symptoms we list below. Because many of these symptoms occur normally, we would like you to compare yourself as you are now compared with how you were before the accident.

For each, will you please circle the number closest to your answer

KEY

0 Not experienced at all
1 Was a problem but no more
2 A mild problem
3 A moderate problem
4 A severe problem

Compared with before the accident, do you now suffer from (please circle):

Headaches	0	1	2	3	4
Feelings of dizziness	0	1	2	3	4
Nausea and/or vomiting	0	1	2	3	4
Sensitivity to noise, easily upset by noise	0	1	2	3	4
Poor sleep	0	1	2	3	4
Tiring more easily, fatigue	0	1	2	3	4
Being irritable, easily angered	0	1	2	3	4
Feeling depressed or tearful	0	1	2	3	4
Feeling frustrated or impatient	0	1	2	3	4
Forgetfulness, poor memory	0	1	2	3	4
Poor concentration	0	1	2	3	4
Taking longer to think	0	1	2	3	4
Blurred vision	0	1	2	3	4
Upset by bright light	0	1	2	3	4
Double vision	0	1	2	3	4
Restlessness	0	1	2	3	4

Are you having any other difficulties?

Please describe and rate them as above

1 _____	0	1	2	3	4
2 _____	0	1	2	3	4

Any other comments:

_____

_____

_____

_____

Appendix 4

4a: Questionnaire for pre-existing symptoms

Have you experienced the following symptoms before your concussion?

Headache	Yes	No
Feelings of dizziness	Yes	No
Nausea and/or vomiting	Yes	No
Sensitivity to noise, easily upset by noise	Yes	No
Poor sleep	Yes	No
Tiring more easily, fatigue	Yes	No
Being irritable, easily angered	Yes	No
Feeling depressed or tearful	Yes	No
Feeling frustrated or impatient	Yes	No
Forgetfulness, poor memory	Yes	No
Poor concentration	Yes	No
Taking longer to think	Yes	No
Blurred vision	Yes	No
Upset by bright light	Yes	No
Double vision	Yes	No
Restlessness	Yes	No

Appendix 4b: Table of Pre-existing Symptoms

Table of Pre-existing Symptoms		
Symptoms	# Yes	# No
1	2	18
2	1	19
3	1	19
4	1	19
5	1	19
6	0	20
7	2	18
8	2	18
9	1	19
10	1	19
11	1	19
12	1	19
13	4	16
14	0	20
15	1	19
16	3	17

This table lists the number of participants who were experiencing symptoms before their concussions compared to the number of participants who didn't have symptoms before their concussions.

Appendix 5: Activity Log

Physical Activities			
	Appointment		
Participant	1	7	15
1	no exercise	50% swim	full swim, no gym class
2	no exercise	no exercise	exercise causes minor symptoms
3	no exercise	1 hour exercise	exercise regular
4	no exercise	no exercise	no exercise
5	no exercsie	regular exercise	regular exercise
6	no exercise	no exercise	lounging in pool
7	no exercise	no exercise	walking and biking
8	no exercise	no exercise	no exercise
9	no exercise	jogging	none reported
10	no exercise	no exercise	no exercise
11	no exercise	no exercise	medium intensity
12	no exercise	no exercise	exercise- symptoms
13	no exercise	no exercise	no exercise
14	no exercise	no exercise	no exercse
15	no exercise reported	normal activities	normal activities
16	no exercise reported	soccers	soccer
17	no exercise	no exercise	physio workouts
18	N/A		
19	training	training	training
20	no exercise	camping	went in ice

This table lists basic recording of physical activity participants were partaking in throughout the course of the study.

Intellectual Activities			
	Appointment		
Participant	1	7	15
1	no school	school/staying awake	full school
2	partial school	partial school	full school
3	reduced school	full school	full school
4	part-time	summer break	sumer break
5	summer break	work part-time	first day next day
6	no school	no school	school attempts failing
7	2 classes	2 classes	school preparation
8	school	school	summer break
9	no school	no school	puzzles
10	school	no school	summe break
11	half days	half days	summer break/preparing for graduation
12	school	school	summer break
13	school	work part-time	work
14	half days	COOP	COOP
15	school	summer break	work
16	summer break/part-time work	work part-time	decreased part-time work
17	part-time school	projects/assignments	part-time school
18	N/A		
19	part-time work	part-time work	part-time work
20	full time school	summer break	part-time work

This table lists basic recording of intellectual/work activity participants were partaking in throughout the course of the study.